

Research Paper

Effect of sowing window and row spacing on growth and yield of pigeonpea [*Cajanus cajan* (L.) Millsp.]

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ABSTRACT

An investigation was carried out to assess the influence of sowing window and planting geometry on growth, phenological development, productivity, and economics of pigeonpea (*Cajanus cajan* (L.) Millsp.) in the Southern Dry Zone of Karnataka. The results indicated that early sowing during the second fortnight of May significantly improved vegetative growth, recording higher plant height (221.7 cm), branches per plant (18.6), leaf area (87.4 dm² plant⁻¹), and total dry matter accumulation (348.2 g plant⁻¹) at harvest. This sowing window also prolonged crop duration and accumulated greater growing degree days to flowering (1684.3 °C day) and maturity (2598.6 °C day). Enhanced growth translated into superior yield attributes, including pods per plant (243.5), seeds per pod (3.8), and 100-seed weight (11.2 g), resulting in the higher grain yield (1636 kg ha⁻¹) and stalk yield (6448 kg ha⁻¹). Delayed sowing during the second fortnight of June led to reduced crop duration, plant height (174.3 cm), and grain yield (1182 kg ha⁻¹). With respect to planting geometry, wider spacing of 240 × 30 cm favoured individual plant growth, whereas the intermediate spacing of 180 × 30 cm produced the maximum grain yield (1504 kg ha⁻¹), net returns (₹52,340 ha⁻¹), and benefit–cost ratio (2.41) by maintaining an optimum plant stand. The interaction of May second fortnight sowing with 180 × 30 cm spacing was found to be the most effective combination for enhancing yield and economic returns of pigeonpea under rainfed conditions.

Key words: *Cajanus cajan*, sowing window, planting geometry, growing degree days, grain yield, benefit–cost ratio

INTRODUCTION

Pulses occupy an important place in India's food system and play a key role in strengthening national food and nutritional security by providing dietary protein, essential amino acids, fibre, vitamins, and minerals, particularly for populations dependent on cereal-based diets. Pulses improve nutritional balance by supplying lysine, which is deficient in cereals, and enhance sustainability through biological nitrogen fixation, improved soil fertility, and increased soil organic carbon (Ali and Gupta 2012, Singh *et al.* 2020). The contribution of pulses to soil health, reduced dependence on chemical fertilizers, and resilience of cropping systems has been widely emphasized in Indian agriculture (Giller 2001, Kumar *et al.* 2018). Among pulse crops, pigeonpea [*Cajanus cajan* (L.) Millsp.] is an important grain legume due to its adaptability to diverse agro-climatic conditions, drought tolerance, and suitability for rainfed ecosystems. It is a deep-rooted perennial shrub grown as

an annual crop, characterized by indeterminate growth and extensive branching (Saxena, 2008). Pigeonpea growth and flowering behaviour are strongly influenced by environmental factors, and appropriate agronomic management is essential to realize its yield potential under rainfed conditions (Choudhary *et al.* 2017).

Pigeonpea is a photo-sensitive crop, and its flowering and reproductive development are influenced by day length and temperature, making sowing time a critical determinant of crop phenology and yield (Summerfield *et al.* 1985, Saxena Yadav 2015). Improper sowing time can lead to poor synchronization between vegetative growth and reproductive development, resulting in reduced biomass accumulation and lower yields (Patel *et al.* 2019). Pigeonpea is well-suited to the Southern Dry Zone of Karnataka, where rainfall is erratic, and soils are predominantly red sandy loams with low organic carbon content. These soils favour deep-rooted crops like pigeonpea, which

can extract moisture from deeper soil layers and withstand intermittent drought stress (Reddy *et al.* 2016). Early monsoon sowing helps the crop establish under adequate soil moisture conditions and improves rainfall-use efficiency (Biradar *et al.* 2020). Varieties such as BRG-3 have shown better performance under early monsoon sowing due to effective synchronization of growth stages with rainfall and temperature regimes (Shivakumar *et al.* 2021).

Time of sowing has a pronounced effect on growth, dry matter accumulation, and yield formation in pigeonpea. Early monsoon sowing promotes uniform germination, extended vegetative growth, enhanced branching, and higher biomass production, resulting in improved pod formation and seed filling (Singh *et al.* 2016). In contrast, delayed sowing shortens the growth duration and often exposes the crop to moisture stress during reproductive stages, leading to poor pod set and reduced grain yield (Chauhan *et al.* 2017, Patil *et al.* 2021). Planting geometry, particularly row spacing, significantly influences canopy architecture, light interception, root spread, and efficiency of intercultural operations in pigeonpea (Saxena *et al.* 2014). Wider row spacing facilitates mechanical weed control, improves aeration, and allows the use of farm machinery such as mini tractors and power weeders, which is advantageous under labour-scarce conditions (Biradar *et al.* 2018). However, excessively wide spacing may reduce plant population and yield per unit area, while very narrow spacing can increase inter-plant competition and hinder mechanization (Patel *et al.* 2020).

Pigeonpea exhibits slow initial growth during early stages, making it highly vulnerable to weed competition for nutrients, moisture, and light (Kumar and Singh, 2014). Effective weed control during the critical period of crop-weed competition is therefore essential to avoid significant yield losses (Yadav *et al.* 2018). However, increasing labour shortages and rising labour costs have made manual intercultural operations difficult, leading to greater reliance on mechanical weeders, mini tractors, and power-operated intercultivators for timely field operations (Patil *et al.* 2019, Nagaraj *et al.* 2022). An optimum combination of sowing window and planting geometry is essential for maximizing productivity and improving harvest index in pigeonpea. Proper sowing time ensures balanced vegetative and reproductive growth, while suitable row spacing enhances efficient dry matter partitioning towards economic yield (Rao

et al. 2015). Harvest index, an indicator of biomass conversion efficiency, has been reported to improve significantly under timely sowing and optimal planting geometry in pigeonpea (Sharma *et al.* 2019, Patil *et al.* 2021).

MATERIALS AND METHODS

A field experiment was conducted during the Kharif season of 2024 at the 'K' Block, Zonal Agricultural Research Station, University of Agricultural Sciences, Gandhi Krishi Vigyana Kendra (GKVK), Bengaluru, Karnataka. The soil of the experimental site was red sandy loam in texture, low in organic carbon (0.44%). The soil was medium in available nitrogen (282.3 kg ha⁻¹), phosphorus (34.5 kg ha⁻¹), and potassium (263.5 kg ha⁻¹). The experiment was laid out in a Factorial Randomized Complete Block Design (FRCBD), treatments consisted of three sowing windows (S), viz., S₁: May second fortnight, S₂: June first fortnight and S₃: June second fortnight and three planting geometries (P), viz., P₁: 120 cm × 30 cm, P₂: 180 cm × 30 cm and P₃: 240 cm × 30 cm. The nine treatment combinations are T₁-S₁P₁ (May 2nd fortnight sowing +120 cm × 30 cm planting), T₂-S₁P₂ (May 2nd fortnight sowing + 180 cm × 30 cm planting), T₃-S₁P₃ (May 2nd fortnight sowing + 240 cm × 30 cm planting), T₄-S₂P₁ (June 1st fortnight sowing + 120 cm × 30 cm planting), T₅-S₂P₂ (June 1st fortnight sowing + 180 cm × 30 cm planting), T₆-S₂P₃ (June 1st fortnight sowing + 240 cm × 30 cm planting), T₇-S₃P₁ (June 2nd fortnight sowing + 120 cm × 30 cm planting), T₈-S₃P₂ (June 2nd fortnight sowing + 180 cm × 30 cm planting), T₉-S₃P₃ (June 2nd fortnight sowing + 240 cm × 30 cm planting) and replicated thrice, comprising of total of 27 plots. The pigeonpea variety BRG-3 was used for the study. The crop was raised with recommended agronomic practices, and the recommended dose of nutrients viz., nitrogen, phosphorus, and potassium at the rate of 25: 50: 25 kg ha⁻¹, were applied in the form of urea, diammonium phosphate (DAP), and muriate of potash, respectively, as a basal dose at the time of sowing uniformly to all plots. Growth observations were recorded at periodic intervals, and yield parameters were recorded at harvest. Plant samples collected at harvest were dried to a constant weight in a hot air oven maintained at 65 ± 5 °C for the estimation of dry matter and nutrient uptake. Grain and stalk yields were recorded separately and expressed on a hectare basis. Harvest index was computed using standard formulae. The experimental data were subjected to analysis of variance, and treatment means were compared

using critical difference (CD) at 5 percent probability level wherever the F-test was found significant.

RESULTS AND DISCUSSION

Effect of sowing window and row spacing on growth attributes of pigeonpea

Growth parameters of pigeonpea, such as plant height, number of branches per plant, leaf area per plant, leaf area index (LAI), dry matter accumulation, phenological stages, and growing degree days (GDD), were significantly influenced by sowing window and row spacing. Observations were recorded at 40, 80, 120 DAS and at harvest, and the results clearly demonstrated the importance of timely sowing and optimum crop geometry for improved growth performance.

Plant height at harvest was significantly influenced by sowing window and row spacing (Table 2). Early sowing during the second fortnight of May (S_1) recorded the taller plants (196.3 cm at 120 DAS and 221.7 cm at harvest), whereas delayed sowing in the second fortnight (S_3) resulted in reduced height (156.8 cm and 174.3 cm, respectively). Wider spacing of 240 cm \times 30 cm (P_3) produced taller plants (182.1 cm at 120 DAS and 206.7 cm at harvest). Numerically, S_1P_3 recorded the maximum plant height at both stages. Number of branches per plant followed a similar trend, with S_1 recording higher branching (34.3 at 120 DAS and 41.9 at harvest) compared to S_3 . Wider spacing (P_3) significantly enhanced branching, and the interaction S_1P_3 produced the maximum branches (47.4 plant⁻¹ at harvest). Leaf area per plant was markedly higher under early sowing and wider spacing. At 120 DAS, S_1 recorded 8668.2 cm², while S_3 recorded lower values (4367.2 cm²). The combination S_1P_3 registered the highest leaf area (9635.7 cm² at 120 DAS). Leaf area index peaked at 120 DAS, with S_1 recording the highest LAI (1.69). Closer spacing (P_1) resulted in higher LAI due to increased plant density, and S_1P_1 recorded the maximum LAI (2.17 at 120 DAS). Phenological development was also affected by the sowing window. Early sowing (S_1) took longer to reach flowering and maturity, accumulating higher growing degree days, whereas delayed sowing (S_3) shortened crop duration with reduced thermal accumulation. Dry matter accumulation was significantly influenced by sowing window and row spacing at harvest (Table 2). Early sowing during the second fortnight of May (S_1) recorded higher dry matter accumulation (244.2 g plant⁻¹ at 120 DAS and 273.4 g plant⁻¹ at harvest) compared to delayed

sowing (S_3). Wider spacing of 240 cm \times 30 cm (P_3) also enhanced biomass production, recording 263.4 g plant⁻¹ at harvest, whereas closer spacing (P_1) resulted in lower dry matter. Although interaction effects were non-significant, the combination S_1P_3 numerically produced the maximum dry matter (288.3 g plant⁻¹ at harvest). Higher biomass under early sowing and wider spacing was attributed to longer growth duration, improved radiation interception, and reduced inter-plant competition, in line with Reddy et al. (2017) and Sharma et al. (2020).

Table 1: Growing degree days to flowering & maturity and days taken to 50% flowering of pigeonpea as influenced by sowing window and row spacing

First date of sowing - May second FN (30 th May 2024)	
Days to 50% flowering	129 days
GDD- flowering	1821.8
GDD- maturity	2670.8
Second date of sowing - June first FN (10 th June 2024)	
Days to 50% flowering	119 days
GDD- flowering	1665.2
GDD- maturity	2486.1
Third date of sowing - June second FN (21 st June 2024)	
Days to 50% flowering	110 days
GDD- flowering	1532.5
GDD- maturity	2324.1

*GDD - Growing degree days

Effect of sowing window and row spacing on yield and yield attributes of pigeonpea

Yield attributes and yield of pigeonpea were markedly influenced by sowing window and planting geometry (Table 3). In general, early sowing during the second fortnight of May resulted in superior yield attributes and higher yields, whereas delayed sowing led to a progressive decline in crop performance. Planting geometry modified these responses by regulating plant competition and resource availability.

Yield attributes

The number of pods per plant varied significantly among sowing windows. The crop sown during the second fortnight of May produced the highest number of pods (176.0 plant⁻¹), followed by the first fortnight of June, while the lowest pod number was recorded under the second fortnight of June sowing. Early sowing allowed the crop to grow under favourable temperatures and longer day length during both vegetative and reproductive phases. This supported better branching, improved flower retention, and higher pod set. In contrast, delayed

sowing exposed the crop to higher temperatures and moisture stress during flowering, leading to flower drop and reduced pod formation. Similar observations have been reported earlier (Reddy *et al.* 2017, Kumar *et al.* 2019, Verma *et al.* 2020). Row spacing also had a significant effect on pod number. Wider spacing of 240 cm × 30 cm recorded more pods per plant (145.6) due to reduced competition for light, nutrients, and moisture. The interaction effect was significant, and the combination of early sowing with wider spacing produced the maximum number of pods (199.3 plant⁻¹), highlighting the advantage of favourable sowing time combined with adequate growing space. Pod length followed a similar trend. Early sowing resulted in longer pods (8.3 cm), whereas delayed sowing reduced pod length. This can be attributed to a steady supply of assimilates and favourable temperature during pod development under early sowing. Wider spacing also favoured pod elongation by improving the canopy microclimate. Although the interaction was not significant, the combination of early sowing and wider spacing recorded the highest pod length (8.6 cm). These results agree with Nagaraju *et al.* (2022) and Swathi *et al.* (2024). The number of seeds per pod was higher under early sowing (6.0) and declined with delayed sowing (4.8). Early sowing ensured better synchrony between flowering and favourable environmental conditions, which improved pollen viability and seed set. Late sowing, on the other hand, shortened the reproductive period and exposed the crop to heat stress, resulting in poor fertilization. Wider spacing also supported higher seed numbers due to better assimilate availability per plant. Similar findings were reported by Sharma *et al.* (2020) and Kumar *et al.* (2023). Pod weight and seed weight per plant were significantly higher under early sowing. The crop sown during the second fortnight of May recorded higher pod weight (246.4 g plant⁻¹) and seed weight (184.8 g plant⁻¹), while the lowest values were observed under delayed sowing. Early sowing enhanced leaf area duration and photosynthetic efficiency, allowing greater accumulation and translocation of assimilates towards reproductive organs. Among planting geometries, wider spacing recorded higher pod and seed weight per plant due to reduced competition. The interaction of early sowing and wider spacing consistently recorded the highest pod and seed weights, whereas delayed sowing with closer spacing recorded the lowest. These results align with the findings of Singh *et al.* (2018) and Sharma *et al.* (2020). Test weight was also influenced by sowing window and spacing. Early sowing produced heavier seeds (14.3 g) compared

to delayed sowing. The longer grain-filling period and moderate temperature under early sowing favoured steady dry matter accumulation in seeds. Wider spacing slightly improved test weight by facilitating better nutrient uptake and assimilate translocation. Similar trends were reported by Verma *et al.* (2020). Overall, early sowing improved yield attributes by providing favourable growing conditions, including adequate moisture, higher solar radiation, and optimum temperature, which together enhanced photosynthesis and reproductive efficiency. Comparable observations were reported by Hari Ram *et al.* (2011), Kithan *et al.* (2020), and Nisha and Dhillon (2020).

Grain yield, stalk yield, and harvest index

Grain yield and stalk yield were significantly affected by sowing window. The crop sown during the second fortnight of May recorded the highest grain yield (1636 kg ha⁻¹) and stalk yield (6448 kg ha⁻¹), followed by the first fortnight of June sowing. The lowest yields were obtained from the second fortnight of June sowing. Early sowing allowed the crop to utilise favourable environmental conditions throughout its growth period, leading to better biomass production and efficient translocation of assimilates to grains. Similar results have been reported by Hari Ram *et al.* (2011) and Kithan *et al.* (2020). Delayed sowing resulted in lower yields due to shortened crop duration, reduced sunshine hours, and unfavourable weather during flowering and pod filling. These conditions restricted photosynthesis and assimilate movement, ultimately reducing yield. Comparable findings were reported by Kumar *et al.* (2008), Rani and Raji Reddy (2010), and Sandeep *et al.* (2020). Planting geometry also influenced yield. Spacing of 180 cm × 30 cm recorded the highest grain yield (1504 kg ha⁻¹) and stalk yield (5997 kg ha⁻¹). This spacing provided a balance between plant population and individual plant growth, ensuring efficient use of available resources. Wider spacing resulted in lower yield due to underutilisation of land area, while closer spacing increased competition among plants. Similar trends were reported by Pavan *et al.* (2011), Sharanappa *et al.* (2018), and Leena *et al.* (2022). Harvest index did not vary significantly among treatments, indicating stable assimilate partitioning across sowing windows and spacings. The lowest grain and stalk yields were recorded under delayed sowing combined with wider spacing, mainly due to shortened growth duration and suboptimal plant population. These observations are in line with Verma *et al.* (2020) and Ramesh *et al.* (2017).

Table 2. Effect of sowing window and row spacing on growth parameters

Treatments	Plant height (cm)	Number of branches (cm)	Leaf area per plant	Leaf area index	Plant dry matter accumulation per plant (g)
Sowing window (S)					
S ₁ : May 2 nd Fortnight	221.7	41.9	41.9	1.6981	273.4
S ₂ : June 1 st Fortnight	197.6	33.8	33.8	1.4001	248.2
S ₃ : June 2 nd Fortnight	174.3	23.6	23.6	0.8418	232.1
F- test	*	*	*	*	*
S.Em±	0.851	0.610	0.610	0.0087	2.421
C.D.(P=0.05)	2.550	1.820	1.820	0.0261	7.259
Planting geometry (P)					
P ₁ : 120 cm × 30 cm	188.2	28.9	28.9	1.6631	239.7
P ₂ : 180 cm × 30 cm	198.7	32.9	32.9	1.2315	250.7
P ₃ : 240 cm × 30 cm	206.7	37.4	37.4	1.0454	263.4
F- test	*	*	*	*	*
S.Em±	0.850	0.610	0.610	0.0087	2.421
C.D.(P=0.05)	2.550	1.820	1.820	0.0261	7.259
Interaction (S × P)					
S ₁ P ₁	213.1	36.0	36.0	2.1741	260.2
S ₁ P ₂	220.9	42.3	42.3	1.5819	271.8
S ₁ P ₃	231.1	47.4	47.4	1.3383	288.3
S ₂ P ₁	184.5	32.7	32.7	1.8006	237.2
S ₂ P ₂	199.7	33.5	33.5	1.3189	249.0
S ₂ P ₃	208.6	35.1	35.1	1.0807	258.3
S ₃ P ₁	167.1	18.1	18.1	1.0144	221.7
S ₃ P ₂	175.4	22.9	22.9	0.7937	231.2
S ₃ P ₃	180.4	29.7	29.7	0.7172	243.5
F- test	NS	*	*	*	NS
S.Em±	1.470	1.050	1.050	0.0151	4.194
C.D.(P=0.05)	4.420	3.150	3.150	0.0452	12.574

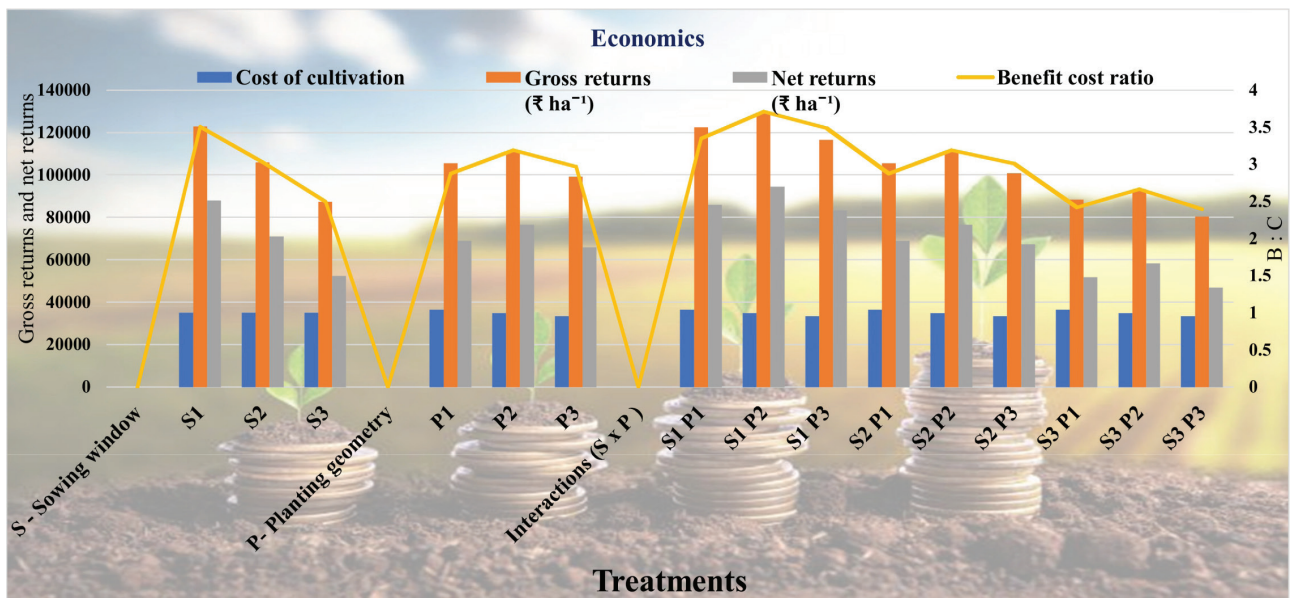


Fig 1: Effect of sowing window and row spacing on economics of pigeonpea

S₁- May 2nd fortnight sowing, S₂- June 1st fortnight sowing and S₃- June 2nd fortnight sowing
 P₁- 120 cm x 30 cm planting, P₂- 180 cm x 30 cm planting and P₃- 240cm x 30 cm planting

Table 3. Yield and yield attributes of pigeonpea as influenced by sowing window and row spacing

Treatments	Number of pods per plant	Pod length (cm)	Number of seeds per pod	Pod weight per plant (g)	Seed weight per plant (g)	Test weight/ 100 seed weight (g)
Sowing window (S)						
S ₁ : May 2 nd Fortnight	176.0	8.3	6.0	246.4	184.8	14.3
S ₂ : June 1 st Fortnight	128.3	7.7	5.5	153.9	107.8	13.7
S ₃ : June 2 nd Fortnight	82.6	7.3	4.8	90.8	60.9	13.4
F- test	*	*	*	*	*	*
S.Em±	0.941	0.050	0.040	1.209	0.878	0.048
C.D.(P=0.05)	2.823	0.150	0.110	3.625	2.631	0.144
Planting geometry (P)						
P ₁ : 120 cm × 30 cm	112.9	7.5	5.2	143.5	103.2	13.6
P ₂ : 180 cm × 30 cm	128.4	7.7	5.4	163.2	117.5	13.8
P ₃ : 240 cm × 30 cm	145.6	8.0	5.6	184.5	132.7	14.0
F- test	*	*	*	*	*	*
S.Em±	0.941	0.050	0.040	1.209	0.878	0.048
C.D.(P=0.05)	2.823	0.150	0.110	3.625	2.631	0.144
Interaction (S × P)						
S ₁ P ₁	151.2	8.0	5.8	211.7	158.8	14.1
S ₁ P ₂	177.6	8.3	6.0	248.6	186.5	14.3
S ₁ P ₃	199.3	8.6	6.2	279.0	209.2	14.7
S ₂ P ₁	124.2	7.5	5.3	149.1	104.3	13.5
S ₂ P ₂	127.2	7.6	5.5	152.6	106.8	13.7
S ₂ P ₃	133.4	7.9	5.6	160.1	112.1	13.8
S ₃ P ₁	63.3	7.1	4.5	69.6	46.6	13.1
S ₃ P ₂	80.3	7.3	4.7	88.3	59.2	13.4
S ₃ P ₃	104.1	7.4	5.1	114.5	76.7	13.6
F- test	*	NS	NS	*	*	NS
S.Em±	1.631	0.090	0.060	2.094	1.520	0.083
C.D. (P=0.05)	4.889	0.260	0.190	6.279	4.557	0.250

P₁ - 120 cm × 30 cm planting, P₂ - 180 cm × 30 cm planting and P₃ - 240 cm × 30 cm planting

FUTURE LINE OF WORK

Fine-tuning of sowing window and spacing for varieties with different durations and across different Agroclimatic zones (with different rainfall patterns and soil type/fertility). Study on the integration of mechanization practices, such as mechanical harvesting, to improve efficiency and yield stability.

CONCLUSION

The growth and productivity of pigeonpea were strongly shaped by when the crop was sown and how closely the plants were spaced. Sowing during the second fortnight of May gave the crop a clear advantage throughout its growth period. Plants established early grew taller, developed more branches and leaf area, and accumulated greater dry matter because they enjoyed a longer and more favourable growing season. This extended growth period delayed flowering, allowed the crop to use more heat units effectively, and supported better

pod and seed formation. As a result, grain and stalk yields were higher under May sowing, nutrient uptake was greater, and farmers obtained the maximum economic returns. In contrast, delaying sowing to the second fortnight of June shortened the crop duration, weakened vegetative growth, reduced yield attributes and profitability, and left more unused nutrients in the soil due to poor crop uptake.

Plant spacing also influenced crop performance in a noticeable way. Wider spacing allowed individual plants to grow vigorously with more branches, larger canopies and higher biomass because of less competition for light, water and nutrients. However, this benefit at the plant level did not translate into higher yield per hectare, as fewer plants were present in the field. The intermediate spacing of 180 × 30 cm struck the best balance between plant population and individual plant performance. This spacing produced the higher grain yield, better nutrient

uptake and superior economic returns compared to closer or wider spacing. Overall, the study shows that timely sowing in the second fortnight of May combined with an optimal spacing of 180 × 30 cm is the most effective strategy for achieving higher yield, better nutrient use and improved profitability in pigeonpea cultivation.

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