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Interrelationship of Quantitative Traits through Correlation and Path Analysis in Chickpea (*Cicer arietinum* L.)

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

The 34 chickpea genotypes were investigated at the Field Experimentation Centre of the Department of Genetics and Plant Breeding, Naini Agricultural Institute, Sam Higginbottom University of Agriculture, Technology and Sciences, Allahabad, U.P., during *Rabi* 2017-2018. The present experiment was conducted in a Randomized Block Design with three replications.

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Observations were recorded on five randomly selected plants for nine quantitative traits from each replication. The mean sum of squares due to genotypes showed significant differences for all traits. The genotype CSJ-1085 (15.91 g) exhibited maximum seed yield per plant, whereas the lowest value (5.70 g) was recorded in genotype CSJ-1101. Seed yield per plant showed a significant positive association with plant height (cm), number of pods per plant, seed index (g), biological yield per plant (g) and harvest index (%) at both genotypic and phenotypic levels, and with number of seeds per pod at the genotypic level only. Path analysis revealed that plant height (cm) and number of pods per plant had the strongest positive direct effects on seed yield (g), followed by biological yield (g), seed index (g) and harvest index (%), making them important selection criteria in chickpea breeding programs.

Keywords: Chickpea; correlation; path analysis; quantitative traits and yield.

1. INTRODUCTION

“Chickpea (*Cicer arietinum* L.) is one of the most important pulse crops grown predominantly during the *Rabi* season in semi-arid regions of the world. The name *Cicer* is derived from the Greek word *kiros*, referring to a renowned Roman family, Cicero, whereas *arietinum* originates from the Latin word *arise*, meaning "ram," in reference to the ram’s head-like shape of the seed” (Singh, 1985). “Chickpea is a self-pollinated, diploid species (2n = 2x = 16) with an estimated genome size of 740 Mbp. It is cultivated across approximately 14.84 million hectares globally, with 96% of the production concentrated in developing countries” (Varshney et al*.,* 2013). Among legume crops, it ranks third in pulse production, fifth in overall food legumes, and fifteenth among all grain crops worldwide, highlighting its critical role in global food security.

Chickpea production has shown a consistent upward trend over the past few decades. According to FAOSTAT (2022), the global chickpea production reached approximately 15.2 million tonnes in 2021, with an average productivity of around 1043 kg/ha. This steady increase is attributed to the development and adoption of improved varieties and better crop management practices. According to Bahl and Salimath (1996), chickpea one of the oldest domesticated pulse crops in India, holds significant value for its diverse applications in food and traditional medicine. Its tender leaves are consumed as vegetables, and the plant exudes organic acids, primarily malic and oxalic acids, which are traditionally utilized for their medicinal properties, including blood purification and treatment of digestive disorders.

“Correlation analysis is a critical tool in plant breeding to assess the strength and direction of association between different traits. In chickpea, understanding correlations among yield-contributing characters such as number of pods per plant, seed weight, and biological yield is essential for effective indirect selection” (Nagar and Karnawat, 2023). Such relationships guide breeders in selecting desirable traits early, thereby improving yield potential and breeding efficiency.

“While correlation studies reveal the association between traits, they do not partition the relationship into direct and indirect effects. Path coefficient analysis thus provides a more detailed understanding by breaking down correlations into components that directly affect yield and those that influence it indirectly” (Yadav et al*.,* 2020; Viswanatha Reddy et al*.,* 2022; Quatadah et al*.,* 2025). In chickpea, traits like number of pods per plant and 100-seed weight have been reported to exert strong direct effects on yield, highlighting their importance as primary selection criteria in breeding strategies.

2. MATERIALS AND METHODS

The present investigation was carried out during the *Rabi* season of 2017–2018 at the Field Experimentation Centre of the Department of Genetics and Plant Breeding, Naini Agricultural Institute, Sam Higginbottom University of Agriculture, Technology and Sciences, Allahabad (U.P). A total of 34 chickpea (*Cicer arietinum* L.) genotypes, including indigenous and exotic lines along with one check variety, were evaluated. The experimental material, received from the Rajasthan Agricultural Research Institute, Durgapura, Rajasthan, was sown on 8th November 2017 following a Randomized Block Design with three replications. Each genotype was grown in plots consisting of three rows of 1 meter length, maintaining a spacing of 30 cm between rows and 10 cm between plants. The list of chickpea genotypes along with their origin

Table 1. List of chickpea genotypes along with their origin

S. No.	Name of Genotypes	Origin
1	CSJ – 1075	RARI, Durgapura
2	CSJ – 1076	RARI, Durgapura
3	CSJ – 1077	RARI, Durgapura
4	CSJ – 1078	RARI, Durgapura
5	CSJ – 1079	RARI, Durgapura
6	CSJ – 1080	RARI, Durgapura
7	CSJ – 1081	RARI, Durgapura
8	CSJ – 1082	RARI, Durgapura
9	CSJ – 1083	RARI, Durgapura
10	CSJ – 1084	RARI, Durgapura
11	CSJ – 1085	RARI, Durgapura
12	CSJ – 1086	RARI, Durgapura
13	CSJ – 1087	RARI, Durgapura
14	CSJ – 1088	RARI, Durgapura
15	CSJ – 1089	RARI, Durgapura
16	CSJ – 1090	RARI, Durgapura
17	CSJ – 1091	RARI, Durgapura
18	CSJ – 1092	RARI, Durgapura
19	CSJ – 1093	RARI, Durgapura
20	CSJ – 1094	RARI, Durgapura
21	CSJ – 1095	RARI, Durgapura
22	CSJ – 1096	RARI, Durgapura
23	CSJ – 1097	RARI, Durgapura
24	CSJ – 1098	RARI, Durgapura
25	CSJ – 1099	RARI, Durgapura
26	CSJ – 1100	RARI, Durgapura
27	CSJ – 1101	RARI, Durgapura
28	CSJ – 1102	RARI, Durgapura
29	CSJ – 1103	RARI, Durgapura
30	CSJ – 1104	RARI, Durgapura
31	CSJ – 1105	RARI, Durgapura
32	CSJ – 1106	RARI, Durgapura
33	CSJ – 1107	RARI, Durgapura
34	UDAY (Check)	RARI, Durgapura

is presented in Table 1. The recommended dose of fertilizers (N:P:K :: 20:40:20) was applied, and all standard agronomic practices were followed to raise a good crop. The gross experimental area was 221 m², with a net plot area of 102 m², and border rows were planted to minimize border effects. The crop was harvested on 27th March 2018. Observations were recorded on five randomly selected plants in each replication for 9 quantitative traits, namely days to 50% flowering, plant height (cm), days to maturity, number of pods per plant, number of seeds per pod, seed index (g), biological yield per plant (g), harvest index (%), and seed yield per plant (g). The data recorded were subjected to statistical analysis. Analysis of variance was conducted following Fisher (1936), and correlation coefficients among the traits were computed as per the method of Al-Jibouri et al*.,* (1958), and path coefficient analysis was performed following Dewey and Lu (1959) to determine direct and indirect effects of component traits on seed yield.

3. RESULTS AND DISCUSSION

The findings of the present study and their interpretation are discussed under the following sections:

3.1 Analysis of Variance

The ANOVA for different characters across 34 chickpea genotypes is presented in Table 2. The mean sum of squares due to genotypic differences revealed significant variation for all the characters studied, namely days to 50% flowering, plant height (cm), days to maturity, number of pods per plant, number of seeds per

pod, seed index (g), biological yield per plant (g), harvest index (%), and seed yield per plant (g). Among these, the highest magnitude of mean sum of squares was observed for number of pods per plant (492.40**), indicating substantial genetic variability. The significant differences among genotypes provide a strong basis for further correlation and path coefficient analysis to understand the interrelationship among traits and their direct and indirect effects on seed yield. Similar findings were reported by Raval et al. (2017) and Yadav et al. (2022) in chickpea, emphasizing the presence of sufficient variability for conducting correlation and path studies.

3.2 Correlation Coefficient Analysis

The correlation coefficient is a statistical measure used to determine the degree and direction of the relationship between two or more variables. A positive correlation value indicates that the changes in two variables occur in the same direction. In the present investigation, correlation coefficient analysis was conducted to measure the mutual relationship between various plant characters and to identify the component characters upon which selection could be based for genetic improvement in seed yield. Understanding the nature, extent, and direction of association among yield-contributing traits is crucial, especially when aiming to combine high yield potential with desirable plant attributes and seed quality characteristics.

In this study, both genotypic and phenotypic correlation coefficients among different traits and their relationships with seed yield per plant were estimated and are presented in Tables 3 and 4 respectively.

3.2.1 Genotypic correlation coefficient analysis

The genotypic correlation analysis revealed that seed yield per plant exhibited a highly significant and positive association with plant height (0.60**), number of pods per plant (0.60**), seeds per pod (1.09**), seed index (0.53**), biological yield per plant (0.55**), and harvest index (0.48**). Conversely, it showed a significant negative association with days to 50% flowering (-0.75**) and days to maturity (-0.81**).

Among the yield components, days to 50% flowering showed a significant positive association with days to maturity (1.09*) and significant negative associations with plant height (-0.77**), number of pods per plant (-0.66**), seed index (-0.73**), biological yield per plant (-0.79**), and harvest index (-0.69**). Plant height displayed significant positive correlations with number of pods per plant (0.79**), seeds per pod (0.86**), seed index (0.22*), biological yield per plant (0.80**), harvest index (0.22*), and seed yield per plant (0.60**), while it had a significant negative correlation with days to maturity (-0.71**).

Days to maturity exhibited significant negative correlations with number of pods per plant (-0.61**), seeds per pod (-1.81**), seed index (-0.66**), biological yield per plant (-0.72**), and harvest index (-0.71**). Number of pods per plant showed significant positive associations with seeds per pod (0.32**), seed index (0.25*), biological yield per plant (0.68**), and harvest index (0.21*). Similarly, seeds per pod were positively correlated with seed index (1.43**), biological yield per plant (1.83**), and harvest index (1.95**). Seed index also exhibited a positive relationship with biological yield per plant (0.21*) and harvest index (0.45**), while biological yield per plant had a significant positive association with harvest index (0.32**).

“Overall, the results indicated that seeds per pod had a strong and significant positive association with seed yield per plant at the genotypic level, suggesting that traits like number of pods per plant and plant height could be effectively utilized in selection programs to improve yield potential in chickpea” (Kumar et al. 2014; Singh et al. 2020; Sinha et al. 2022).

3.2.2 Phenotypic correlation coefficient analysis

Phenotypic correlation coefficient analysis showed that seed yield per plant was positively and significantly associated with plant height (0.55**), number of pods per plant (0.54**), seed index (0.50**), biological yield per plant (0.50**), and harvest index (0.47**), while a positive but non-significant association was recorded with seeds per pod (0.17). Significant negative associations were observed with days to 50% flowering (-0.55**) and days to maturity (-0.67**).

Days to 50% flowering had a significant positive correlation with days to maturity (0.71**), but it was negatively associated with plant height (-0.53**), number of pods per plant (-0.43**), seeds per pod (-0.34**), seed index (-0.51**), biological yield per plant (-0.55**), and harvest

index (-0.51**). Plant height was positively correlated with number of pods per plant (0.71**), seed index (0.20*), biological yield per plant (0.69**), and harvest index (0.21*), and a non-significant positive association with seeds per pod (0.16), while showing a significant negative correlation with days to maturity (-0.57**).

Days to maturity exhibited significant negative correlations with number of pods per plant (-0.50**), seeds per pod (-0.25*), seed index (-0.51**), biological yield per plant (-0.58**), and harvest index (-0.56**). Number of pods per plant had a significant positive association with seed index (0.25*), biological yield per plant (0.61**), and harvest index (0.20*), whereas a non-significant positive association was noted with seeds per pod (0.07). Seeds per pod displayed a significant positive correlation with biological yield per plant (0.23*).

"In phenotypic correlations, plant height, number of pods per plant, and seed index exhibited strong positive associations with seed yield per plant. The magnitude of genotypic correlations was generally higher than the corresponding phenotypic correlations, indicating that environmental factors may have masked the true genetic associations among traits" (Kumar et al. 2014; Singh et al. 2020; Sinha et al. 2022).

Table 2. Analysis of variance for different quantitative traits in 34 chickpea genotypes

S. No.	Traits	Mean Sum of Squares		
		Replication (d.f = 2)	Treatments (d.f = 33)	Error (d.f = 66)
1.	Days to 50% Flowering	3.09	68.37**	12.78
2.	Plant height (cm)	0.75	402.74**	24.80
3.	Days to maturity	4.77	20.32**	3.15
4.	Number of pods per plant	34.72	492.40**	18.28
5.	Number of seeds per pod	0.02	0.16**	0.17
6.	Seed index (g)	0.71	38.17**	0.93
7.	Biological yield per plant (g)	0.53	31.35**	1.14
8.	Harvest index (%)	1.78	175.34**	1.17
9.	Seed yield per plant (g)	0.23	18.08**	0.46

*Significant at 5%, ** Significant at 1% level of significance

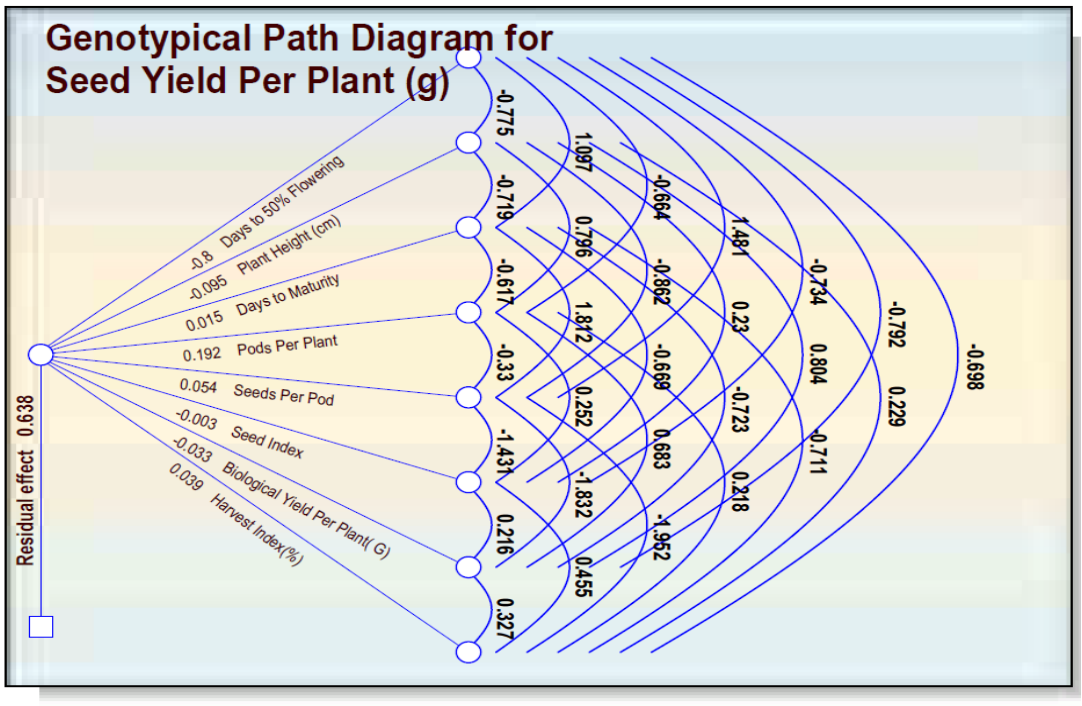

Fig. 1. Genotypical path diagram for seed yield per plant (g)

Table 3. Genotypic Correlation Coefficients Between Seed Yield and Its Component Traits in Chickpea

S. No.	Traits	Plant height	Days to maturity	Pods per plant	Seeds per pod	Seed index	Biological yield per plant	Harvest index	Seed yield per plant
1	Days to 50% flowering	-0.77**	1.09	-0.66**	-1.48**	-0.73**	-0.79**	-0.69**	-0.75**
2	Plant height	**1.00**	-0.71**	0.79**	0.86**	0.22*	0.80**	0.22*	0.60**
3	Days to maturity		**1.00**	-0.61**	-1.81**	-0.66**	-0.72**	-0.71**	-0.81**
4	Pods per plant			**1.00**	0.32**	0.25*	0.68**	0.21*	0.60**
5	Seeds per pod				**1.00**	1.43**	1.83**	1.95**	1.09**
6	Seed index					**1.00**	0.21*	0.45**	0.53**
7	Biological yield per plant						**1.00**	0.32**	0.55**
8	Harvest index							**1.00**	0.48**

**Significant at 5%, ** Significant at 1% level of significance*

Table 4. Phenotypic correlation coefficients between seed yield and its component traits in chickpea

S. No.	Traits	Plant height	Days to maturity	Pods per plant	Seeds per pod	Seed index	Biological yield per plant	Harvest index	Seed yield per plant
1	Days to 50% flowering	-0.53**	0.71**	-0.43**	-0.34**	-0.51**	-0.55**	-0.51**	-0.55**
2	Plant height	**1.00**	-0.57**	0.71**	0.16	0.20*	0.69**	0.21*	0.55**
3	Days to maturity		**1.00**	-0.50**	-0.25*	-0.51**	-0.58**	-0.56**	-0.67**
4	Pods per plant			**1.00**	0.07	0.25*	0.61**	0.20*	0.54**
5	Seeds per pod				**1.00**	0.19	-0.22*	0.23*	0.17
6	Seed index					**1.00**	0.20*	0.44**	0.50**
7	Biological yield per plant						**1.00**	0.29**	0.50**
8	Harvest index							**1.00**	**0.47****

**Significant at 5%, ** Significant at 1% level of significance*

3.3 Path Coefficient Analysis

When multiple independent variables influence a particular dependent variable, the interdependence among variables becomes complex, making simple correlation insufficient to explain the true relationships. Therefore, path coefficient analysis was employed to partition the correlation coefficients into direct and indirect effects, providing better insight into the causal relationships influencing seed yield (Tables 5 and 6).

3.3.1 Genotypic path coefficient analysis

At the genotypic level, path analysis revealed that plant height (0.60) and number of pods per plant (0.60) exerted the highest positive direct effects on seed yield per plant, followed by biological yield per plant (0.55), seed index (0.53), and harvest index (0.48). Days to 50% flowering showed the highest negative direct effect (-0.80) on seed yield, but positive indirect effects via plant height, number of pods per plant, seed index, biological yield, and harvest index, while exhibiting negative indirect effects through days to maturity and seeds per pod.

Plant height showed a negative direct effect (-0.09) on seed yield but contributed positively through its indirect effects via days to 50% flowering, days to maturity, and seeds per pod. Similarly, days to maturity showed a slight positive direct effect (0.01) on seed yield, with positive indirect effects through days to 50% flowering and seeds per pod.

Number of pods per plant had a high positive direct effect (0.19) on seed yield, with additional positive indirect effects through plant height, seed index, biological yield, and harvest index. Seeds per pod, seed index, biological yield per plant, and harvest index also contributed through varying degrees of direct and indirect effects.

“Traits like days to maturity, number of pods per plant, seeds per pod, and seed index exhibited positive direct effects and significant correlations with seed yield, suggesting their utility in chickpea breeding programs for yield improvement” (Kuldeep et al. 2021; Ali et al. 2011; Borate et al. 2010; Vaghela et al. 2025; Pandey et al. 2013 and Thakur et al. 2018).

3.3.2 Phenotypic path coefficient analysis

At the phenotypic level, plant height (0.55) had the highest positive direct effect on seed yield per plant, followed by number of pods per plant (0.54), seed index (0.50), biological yield per plant (0.50), and harvest index (0.47). Days to 50% flowering showed a slight positive direct effect on seed yield, but negative indirect effects through other traits. Similarly, plant height contributed indirectly to seed yield through number of pods per plant, seeds per pod, seed index, and biological yield.

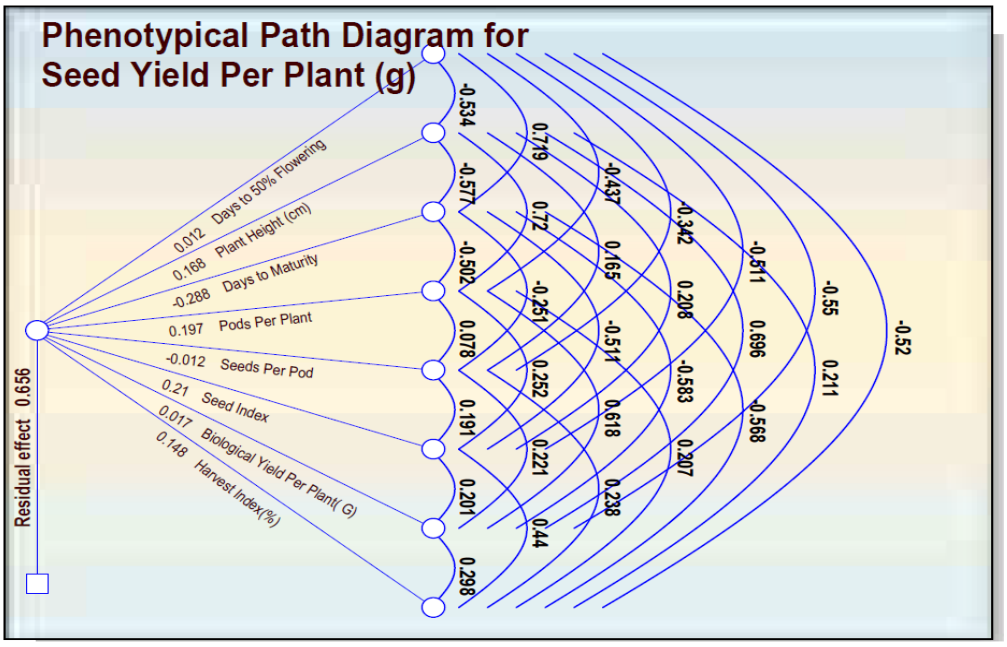

Fig. 2. Phenotypical path diagram for seed yield per plant (g)

Table 5. Genotypic direct and indirect effects of various traits on seed yield and its components in chickpea

Traits	Days to 50% flowering	Plant height	Days to maturity	Pods per plant	Seeds per pod	Seed index	Biological yield	Harvest index	Seed yield per plant
Days to 50% flowering	**-0.80**	0.61	-0.87	0.53	-1.18	0.58	0.63	0.55	-0.75
Plant height	0.07	**-0.09**	0.06	-0.07	0.08	-0.02	-0.07	-0.02	0.60
Days to maturity	0.01	-0.01	**0.01**	-0.00	0.02	-0.01	-0.01	-0.01	-0.81
Pods per plant	-0.12	0.15	-0.11	**0.19**	-0.06	0.04	0.13	0.04	0.60
Seeds per pod	0.08	-0.04	0.09	-0.01	**0.05**	-0.07	-0.09	-0.10	-1.09
Seed index	0.00	-0.00	0.00	-0.00	0.00	**0.02**	0.01	0.01	0.53
Biological yield	0.02	-0.02	0.02	-0.02	0.06	-0.00	**-0.03**	-0.01	0.55
Harvest index	-0.02	0.00	-0.02	0.00	-0.07	0.01	0.01	**0.03**	0.48

Residual effect = 0.23

Table 6. Phenotypic direct and indirect effects of various traits on seed yield and its components in chickpea

Traits	Days to 50% flowering	Plant height	Days to maturity	Pods per plant	Seeds per pod	Seed index	Biological yield	Harvest index	Seed yield per plant
Days to 50% flowering	**0.01**	-0.00	0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.55
Plant height	-0.08	**0.16**	-0.09	0.12	0.02	0.03	0.11	0.03	0.55
Days to maturity	-0.20	0.16	**-0.28**	0.14	0.07	0.14	0.16	0.16	-0.67
Pods per plant	-0.08	0.14	-0.09	**0.19**	0.01	0.04	0.12	0.04	0.54
Seeds per pod	0.00	-0.00	0.00	-0.00	**-0.01**	-0.00	-0.00	-0.00	0.17
Seed index	-0.10	0.04	-0.10	0.05	0.04	**0.20**	0.04	0.09	0.50
Biological yield	-0.00	0.01	-0.01	0.01	0.00	0.00	**0.01**	0.00	0.50
Harvest index	-0.07	0.03	-0.08	0.03	0.03	0.06	0.04	**0.14**	0.47

Residual effect = 0.22

"The results suggest that plant height, number of pods per plant, seed index, and biological yield per plant are key determinants of seed yield and should be given due consideration during selection in chickpea breeding programs. These findings corroborate earlier reports" (Kuldeep et al. 2021; Ali et al. 2011; Borate et al. 2010; Vaghela et al. 2025; Pandey et al. 2013 and Thakur et al. 2018).

4. CONCLUSIONS

The present study on 34 chickpea genotypes revealed significant genetic variability for all traits studied. Correlation analysis indicated that plant height, number of pods per plant, biological yield per plant, seed index, and harvest index exhibited strong positive associations with seed yield at both genotypic and phenotypic levels. Path coefficient analysis further confirmed that plant height, number of pods per plant, seed index, biological yield, and harvest index had high positive direct effects on seed yield per plant, suggesting their crucial role in yield enhancement. Genotypes such as CSJ 1085, CSJ 1088, CSJ 1090, and CSJ 1079 were identified as superior for seed yield. Hence, priority should be given to these key traits during selection to achieve substantial genetic gains for yield improvement in chickpea breeding programs.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of this manuscript.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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