RESEARCH ARTICLE Legume Research- An International Journal, Volume 48 Special Issue: 154-162 (November 2025)

# Correlation Matrix and Correlogram Analysis for Growth and Yield Attributes of Pigeon Pea (*Cajanus cajan* L.) under Organic Mulching and System of Intensification

Nachiketa[1], Sandeep Menon[1], Gurpreet Singh[1], Samprikta Priyadarshini[1], Ajeet Jakhad[1]

10.18805/LR-5576


## ABSTRACT

**Background:** Pigeon pea productivity can be influenced by planting geometry and mulching practices, which modulate resource use efficiency and plant architecture. Understanding the interaction between system intensification and mulching is essential for enhancing crop yield and optimizing plant growth in pigeon pea (AL-882).

**Methods:** A field trial was conducted using a split plot design comprising three planting geometries (40×20 cm, 60×20 cm, 80×20 cm) as main plots and four mulching treatments (wheat straw, sugarcane mulch, live mulch, and no mulch) as subplots. Agronomic and yield parameters were measured and subjected to correlation analysis to evaluate how plant structure traits and mulching influenced productivity.

**Result:** Results revealed that 60×20 cm spacing produced 11.04% higher grain yield compared to the lowest yielding geometry, while wheat straw mulch increased grain yield by 17.92% over no mulch. Plant height showed a robust positive correlation with canopy spread (r = 0.983), branching, pod and grain number, pod length, test weight, grain, and biological yield (all p<0.01). Wider canopy spread and a greater number of branches correlated strongly with seed and biomass yields. Both grain yield and biological yield were highly correlated (r = 0.978, p<0.001), confirming that increased seed output boosts total biomass. Overall, optimal plant structure and reproductive traits integrated with appropriate intensification and mulching improved pigeon pea productivity.


**Key words:** Correlation matrix, Correlogram analysis, *Kharif*, Organic mulching, Pigeon pea, System of intensification, Yield.

## INTRODUCTION

Pigeon pea (*Cajanus cajan* L.), a member of the Fabaceae family, is a versatile perennial legume well-known for its ability to adapt to diverse agro-ecological conditions. Morphologically, the plant grows erect, reaching heights of 1-4 meters depending on variety and agronomic practices. Pigeon pea is characterized by its trifoliate leaves, conspicuous yellow to purple flowers and elongated pods that typically contain 4-5 seeds. The species possesses a robust taproot system that penetrates deep into the soil, enabling efficient extraction of water and nutrients from subsoil layers, which supports its resilience in drought-prone and marginal areas (Pranati *et al.,* 2024). Beyond its natural capacity for biological nitrogen fixation through symbiosis with *Rhizobium* spp., pigeon pea plays an important role in soil fertility restoration and intercropping systems. The crop exhibits considerable agro-morphological diversity, with substantial genotypic variation in growth duration, branching pattern and disease resistance traits that underpin the success of pigeon pea breeding programs globally (Singh *et al.,* 2024).

In terms of global significance, pigeon pea is cultivated on over 7 million hectares around the world, with India alone accounting for nearly three-quarters of the total area and production. India's pigeon pea production exceeded 4.6 million tons, with notable cultivation in states such as Maharashtra, Madhya Pradesh, Karnataka and Uttar Pradesh. Over the past decade, adoption of improved varieties and management practices has led to a stabilization of yields, although average productivity (approximately 800-1,000 kg/ha) remains lower than the estimated potential, largely due to abiotic and biotic stress factors (Haji *et al.,* 2024). Outside India, significant expansion of pigeon pea cultivation has been reported in Africa (especially in Malawi, Tanzania and Kenya), as well as in Thailand and the Caribbean, contributing to food security and income diversification in smallholder farming systems (Pathade and Kumar, 2025). Pigeon pea in Punjab is grown on approximately 2,600 hectares with a total production of 2,630 tonnes and an average yield of about 10.13 quintals per hectare (Nisha and Dhillon, 2020).

Nutritionally, pigeon pea seeds are valued for their high protein content (20-22%), surpassing many other

[1]Department of Agronomy, School of Agriculture, Lovely Professional University, Phagwara-144 411, Punjab, India.

**Corresponding Author:** Gurpreet Singh, Department of Agronomy, School of Agriculture, Lovely Professional University, Phagwara-144 411, Punjab, India. Email: gurpreet.25331@lpu.co.in ORCID: 0000-0002-8315-4157

**How to cite this article:** Nachiketa, Menon, S., Singh, G., Priyadarshini, S. and Jakhad, A. (2025). Correlation Matrix and Correlogram Analysis for Growth and Yield Attributes of Pigeon Pea (*Cajanus cajan* L.) under Organic Mulching and System of Intensification. *Legume Research*. **48 (Special Issue):** 154-162. doi: 10.18805/LR-5576.

**Submitted:** 22-09-2025 **Accepted:** 17-11-2025 **Online:** 27-11-2025

pulses and making them a staple in plant-based diets. In addition to protein, pigeon pea provides complex carbohydrates, significant amounts of lysine, threonine, methionine, vitamins (notably folate and vitamin B-complex) and minerals including iron, calcium, potassium, phosphorus and magnesium (Singh *et al.,* 2024). The nutritional density of pigeon pea is of paramount importance for combating malnutrition and micronutrient deficiencies prevalent in developing regions (Mashifane *et al.,* 2025).

Correlation matrix analysis is a fundamental statistical method in agronomy, used to examine the interrelationships among multiple plant growth and yield parameters. By generating pairwise correlation coefficients, researchers can discern how traits such as plant height, primary branches, pod number, seed weight and harvest index relate to one another, which is crucial for crop improvement and management optimization (Uppal *et al.,* 2024). High positive correlations between certain traits suggest potential for simultaneous selection in breeding programs, whereas negative correlations may indicate resource trade-offs or developmental antagonisms (Pal and Santra, 2025). For example, a strong correlation between the number of branches and pod yield could guide genotype selection and agronomic interventions. In the pigeon pea research context, correlation matrix analysis has been instrumental in identifying principal yield-contributing factors under varying environmental and management conditions, facilitating targeted approaches to enhance both productivity and adaptability (Mahalakshmi *et al.,* 2024).

Correlogram analysis builds upon correlation matrices by providing a visual, interpretable depiction of complex trait relationships in multivariate datasets. Correlograms, typically rendered as colored graphical matrices, enable rapid identification of patterns, clusters or groups of traits exhibiting similar behavior. Such visual tools are invaluable for handling large datasets, highlighting strong positive or negative associations and quickly detecting the underlying structure and possible redundancies among measured parameters (Uppal *et al.,* 2024). Correlogram analyses have advanced the interpretation of interactions between physiological, morphological and yield components under different treatments, such as mulching or planting density. This facilitates the design of integrated management strategies and supports decision-making in precision agriculture and breeding (Singh *et al.,* 2024).

Organic mulching using wheat straw, sugarcane trash and live mulches such as cowpea has become an increasingly important practice for enhancing crop productivity, environmental quality and resource-use efficiency. Organic mulch conserves soil moisture by reducing surface evaporation, suppresses weed emergence through physical barrier effects and adds organic matter to the soil upon decomposition, thus improving soil structure, fertility and microbial activity (Adhikari *et al.,* 2024). Application of wheat straw and sugarcane mulch has been shown to moderate soil temperature, provide habitat for beneficial soil organisms and reduce the need for irrigation or herbicides. Live mulching with crops like cowpea offers the dual benefits of N-fixation and ground cover, which can further enhance nutrient cycling and suppress soil erosion. The integration of these mulching strategies in pigeon pea-based systems has led to improved growth parameters, higher pod and seed yields and reduced chronic pest pressures outcomes that are gaining traction in both organic and conservation agriculture frameworks (Hammad *et al.,* 2024).

The system of crop intensification (SCI) operationalized through variable row and plant spacings (*e.g.*, 40×20 cm, 60×20 cm, 80×20 cm), represents a dynamic approach to maximizing pigeon pea productivity and resilience. SCI strategies, originally developed in rice and later extended to other field crops, rearrange plant populations to optimize light interception, air circulation and belowground resource use (Matta *et al.,* 2024). Research indicates that narrower spacings (*e.g.*, 40×20 cm) can boost plant population and total biomass, whereas wider spacings (*e.g.*, 80×20 cm) may favor greater individual plant growth and disease suppression due to enhanced aeration. The selection of optimal spacing depends on varietal characteristics, soil fertility and anticipated stress factors. In pigeon pea, recent studies have documented that SCI improves physiological efficiency, yield components such as pods per plant and 100-seed weight and supports integrated weed and pest management. Adoption and refinement of SCI, especially in combination with organic mulching, have the potential to synergistically enhance pigeon pea yield, resource-use efficiency and farmer incomes in both rainfed and irrigated environments (Kumakech *et al.,* 2024).

Mulching and proper spacing are vital for pigeon pea cultivation in Punjab due to their role in conserving soil moisture, moderating temperature and suppressing weeds, all of which are crucial under Punjab's semi-arid and variable climate. Application of organic mulches such as straw or pigeon pea residue improves water retention and nutrient availability, resulting in enhanced growth parameters, higher pod number and increased seed yield compared to non-mulched conditions. Optimal plant spacing ensures adequate sunlight penetration and aeration, reducing disease pressure and allowing plants to take full advantage of soil resources, thereby maximizing yield potential in the challenging agro-climatic conditions of Punjab (Solanki *et al.,* 2019).

## MATERIALS AND METHODS

### Study area

During the *Kharif* season 2024-25, the field experiment was conducted in the Department of Agronomy's Research Farm at Lovely Professional University in Phagwara, Punjab, India. This research site is in the Northern plain zone, specifically between 31°14′43″N latitude and 75°42′00″E, at 243 m mean sea level, as shown in Fig 2. The meteorological data was acquired at the university's

Agromet observatory located at 31°14′41″N, 75°42′05″E latitude and longitude throughout the crop growing season shown in Fig 1. Temperatures throughout the crop season ranged from 39.4°C to 10.3°C.

The initial physico-chemical analysis of the experimental soil (0-15 cm depth) revealed slightly acidic pH with low electrical conductivity and medium organic carbon content. The available nitrogen was medium, phosphorus was low and potassium was medium as per standard fertility ratings (Table 1).

The experimental site enjoys a subtropical climate where hot winds in the summer blow for a longer time during the day and temperatures remain high during the night (Fig 2). The experiment was conducted under a subtropical climate and the average temperature during the crop growth phase (July to December 2024) ranged from 18.5°C to 36.2°C. The highest temperatures were recorded during the sowing early vegetative stages in July and August, while moderate temperatures prevailed during September and October. These temperature conditions were favourable for the growth and development of pigeon pea.

**Design and layout**

The experiment was conducted in a split plot design, with 12 treatments. In this design, the system of intensification is allocated as the main plots, while types of organic mulching are applied within subplots. This approach, which includes three major plot treatments and four subplot treatments, provides for an effective examination of the treatments separate and combined impacts. The split plot design maximizes the practical implementation of complex field experiments while still ensuring credible statistical comparisons of both the main effects and interactions. The treatment includes $T_1$ - 40 cm × 20 cm + Wheat straw mulch; $T_2$ - 40 cm × 20 cm + Sugarcane mulch; $T_3$ - 40 cm × 20 cm + Live mulch; $T_4$ - 40 cm × 20 cm + No mulch; $T_5$ - 60 cm × 20 cm + Wheat straw mulch; $T_6$ - 60 cm × 20 cm + Sugarcane mulch; $T_7$ - 60 cm × 20 cm + Live mulch; $T_8$ - 60 cm × 20 cm + No mulch; $T_9$ - 80 cm × 20 cm + Wheat straw mulch; $T_{10}$ - 80 cm × 20 cm + Sugarcane mulch; $T_{11}$ - 80 cm × 20 cm + Live mulch; $T_{12}$ - 80 cm × 20 cm + No mulch.

**Table 1:** Physio-chemical characteristics of the soil before the beginning of experiment (0-15 cm depth).

| Soil characteristics | Values |
|---|---|
| pH (1.2.5) | 6.17 |
| Electrical conductivity (dS/m) | 0.19 |
| Organic carbon (%) | 0.46 |
| Available N (kg/ha) | 145.00 |
| Available P (kg/ha) | 15.69 |
| Available K (kg/ha) | 171.00 |

**Variety (Pigeon pea)**

AL-882 is a high-yielding pigeon pea (Arhar) variety that is widely planted in Punjab, notably during the *Kharif* season, because to its broad adaptability and consistent performance in the state's different agro-climatic conditions. AL-882 was sown on July 8th, 2024, at a seed rate of 15-18 kg/ha, matures medium and is ready for harvest in approx. 132 days. The cultivar is noted for its high resilience to key pests and diseases, particularly wilt and sterility mosaic virus, which ensures consistent field performance.

AL-882 was harvested on November 20th, 2024, demonstrating its viability for both rainfed and irrigated agricultural systems. Under proper agronomic treatment, AL-882 produces consistent grain yield of 5.4 quintals/acre, with bold, yellow-brownish seeds that are popular in the market. Its strong stem strength, good branching habit and effective pod filling capacity make it a popular choice among farmers seeking long-term revenue, high-quality grain production and feed from crop wastes.

**Growth analysis of pigeon pea**

The growth parameters were rigorously documented to determine vegetative development. Plant population was counted twice: once during the initial establishment stage by counting the number of emerging seedlings within each net plot area and again after harvest by noting the total number of surviving plants per plot. Plant height was

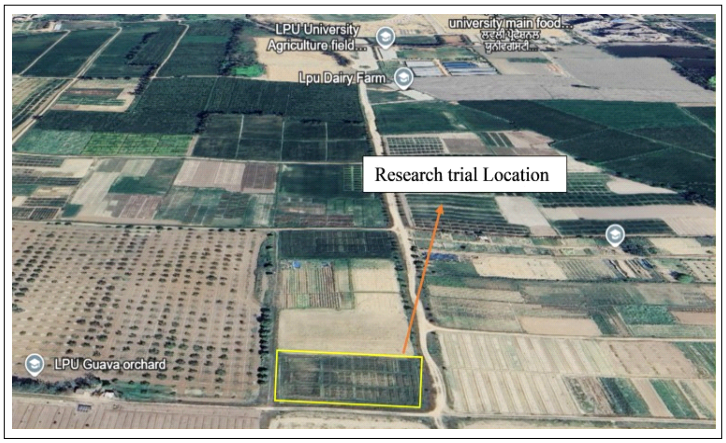



**Fig 1:** Research trial location at Lovely Professional University, Phagwara, Punjab.

measured using a measuring scale from the plant's base at ground level to the tip of the topmost fully opened leaf, assuring accuracy at each point of observation. The canopy spread was determined by measuring the plant's horizontal spread in two perpendicular directions (north-south and east-west) and computing the average. For leaf count observations, both primary and secondary leaves per plant were counted manually by selecting five healthy, randomly tagged plants from each plot. To precisely track progressive vegetative growth, these observations were made at regular intervals of 30, 60, 90 and 120 days after sowing (DAS), as well as harvest.

**Yield attributes of pigeon pea**

At harvest, pods per plant were counted from five randomly tagged plants to determine yield. Grains from chosen pods were manually counted to ascertain the number of grains in each. Pod length was measured on a centimetre scale, taking the average of five typical pods per plot. The harvested pods of these plants were shelled and the grains were cleaned and weighed to determine grain yield (q/ha). The test weight was determined by randomly selecting and weighing 1000 clean, air-dried grains. To calculate biological yield (q/ha), the complete above-ground biomass (including stems and pods) was harvested, dried, weighed and converted to a per-hectare basis. The harvest index (HI) was then determined as the ratio of grain yield to total biological yield, using the standard approach published by Donald and Hamblin (1976).

**Yield assessment studies**

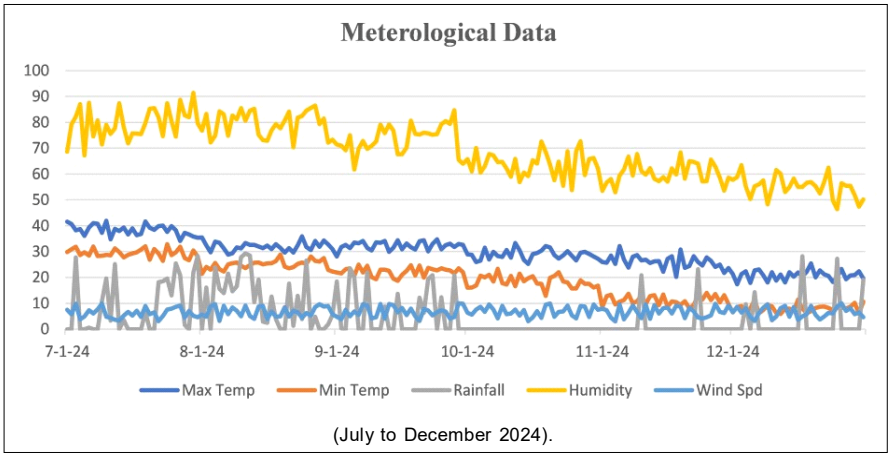
**Correlation matrix analysis between growth and yield attributes**

Correlation analysis is a statistical approach for determining the strength and direction of correlations between two or more variables in agricultural research, such as growth and yield features. Correlation coefficients allow researchers to measure how differences in features such as plant height or number of leaves per plant relate to yield components, assisting in the identification of critical growth parameters influencing productivity (Kasu-Bandi *et al.,* 2019). In the current study, correlation analysis was used to investigate the correlations between various growth and yield parameters. The analysis was carried out using GRAPES (General R-based analysis platform empowered by statistics), a well-known software platform for statistical analysis in agricultural research. GRAPES enabled the precise computation of correlation coefficients, indicating the strength and direction of relationships between the measured variables.

Correlation matrix analysis was chosen over regression and path analysis because it efficiently reveals the pairwise relationships and interdependencies among multiple growth and yield attributes of pigeon pea without imposing directional causality or complex model assumptions. This allows for the identification of key traits that are strongly associated, providing essential insight for preliminary screening and guiding further detailed analysis in agronomic research.

**Correlogram analysis**

Correlogram analysis is a graphical tool for visualizing the correlation matrix, making it easier to grasp the links between various growth and yield variables in agricultural research. Correlograms illustrate which attributes are closely associated to yield, either favorably or negatively, by presenting correlation coefficients as color gradients or patterns. This visual technique makes it easier to identify crucial growth characteristics that influence productivity, as well as to locate clusters of similar traits. Correlograms provide an accessible way to notice patterns in agricultural studies, leading further statistical analysis and informing crop improvement and management decisions (Graffelman *et al.,* 2023). The present study used correlogram analysis to investigate the correlations between growth and yield parameters. The analysis was carried out using GRAPES software, a dependable statistical platform extensively utilized in agricultural research.




(July to December 2024).

**Fig 2:** Mean standard meteorological data weather parameters and total rainfall during the cropping season.

### Statistical analysis

The recorded data was imported into MS Excel for averaging and preliminary calculations. A one-way analysis of variance (ANOVA) was then performed using CVSTAT software to determine significant differences between treatments at the 95% confidence level (p = 0.05). Tables show the values for critical difference (CD) and standard error of mean (SEM). To determine distinctions between treatment methods. All statistical analyses were carried out using CVSTAT software.

## RESULTS AND DISCUSSION

Correlation matrix and Correlogram analysis of growth and yield relationships in pigeon pea (*Cajanus cajan* L.) under organic mulching and system of intensification (Table 2 and 3 and Fig 3).

### Plant population

Plant population exhibited low to moderate positive correlations with most growth and yield parameters, such as plant height (r = 0.174), canopy spread (r = 0.249), number of primary branches (r = 0.316) and pods per plant (r = 0.498). These associations indicate that higher plant population can contribute modestly to overall yield components, likely due to increased competition for resources at higher densities. However, excessive crowding can diminish individual plant performance, as supported by Kumakech *et al.,* (2024) and Bansal *et al.,* (2022), which found optimal yields at moderate planting densities.

### Plant height (cm)

Plant height showed very strong positive correlations with almost all growth and yield traits: Canopy spread (r = 0.983, p<0.001), number of primary branches (r = 0.960, p<0.001), number of secondary branches (r = 0.919, p<0.01), pods per plant (r = 0.936, p<0.01), grains per pod (r = 0.999, p<0.001), length of pod (r = 0.987, p<0.01), test weight (r = 0.948, p<0.01), grain yield (r = 0.984, p<0.01) and biological yield (r = 0.999, p<0.001). This demonstrates that taller plants generally possess superior vegetative vigor, translating to greater yield and biomass. Similar findings have been consistently reported by (Pooja *et al.,* 2024) and (Gupta and Sahu, 2025) in contemporary pigeon pea research, affirming that increased plant height is a key selection indicator for higher productivity.

### Canopy spread (cm)

Canopy spread was also strongly positively correlated with nearly all major yield and growth traits (r = 0.995 with primary branches, r = 0.936 with grain yield, both p<0.001). A wider canopy indicates a larger photosynthetic area and improved resource capture, resulting in increased productivity. Dash *et al.* (2024) and Mahendraraj *et al.* (2024) support the role of canopy expansion in maximizing pod and grain yield formation through enhanced light interception and assimilate partitioning.

### Number of primary branches

The number of primary branches displayed strong positive correlations with number of secondary branches (r = 0.992, p<0.001), pods per plant (r = 0.969, p<0.001), grains per

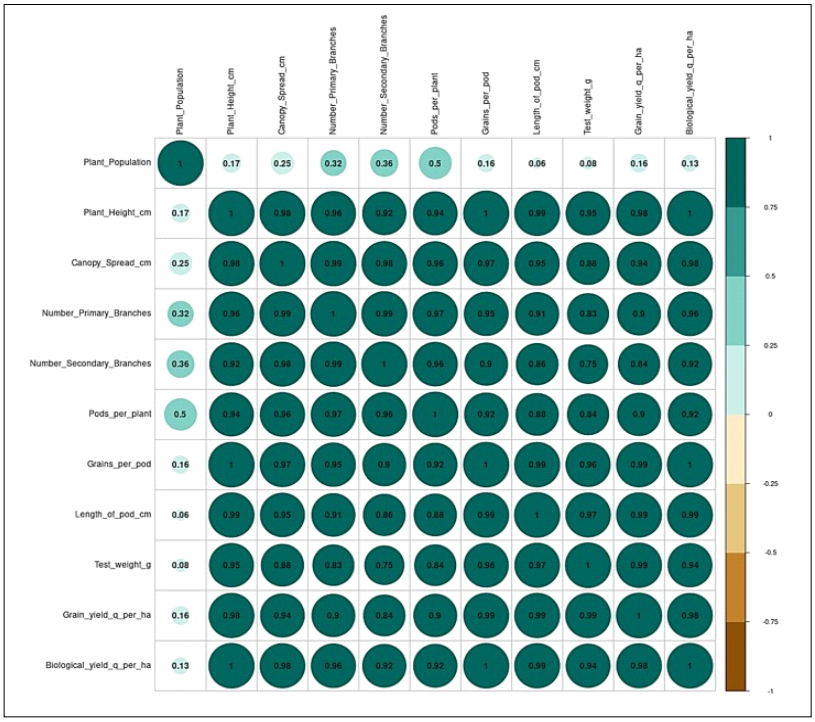



**Fig 3:** Correlogram analysis of growth and yield traits under system of intensification and organic mulching in pigeon pea.

**Table 2:** Correlation matrix analysis of growth and yield traits under system of intensification and organic mulching in pigeon pea.

| | Plant population | Plant height | Canopy spread | Number primary branches | Number secondary branches | Pods per plant | Grains per pod | Length of pod | Test weight | Grain yield | Biological yield |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Plant population | 1 | 0.174 | 0.249 | 0.316 | 0.36 | 0.498 | 0.156 | 0.061 | 0.078 | 0.164 | 0.133 |
| Plant height | 0.174 | 1 | 0.983*** | 0.96*** | 0.919** | 0.936** | 0.999*** | 0.987*** | 0.948** | 0.984*** | 0.999*** |
| Canopy spread | 0.249 | 0.983*** | 1 | 0.995*** | 0.975*** | 0.96*** | 0.973*** | 0.95** | 0.878** | 0.936** | 0.982*** |
| Number primary branches | 0.316 | 0.96*** | 0.995*** | 1 | 0.992*** | 0.969*** | 0.946** | 0.912** | 0.829* | 0.901** | 0.959*** |
| Number secondary branches | 0.36 | 0.919** | 0.975*** | 0.992*** | 1 | 0.957*** | 0.899** | 0.858* | 0.755* | 0.841* | 0.918** |
| Pods per plant | 0.498 | 0.936** | 0.96*** | 0.969*** | a0.957*** | 1 | 0.924** | 0.879** | 0.835* | 0.904** | 0.923** |
| Grains per pod | 0.156 | 0.999*** | 0.973*** | 0.946** | 0.899** | 0.924** | 1 | 0.992*** | 0.96*** | 0.99*** | 0.997*** |
| Length of pod | 0.061 | 0.987*** | 0.95** | 0.912** | 0.858* | 0.879** | 0.992*** | 1 | 0.975*** | 0.986*** | 0.988*** |
| Test weight | 0.078 | 0.948** | 0.878** | 0.829* | 0.755* | 0.835* | 0.96*** | 0.975*** | 1 | 0.986*** | 0.942** |
| Grain yield | 0.164 | 0.984*** | 0.936** | 0.901** | 0.841* | 0.904** | 0.99*** | 0.986*** | 0.986*** | 1 | 0.978*** |
| Biological yield | 0.133 | 0.999*** | 0.982*** | 0.959*** | 0.918** | 0.923** | 0.997*** | 0.988*** | 0.942** | 0.978*** | 1 |

Note: *** Correlation is significant at 0.001 level (two tailed); ** Correlation is significant at 0.01 level (two tailed); * Correlation is significant at 0.05 level (two tailed).

**Table 3:** Matrix of P-values (Correlation matrix).

| | Plant population | Plant height | Canopy spread | Number primary branches | Number secondary branches | Pods per plant | Grains per pod | Length of pod | Test weight | Grain yield | Biological yield |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Plant population | NA | 0.708 | 0.590 | 0.490 | 0.427 | 0.255 | 0.739 | 0.897 | 0.867 | 0.725 | 0.777 |
| Plant height | 0.708 | NA | 0.000 | 0.001 | 0.003 | 0.002 | 0.000 | 0.000 | 0.001 | 0.000 | 0.000 |
| Canopy spread | 0.590 | 0.000 | NA | 0.000 | 0.000 | 0.001 | 0.000 | 0.001 | 0.009 | 0.002 | 0.000 |
| Number primary branches | 0.490 | 0.001 | 0.000 | NA | 0.000 | 0.000 | 0.001 | 0.004 | 0.021 | 0.006 | 0.001 |
| Number secondary branches | 0.427 | 0.003 | 0.000 | 0.000 | NA | 0.001 | 0.006 | 0.014 | 0.050 | 0.018 | 0.004 |
| Pods per plant | 0.255 | 0.002 | 0.001 | 0.000 | 0.001 | NA | 0.003 | 0.009 | 0.019 | 0.005 | 0.003 |
| Grains per pod | 0.739 | 0.000 | 0.000 | 0.001 | 0.006 | 0.003 | NA | 0.000 | 0.001 | 0.000 | 0.000 |
| Length of pod | 0.897 | 0.000 | 0.001 | 0.004 | 0.014 | 0.009 | 0.000 | NA | 0.000 | 0.000 | 0.000 |
| Test weight | 0.867 | 0.001 | 0.009 | 0.021 | 0.050 | 0.019 | 0.001 | 0.000 | NA | 0.000 | 0.001 |
| Grain yield | 0.725 | 0.000 | 0.002 | 0.006 | 0.018 | 0.005 | 0.000 | 0.000 | 0.000 | NA | 0.000 |
| Biological yield | 0.777 | 0.000 | 0.000 | 0.001 | 0.004 | 0.003 | 0.000 | 0.000 | 0.001 | 0.000 | NA |

pod (r = 0.946, p<0.01), grain yield (r = 0.901, p<0.01) and biological yield (r = 0.959, p<0.001). More primary branches enhance the reproductive sink, increasing pod and ultimately seed production. These outcomes are well-aligned with recent breeding recommendations targeting greater branching for yield improvement (Bhagat *et al.,* 2022 and Pranati *et al.,* 2024).

**Number of secondary branches**

Secondary branches had very robust positive correlations with pods per plant (r = 0.957, p<0.001), grains per pod (r = 0.899, p<0.01) and grain yield (r = 0.841, p<0.01). The proliferation of secondary branches increases the sites for pod development, thus supporting higher yields. (Pooja *et al.,* 2024) and (Shukla *et al.,* 2025) highlights the importance of optimizing both primary and secondary branching in pigeon pea breeding programs.

**Number of pods per plant**

Pods per plant were highly positively correlated with yield-determining traits-particularly grains per pod (r = 0.924, p<0.01), grain yield (r = 0.904, p<0.01) and biological yield (r = 0.923, p<0.001). Thus, a higher pod number directly drives yield gains, confirming findings from multi-year genetic studies identifying pods per plant as a central driver of pigeon pea seed yield (Mukherjee *et al.,* 2025 and Patel *et al.,* 2025).

**Number of grains per pod**

Grains per pod correlated significantly with length of pod (r = 0.992, p<0.001), test weight (r = 0.963, p<0.001), grain yield (r = 0.990, p<0.001) and biological yield (r = 0.997, p<0.001). Maximizing grains per pod is a highly effective approach for improving overall productivity, validated by Jha *et al.* (2024) and Mukherjee *et al.* (2025) that emphasize grain set per pod as a critical factor.

**Length of pod (cm)**

Length of pod showed strong positive correlations with test weight (r = 0.975, p<0.001), grain yield (r = 0.986, p<0.001) and biological yield (r = 0.988, p<0.001). Longer pods typically accommodate more seeds and thus higher yield, a pattern reinforced in agronomic evaluations of pod morphology and pigeon pea yield (Bernhard and Schubert, 2021 and Usha *et al.,* 2023).

**Test weight (g)**

Test weight also had robust positive correlations with both grain (r = 0.986, p<0.001) and biological yield (r = 0.942, p<0.001). This underscores the influence of seed size and density on final productivity, supported by in path coefficient studies identifying test weight as a significant positive contributor to yield.

Test weight demonstrated robust positive correlations with both grain yield (r = 0.986, p<0.001) and biological yield (r = 0.942, p<0.001), highlighting the significant impact of seed size and density on overall productivity. Larger and denser seeds typically contribute to higher total output by enhancing both seed and biomass accumulation. This relationship is supported by Jayalakshmi *et al.* (2023) found that test weight was among the strongest contributors to seed yield per plant in pigeon pea, with path analysis confirming its pivotal direct and indirect effects on both grain and biological yields. Pooja *et al.* (2024) emphasized that genotypes with higher test weight consistently outperformed others in yield trials and recommended targeting test weight in breeding and selection for enhanced crop performance.

**Grain yield (q/ha)**

Grain yield displayed the strongest positive associations with biological yield (r = 0.978, p<0.001), confirming that increased grain harvest is closely linked with total biomass produced. Yield was also strongly correlated with almost all measured growth traits, reflecting the multifactorial control of productivity in pigeon pea (Pashawar *et al.,* 2024). Modern breeding programs emphasize the integration of these traits for varietal improvement (Trivedi *et al.,* 2024).

**Biological yield (q/ha)**

Biological yield was positively and significantly associated with nearly every growth and yield parameter. This clearly demonstrates that enhancements in plant structure (height, branching, canopy) and reproductive output (pods, grain set, seed size) collectively drive overall biomass accumulation, as detailed by Sharifi *et al.* (2018) and Kandarkar *et al.* (2020) in integrating phenotypic and yield data.

## CONCLUSION

This study revealed significant associations among various growth and yield traits in pigeon pea, identifying critical factors that influence productivity. Strong positive correlations were observed between grain yield and key parameters such as plant height, canopy spread, number of branches, pods per plant, grains per pod, pod length and test weight. Enhanced vegetative growth and reproductive development, reflected in taller plants with extensive branching and larger canopies, contributed to greater biomass and seed production. For the system of intensification, the highest grain yield treatment (60×20 cm) is approximately 11.04 per cent better than the lowest treatment (40×20 cm). For organic mulching, the best mulching treatment (Wheat Straw) is about 17.92 per cent better in grain yield compared to no mulch. The findings highlight the importance of integrating these traits in breeding programs and crop management to optimize yield potential. Additionally, optimal plant population density was shown to balance resource competition and productivity effectively. While the study provides valuable insights into trait interrelationships, it is based on data from a single growing season; therefore, further multi-season trials are recommended to validate and refine these conclusions for sustainable pigeon pea production.

## ACKNOWLEDGEMENT

We express our sincere gratitude to the Department of Agronomy at Lovely Professional University, Phagwara, for their invaluable support and assistance throughout the completion of this work.

### Ethical issues

None.

### Conflict of interest

The authors declare that they have no conflict of interest.

## REFERENCES

Adhikari, J.B., Yadav, D.R., Ghalan, C. and Yadav, D.K. (2024). Effect of mulching on growth and yield of sugarcane at subtropical region of Nepal. *International Journal of Novel Research and Development*. **9(12):** 556-560.

Bansal, K.K., Sandhu, K.S., Bharti, V., Saha, A., Srivastava, H., Nesar, N.A. and Attri, M. (2022). Influence of varieties and spacings on growth, yield attributes and productivity of Pigeonpea. *Indian Journal of Agricultural Research*. **58(6):** 1181-1186. doi: 10.18805/ijare.A-5748.

Bernhard, M. and Schubert, M. (2021). Correcting imprecise object locations for training object detectors in remote sensing applications. *Remote Sensing*. **13(24):** 4962. doi: 10.3390/rs13244962.

Bhagat, P., Giri, S.K., Kumar, K., Tiwari, J.K. and Sinha, S.K. (2022). Genetic variability and association studies for seed yield and related trait in pigeonpea [*Cajanus cajan* (L.) Millsp.]. *Pharma Innovation*. **11(9):** 2963-2966.

Dash, S., Murali, K., Bai, S.K., Rehman, H.A. and Sathish, A. (2024). Influence of sowing window and planting geometry on pigeonpea nutrient uptake, quality and yield. *Mysore Journal of Agricultural Sciences*. **58(1):** 387-396.

Donald, C.M. and Hamblin, J. (1976). The biological yield and harvest index of cereals as agronomic and plant breeding criteria. *Advances in Agronomy*. **28:** 361-405. https://doi.org/10.1016/S0065-2113(08)60559-3.

Graffelman, J. and de Leeuw, J. (2023). Improved approximation and visualization of the correlation matrix. *The American Statistician*. **77(4):** 432-442. doi: 10.1080/00031305.2023.2186952.

Gupta, R. and Sahu, M. (2025). Correlation and path analysis for yield and its attributing traits in pigeonpea [*Cajanus cajan* (L.) Mill sp.]. *Plant Archives*. **25(1):** 490-494.

Haji, A., Roobab, U., Aslam, A. and Ghani, M.A. (2024). Nutritional composition, bioactive compounds, food applications and health benefits of pigeon pea (*Cajanus cajan*). *Legume Science*. e233. https://doi.org/10.1002/leg3.233.

Hammad, H., Gul, B., Khan, H., Fawad, M.H., Ali, H. and Bakht, T. (2024). Comparison of organic mulches with various weed control strategies for weed management in maize. *Pakistan Journal of Weed Science Research*. **30(2):** 65-74.

Jayalakshmi, M., Babu, G.P., Kalyani, D.L. and Chaithanya, B.H. (2023). On farm testing on foliar application of nutrients and growth regulators in pigeonpea (*Cajanus cajan* L.). *Legume Research*. **46(8):** 1041-1047. doi: 10.18805/LR-5150.

Jha, V., Yadav, A., Quatadah, S.M., Srivastava, A., Singh, K. and Kumar, J. (2024). Assessment of genetic diversity and path coefficient analysis for grain yield in pigeon pea [*Cajanus cajan* (L.) Millsp.]. *International Journal of Advanced Biochemistry Research*. **8(5):** 632-635.

Kandarkar, K.G., Kute, N.S., Tajane, S.A. and Ingle, A.U. (2020). Correlation and path analysis for yield and its Contributing traits in pigeonpea [*Cajanus cajan* (L.) Mill. Sp.]. *Journal of Pharmacognosy and Phytochemistry*. **9(4):** 1629-1632.

Kasu-Bandi, B.T., Lukanga, P. and Tshibuyi, B. (2019). Correlations between growth and yield parameters of soybean under Bradyrhizobium japonicum input. *American Journal of Agricultural and Biological Sciences*. **14(2):** 86-94. https://doi.org/10.3844/ajabssp.2019.86.94.

Kumakech, A., Opio, T. and Turyagyenda, F.L. (2024). Effect of plant spacing on pigeonpea grain yield in Northern Uganda. *Brazilian Journal of Science*. **3(4):** 41-47.

Kumakech, A., Opio, T. and Turyagyenda, F.L. (2024). Effect of plant spacing on pigeonpea grain yield in Northern Uganda. *Brazilian Journal of Science*. **3(4):** 41-47. doi: 10.14295/bjs.v3i4.548.

Mahalakshmi, P.J., Satish, Y., Ramana, J.V. and Raju, M.R.B. (2024). Correlation and path coefficient analysis for yield and its component traits in advanced breeding lines of rice (*Oryza sativa* L.). *Journal of Advances in Biology and Biotechnology*. **27(9):** 769-777. doi: 10.9734/jabb/2024/v27i91350.

Mahendraraj, S., Collins, M., Chauhan, Y., Mellor, V. and Rachaputi, R.C.N. (2024). Dynamics of productivity in pigeonpea [*Cajanus cajan* (L.) Millsp.] in subtropical Australia. *Agronomy Journal*. **116(6):** 2827-2840. doi: 10.1002/agj2.21667.

Mashifane, D.C., Mathew, I., Shonhai, A., Onipe, O.O. and Gwata, E.T. (2025). Evaluation of selected nutritional attributes among pigeon pea (*Cajanus cajan*) landraces. *Food Research*. **9(4):** 106-114. https://doi.org/10.26656/fr.2017.9(4).250

Matta, F. de, P., Godoy, R., Oliveira, P.P.A. and Ferraz Júnior, R.S. (2024). Row spacing for pigeon pea sowing and its influence on the recovery of degraded pasture. *Pesquisa Agropecuaria Brasileira*. **59.** doi: 10.1590/s1678-3921.pab2024.v59.03516.

Mukherjee, E., Chaudhary, L. and Kumar, M. (2025). Dissecting yield-associated genetic diversity in early-maturing pigeon-pea (*Cajanus cajan* L.) through morphophysiological trait analysis. *Genetic Resources and Crop Evolution*. **72(8):** 10425-10440. doi: 10.1007/s10722-025-02576-9.

Nisha and Dhillon, B.S. (2020). Effect of sowing time and mulching on the performance of pigeon pea (*Cajanus cajan* L.). *Phyto Journal*. **9(4):** 881-886.

Pal, R. and Santra, C.K. (2025). Analysis of trait variation and correlations in hybrid rice seed production using CMS breeding techniques. *Current Agriculture Research Journal*. **12(3):** 1218-1226. doi: 10.12944/carj.12.3.16.

Pashawar, S.S., Khobragade, A.M., Katait, S.A., Gote, G.N., Singh, H., Chavhan, L.P. and Kumar, P. (2024). Relationship between agrometeorological indices, crop phenology and yield of pigeonpea as influenced by different dates of sowing and varieties. *International Journal of Research in Agronomy*. **7(9):** 515-518. doi: 10.33545/2618060x.2024.v7.i9g.1588.

Patel, D.P., Patel, P.R. and Patel, D.G. (2025). Insights into productive traits of pigeonpea [*Cajanus cajan* (L.) Millsp.]: A study of character associations and path coefficients. *International Journal of Advanced Biochemistry Research*. **9(1S):** 174-177. doi: 10.33545/26174693.2025.v9.i1sc.3450.

Pathade, K.L. and Kumar, V. (2025). Changing scenario in area, production and productivity of pigeon pea in state of Maharashtra in two decades and its implications. *International Journal of Statistics and Applied Mathematics*. **10(Special Issue 2, Part A):** 6-9.

Pooja Rambhau, C., Gite, V.K., Patil, D.K., Bhakad, V.R. and Madake, A.A. (2024). Studies on correlation and path coefficient analysis for yield and yield contributing characters in Pigeonpea [*Cajanus cajan* (L). millips]. *International Journal of Current Microbiology and Applied Sciences*. **13(1):** 144-149. doi: 10.20546/ijcmas.2024.1301.018.

Pranati, J., Chilakamarri, V., Kalyan, A., Shruthi, H.B., Bomma, N., Yogendra, K. and Gangashetty, P. (2024). Strategizing pigeonpea for enhancing health-benefitting traits: A path to nutritional advancements. *Crop Design*. **3(4):** 100068. doi: 10.1016/j.cropd.2024.100068.

Pranati, J., Kumar, C.V.S., Gangashetty, P.I., Sharma, M., Pandey, M.K. and Sajja, S. (2024). Genetic studies on yield and its components in pigeonpea [*Cajanus cajan* (L.) millsp.]. *Journal of Experimental Agriculture International*. **46(10):** 461-466. doi: 10.9734/jeai/2024/v46i102969.

Sharifi, P., Astereki, H. and Pouresmael, M. (2018). Evaluation of variations in chickpea (*Cicer arietinum* L.) yield and yield components by multivariate technique. *Annals of Agrarian Science*. **16(2):** 136-142. doi: 10.1016/j.aasci.2018.02.003.

Shukla, S., Pande, G.P., Bhadauriya, S.S., Mishra, S.P. and Kushwaha, K. (2025). Yield and its contributing traits: A path analysis approach in pigeon pea. *International Journal of Advanced Biochemistry Research*. **9(1S):** 923-925. doi: 10.33545/26174693.2025.v9.i1sI.3630.

Singh, B., Upadhyay, D.K., Jha, A., Singh, R.K., Chaubey, T. and Pandey, S. (2024). Correlation matrix and stability analysis for morpho-physiological characteristics in extant cultivars of tomato (*Solanum lycopersicum* L.). *Vegetable Science*. **51(02):** 283-291. https://doi.org/10.61180/vegsci.2024.v51.i2.12.

Singh, S., Lawrence, R. and Jeyakumar, E. (2024). Microbial technology based sustainable pigeon pea crop management under environmental stress. *International Journal of Current Microbiology and Applied Sciences*. **13(2):** 102-114. doi: 10.20546/ijcmas.2024.1302.015.

Solanki, M.A., Chalodia, A.L., Dabhi, P.V. and Fadadu, M.H. (2019). Effect of Pigeonpea to irrigation and mulch regime. *International Journal of Current Microbiology and Applied Sciences*. **8(07):** 43-52. doi: 10.20546/ijcmas.2019.807.006.

Trivedi, A., Yadav, A., Quatadah, S.M., Tiwari, S. and Srivastava, A. (2024). Genetic characterization and trait association studies in pigeon pea [*Cajanus cajan* (L.) Millsp.] germplasm. *International Journal of Advanced Biochemistry Research*. **8(8):** 240-244. doi: 10.33545/26174693.2024.v8.i8d.1745.

Uppal, P., Kumar, A., Singh, R., Kaundal, S. and Priyanka. (2024). Correlation and path coefficient analysis of different maize genotypes under rainfed condition. *International Journal of Advanced Biochemistry Research*. **8(7S):** 112-117. doi: 10.33545/26174693.2024.v8.i7sb.1473.

Usha, N., Patil, S.B., Nandagavi, R.A. and Kiran, B.O. (2023). Changes in growth and yield of pigeonpea genotypes under different growing environments. *Journal of Farm Sciences*. **36(1):** 8-15.