



Association Studies in Advanced Breeding and Germplasm Lines of Chickpea (*Cicer arietinum* L.)

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ABSTRACT

The present investigation was conducted during *rabi* (October, 2021– April, 2022) in the research area of AICRP Chickpea, RAK College of Agriculture, Sehore, Madhya Pradesh, India to study correlation analysis and path analysis for yield and its attributes among the 120 advanced breeding lines of chickpea. These lines derived from Desi×Desi, Desi×Kabuli, Kabuli×Desi and Kabuli×Kabuli crosses, as well as existing germplasm and varieties. The observations were recorded for eleven yield and its contributing traits. The correlation studies revealed that the traits such as plant height, leaflet size, biological yield, 100-seed weight and harvest index were found to be significantly associated with seed yield. Path analysis showed that biological yield plant⁻¹ had highest direct effect towards the seed yield plant⁻¹ followed by the harvest index, days to maturity, 100-seed weight, leaflet size, number of seeds pod⁻¹, peduncle length indicating that selection of these traits would help in improving the seed yield plant⁻¹ directly. Based on overall study of association analysis seven traits like leaflet size, plant height, peduncle length, seed yield plant⁻¹, biological yield plant⁻¹, 100-seed weight and harvest index were found to be determining characters for the improvement of yield in chickpea.

KEYWORDS: Advanced breeding lines, association analysis, chickpea, correlation

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Data Availability Statement: Legal restrictions are imposed on the public sharing of raw data. However, author have full right to transfer or share the data in raw form upon request subject to either meeting the conditions of the original consents and the original research study. Further, access of data needs to meet whether the user complies with the ethical and legal obligations as data controllers to allow for secondary use of the data outside of the original study.

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1. INTRODUCTION

Chickpea (*Cicer arietinum* L.) is a large pulse crop plant in India, and across the globe used as human food in the Asian and African nations. It is ranked 1st among the pulse crops that are widely cultivated during Rabi season in India and falls in the family Fabaceae. It is popularly known as Bengal gram or gram. It was derived out of *Cicer reticulatum* which is a wild ancestor of chickpea. The two main centres of origin of chickpea as illustrated by Vavilov (1926) include Southwest Asia (Turkey) and the Mediterranean region with Ethiopia being a secondary center of origin. There are 43 species in the *Cicer* genus, 34 perennial, 8 wild annual and an annual that has been cultivated (Van Der Maesen, 1972; Muehlbauer and Tullu, 1993). Chickpea is a self-pollinated diploid with $2x=16$ chromosomes in its genome (Arumunganathan and Earle, 1991), and its genome size is estimated to be 740 Mbp (Varshney et al., 2013) although cross-pollination is observed to occur (up to 1 percent) (Smithson et al., 1985). Chickpea has a global area of 15 Mha, a production of 19 Mt and a productivity of 1.3 t/ha, compared to India which is the largest chickpea producer in the world with an area of 10.5 mha and a production of 11.3 Mt and a productivity of 1.1 t ha⁻¹ Madhya Pradesh is the highest producer of chickpea in India with production of 40% of the total production in the country, followed by Rajasthan and Maharashtra (Anonymous, 2020).

In addition to the economic contribution, chickpea enhances sustainable agriculture because atmospheric nitrogen fixation occurs with the help of symbiotic relationship with *Mesorhizobium ciceri*. Nevertheless, the alteration of climatic conditions is generating serious deficits in yield. According to the recent reports, production is in terminal drought and heat stress at the reproductive stage. Yield-related characteristics that are prone to changes in various environments need to be established by establishing genotypic differences in order to stabilize production in areas that are prone to stresses (Kebede et al., 2023). Population increase requires the production of high yielding varieties that will satisfy the consumption demands. Genetic enhancement can be carried out by tapping the genetic variation in germplasm and better breeding lines. According to (Tultani et al., 2023, 2024), contemporary breeding implies multi-trait models, which include phenological, physiological, and morphological phenotypes to reduce the yield potential plateau. The most important thing in any crop breeding program is association studies. They contain details on the yield contributing characters that aid in the determination of elite genotypes. The data available on the relationship between different traits is used in the selection and breeding of better cultivars. The quantitative characters have displayed important positive correlations in genetically diverse chickpea genotypes of different parts

of India (Tultani et al., 2023). Path coefficient analysis has also been extensively used in breeding of plants to determine correlations between grain yield and contributing characters. It explains the reasons behind the relation, as it divides the correlation coefficient into direct and indirect effects (Kumar et al., 2024, Anita et al., 2025). The importance of such partitioning lies in the fact that even simple correlation can occasionally be deceptive in case it is affected by the indirect influences of other traits. The current study was therefore conducted to research the correlation analysis and path analysis of yield and its characteristics in 120 advanced breeding lines of chickpea to determine the best selection criteria to be used in the future breeding programs.

2. MATERIALS AND METHODS

The present investigation was conducted during *rabi* (October, 2021–April, 2022) in the research area of AICRP Chickpea, RAK College of Agriculture, Sehore, Madhya Pradesh. The soil in the field of investigation was clay loam vertosol. The experimental plant material in this study consisted of 120 genotypes of Chickpea collected from the AICRP on Chickpea at R.A.K College of Agriculture Sehore. All the lines were grown by adapting proper spacing of (30×10 cm²) in completely randomised block design with three replications. A standardized set of cultural practises were followed to grow a healthy crop.

Total of 11 observations were collected such as days to flowering, Days to maturity, Leaflet size, Peduncle length, Plant height, Pod size, Number of seeds pod⁻¹, 100-seed weight (seed size), Biological yield, Seed yield, Harvest index were taken from the five randomly selected plants except the days to flowering and maturity which were taken based on plot basis. Genotypic correlation was estimated as per the procedure suggested by Al-jibouri et al. (1958) and path analysis as per suggested by Wright (1921) and Dewey and Lu (1959). All the data were analysed by using R software (version 4.1.2) and Windostat (version 9.1).

3. RESULTS AND DISCUSSION

3.1. Correlation

The data regarding genotypic and phenotypic correlation coefficient was given in Table 1 and heatmaps for both were represented in Figure 1 and 2 respectively. Correlation analysis results revealed that estimates ranged from -0.414 (PH vs HSW) to 0.991 (DF vs DM). Characters such as plant height (0.166), leaflet size (0.2584), pod size (0.2999), biological yield (0.9296), 100-seed weight (0.2566), harvest index (0.3469) were positive and highly significantly associated with the seed yield plant⁻¹, highest positive values along with significance suggested that selection of these traits in the yield improvement would be helpful. Days to 50% flowering (-0.1492) days to maturity (-0.1519),

Table 1: Genotypic (Gc) and phenotypic correlation (Pc) analysis of yield and yield attributes in chickpea

Characters	Gc Pc	Days to 50% flowering	Days to maturity	Plant height (cm)	Leaf let size (mm)	Peduncle length (mm)	Pod size (mm)
Days to 50% flowering	Gc	1	0.9900***	-0.3252**	-0.0354**	-0.2179**	-0.1947**
	Pc	1	0.9915**	-0.3139**	-0.0398**	-0.2076**	-0.1815**
Days to maturity	Gc		1	-0.3186**	-0.0360**	-0.2225**	-0.1981**
	Pc		1	-0.3147**	-0.04**	-0.2120**	-0.1833**
Plant height (cm)	Gc			1	0.3230**	0.2998**	0.4814**
	Pc			1	0.3127**	0.2870**	0.4506**
Leaf let size (mm)	Gc				1	0.2129**	0.2001**
	Pc				1	0.1985**	0.1856**
Peduncle length (mm)	Gc					1	0.2378**
	Pc					1	0.2297**
Pod size (mm)	Gc						1
	Pc						1

Table 1: Continue...

Characters	Gc Pc	Number of seeds pods ⁻¹	Biological yield plant ⁻¹ (g)	100 seed weight (g)	Harvest index (%)	Seed yield plant ⁻¹
Days to 50% flowering	Gc	0.2004**	-0.1818**	-0.4091**	0.1119**	-0.1554**
	Pc	0.1539**	-0.1746**	-0.4022**	0.1056**	-0.1492**
Days to maturity	Gc	0.2013**	-0.1821**	-0.4196**	0.1048**	-0.1568**
	Pc	0.1471**	-0.1765**	-0.4142**	0.1002**	-0.1519**
Plant height (cm)	Gc	-0.1056**	0.2255**	0.4842**	-0.1179	0.1666**
	Pc	-0.054**	0.2219**	0.4747**	-0.1076**	0.166**
Leaf let size (mm)	Gc	-0.1014**	0.2491**	0.1817**	0.0915***	0.2731**
	Pc	-0.0741**	0.2362**	0.1771**	0.0867**	0.2584**
Peduncle length (mm)	Gc	-0.0939**	-0.0435**	0.4063**	-0.1910**	-0.0823**
	Pc	-0.072**	-0.0474**	0.3831**	-0.1713**	-0.0803**
Pod size (mm)	Gc	0.0333	0.3630**	0.4546**	0.0034**	0.3332**
	Pc	-0.0055	0.3283**	0.4293**	-0.0025	0.2999**
No of seeds pod ⁻¹	Gc	1	-0.1261**	-0.1422**	0.1401**	-0.0598**
	Pc	1	-0.0698**	-0.0832**	0.0975**	-0.0231**
Biological yield plant ⁻¹ (g)	Gc		1	0.2561**	0.0165**	0.9303***
	Pc		1	0.2515**	0.0268**	0.9296**
100 seed weight (g)	Gc			1	0.0036	0.2616**
	Pc			1	0.0058	0.2566**
Harvest index (%)	Gc				1	0.3366**
	Pc				1	0.3469**
Seed yield plant ⁻¹	Gc					1
	Pc					1

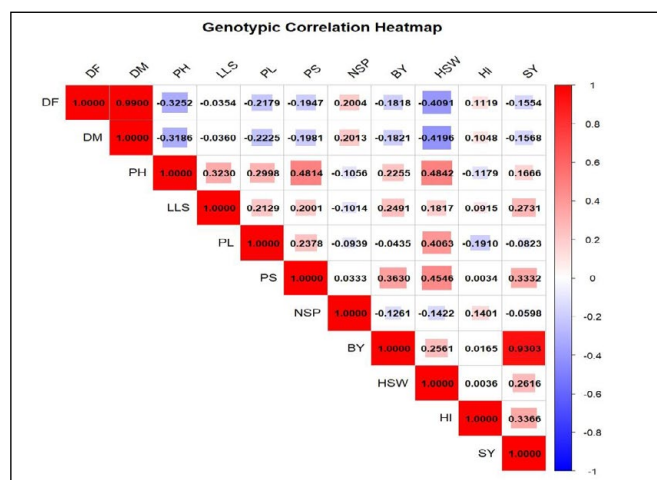


Figure 1: Genotypic correlation heatmap

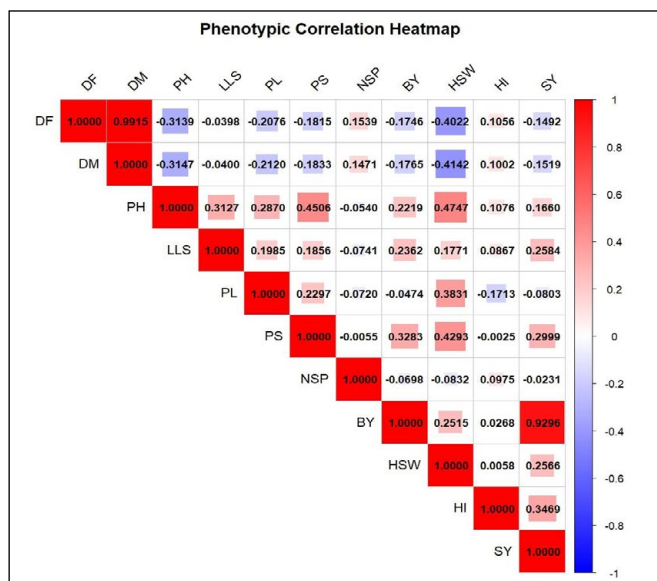


Figure 2: Phenotypic correlation heatmap

peduncle length (-0.0803), number of seeds pod⁻¹ (-0.0231) were negatively significant with the seed yield plant⁻¹ which implied that selection of these characters would hinder the yield performance of the crop. The study of correlation analysis reveals that most of the characters such as plant height, leaflet size, pod size, biological yield, 100-seed weight, harvest index was positively significant towards seed yield per plant. Similar results were reported by Arshad et al. (2003), and Ali et al. (2010), where plant height, leaflet size and pod size were positively correlated with the seed yield per plant. biological yield, 100-seed weight were positively correlated with seed yield in accordance with Noor et al. (2003), Babbar et al. (2012), Singh et al. (2021) harvest index was positively significant towards seed yield per plant⁻¹.

3.2. Path analysis

Correlation coefficient was derived into direct and indirect

effects by path analysis that showed the exact relationships among the traits that were not estimated by the correlation analysis. In the present study seed yield plant⁻¹ was considered as dependent variable and remaining all the 10 were considered as independent variables. The path coefficient analysis showed the direct and indirect effects of different traits on seed yield plant⁻¹ were given in Table 2 and path diagram in Figure 3. According to path analysis, biological yield plant⁻¹ had highest direct effect (0.9172) towards the seed yield plant⁻¹ followed by the harvest index (0.3208), days to maturity (0.0603), 100-seed weight (0.0269), leaflet size (0.0171), number of seeds pod⁻¹ (0.0162) and peduncle length (0.0111) indicating that selection of these traits would help in improving the seed yield plant⁻¹ directly. The remaining traits viz., days to flowering, plant height and pod size showed negative direct effect on seed yield plant⁻¹. The residual effect of phenotypic path analysis was 0.1740 and it was low. Low residual value revealed that characters included in the investigation expressed high percentage of variation in the seed yield. The trait biological yield plant⁻¹ showed significantly positive direct effect strongly that indicated it was in close correlation with the seed yield plant⁻¹. Plant height and pod size showed significant positive correlation with negative direct effects with seed yield plant⁻¹. Thus, its positive correlation with seed yield plant⁻¹ mainly due to its indirect effects via biological yield plant⁻¹. Path analysis states that biological yield plant⁻¹ and harvest index could be considered as major yield contributing traits and should be considered during selection for improvement in seed yield plant⁻¹ as they exhibited high positive direct effect as well as positive correlation with seed yield plant⁻¹. Hence, it suggested that these characteristics should be preferred for the crop improvement programme.

Studies on path analysis revealed that biological yield plant⁻¹ had highest direct effect towards the seed yield plant⁻¹ similar results were reported by the Jeena et al. (2002),

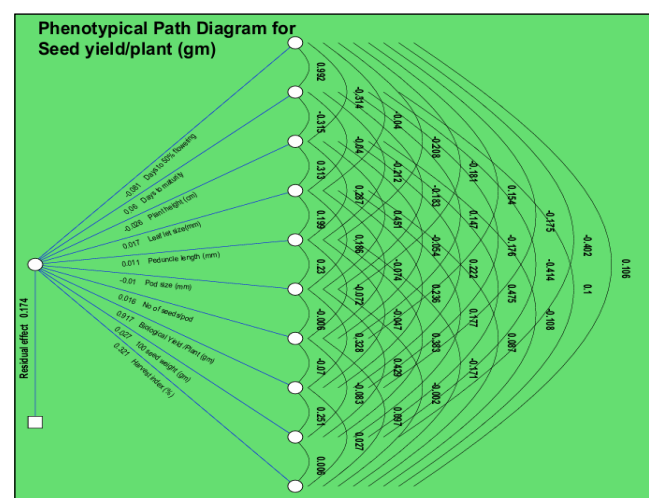


Figure 3: Path coefficients of yield and yield components

Table 2: Path coefficients of yield and yield components in chickpea

Characters	Days to 50% flowering	Days to maturity	Plant height (cm)	Leaflet size (mm)	Peduncle length (mm)
Days to 50% flowering	-0.0812	-0.0805	0.0255	0.0032	0.0169
Days to maturity	0.0598	0.0603	-0.019	-0.0024	-0.0128
Plant height (cm)	0.008	0.0081	-0.0256	-0.008	-0.0073
Leaf let size (mm)	-0.0007	-0.0007	0.0053	0.0171	0.0034
Peduncle length (mm)	-0.0023	-0.0024	0.0032	0.0022	0.0111
Pod size (mm)	0.0018	0.0018	-0.0044	-0.0018	-0.0022
No of seeds pod ⁻¹	0.0025	0.0024	-0.0009	-0.0012	-0.0012
Biological yield plant ⁻¹ (g)	-0.1601	-0.1619	0.2035	0.2167	-0.0435
100 seed weight (g)	-0.0108	-0.0111	0.0127	0.0048	0.0103
Harvest index (%)	0.0339	0.0322	-0.0345	0.0278	-0.055
Seed yield plant ⁻¹ (g)	-0.1492	-0.1519	0.166	0.2584	-0.0803

Table 2: Continue...

Characters	Pod size (mm)	Number of seeds pods ⁻¹	Biological yield plant ⁻¹ (g)	100 seed weight (g)	Harvest index (%)
Days to 50% flowering	0.0147	-0.0125	0.0142	0.0327	-0.0086
Days to maturity	-0.0111	0.0089	-0.0106	-0.025	0.006
Plant height (cm)	-0.0115	0.0014	-0.0057	-0.0121	0.0028
Leaf let size (mm)	0.0032	-0.0013	0.004	0.003	0.0015
Peduncle length (mm)	0.0026	-0.0008	-0.0005	0.0043	-0.0019
Pod size (mm)	-0.0097	0.0001	-0.0032	-0.0042	0
No of seeds pod ⁻¹	-0.0001	0.0162	-0.0011	-0.0013	0.0016
Biological yield plant ⁻¹ (g)	0.3011	-0.064	0.9172	0.2306	0.0246
100 seed weight (g)	0.0115	-0.0022	0.0068	0.0269	0.0002
Harvest index (%)	-0.0008	0.0313	0.0086	0.0018	0.3208
Seed yield plant ⁻¹ (g)	0.2999	-0.0231	0.9296	0.2566	0.3469

Residual effect=0.1740

Babbar et al. (2012), Kumar et al. (2019), Kumar et al. (2024), Tsehaye et al. (2020), Jain et al. (2025) and Aung et al. (2021), followed by the harvest index, days to maturity in accordance with Kebede et al. (2023) 100-seed weight this result in accordance with Noor et al. (2003), leaflet size, number of seeds pod⁻¹, similarly reported by Guler et al. (2001) peduncle length indicating that selection of these traits will helps in improving the seed yield per plant directly. Traits such as plant height, days to 50% flowering in accordance with Jain et al. (2025). Tutlani et al. (2023) and pod size with Aung et al. (2023) were negative direct effect towards seed yield plant⁻¹.

4. CONCLUSION

Genetic variation between genotypes and this implies that there was a possibility of progress in the isolation

of generations. Correlation analysis results revealed that characters such as plant height, leaflet size, pod size, biological yield, 100-seed weight, harvest index were positive and significantly associated and directly improve the seed yield per plant highest positive values along with significance suggests that selection of these traits in the yield improvement will be helpful. The best positive correlations with seed yield were observed between the biological yield per plant and harvest index. The study enabled the explanation of genetic structure of major traits by combining correlation and path analyses.

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