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Correlation and path analysis in chickpea (*Cicer arietinum* L.) genotypes under late sown condition

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Abstract
Pulses play a vital role in various cropping systems across the country, with specific preferences and suitability varying by region. They are particularly beneficial for sustainable agriculture due to their ability to efficiently use limited soil moisture and nutrients, while also enhancing the physical and chemical properties of the soil. The present investigation was carried out to study the association between different characters and find out the direct and indirect effects of various quantitative characters on seed yield in fifty genotypes of chickpea (*Cicer arietinum* L.) for eleven quantitative characters. The experiment was conducted during *Rabi*, 2022-23 at Zonal Agricultural Research Station, Ganeshkhind, Pune.
The study revealed that the Seed yield per plant had significant and positive correlation with days to 50 percent flowering, plant height, plant spread, primary branches per plant, number of pods per plant, number of seeds per pod and 100-seed weight. It also had non-significant positive correlation with days to maturity, number of secondary branches per plant and protein content. In the path analysis, highest positive direct effect on seed yield per plant was observed through number of pods per plant (0.7100), 100-seed weight (0.5610) and number of seeds per pod (0.1512). The trait days to maturity (0.0186), plant spread (0.0186), primary branches per plant (0.0057), secondary branches per plant (0.0295) and protein content (0.0109) showed positive direct effect on seed yield per plant. The direct selection to these traits will be beneficial for yield improvement programmes.

Keywords: Chickpea, direct effect, indirect effect, correlation, seed yield

Introduction
Chickpea is the leading pulse crop in India, accounting for approximately 49% of total pulse production. It is cultivated across nearly all regions of the country, and in recent years, there has been a notable increase in both production and productivity. Chickpea (*Cicer arietinum* L.) is the most favoured pulse for consumption. The first grain legume crop that humans domesticated was the chickpea (*Cicer arietinum* L.) (Van der Maesen 1987) [13]. It goes by the names gram, Bengal gram, chhola, chana, garbanzo bean or Egyptian pea as well. According to Aggarwal *et al*. (2015) [1], it comes in third place behind the field pea (*Pisum sativum*) and common bean (*Phaseolus vulgaris*).
Path coefficient analysis is a statistical technique that helps to identify traits that can be used to improve crop yield. It is employed to investigate the direct and indirect effects of variables on one another. Path analysis operates by separating the correlation coefficient between two traits into direct and indirect effects. Path analysis was used for determination of the amount and direction of direct and indirect effects of different yield and other yield related components. More reliable data is provided by correlation coefficients and path effects, which can be utilized in a variety of crop development initiatives. Direct selection based on these traits will be effective if the correlation between a causal factor and its direct effect is roughly equal in strength, indicating a strong and clear relationship between the variables. However, indirect causal factors should be considered if the correlation coefficient is positive and the direct effect is negative or negligible. Character information and their relative relevance are thus provided via path analysis. To establish a cause and effect relationship the first step was used to partition genotypic and phenotypic correlation coefficient into direct and indirect effects by path analysis as suggested by Dewey and Lu (1959) [5] and developed by Wright (1921) [15].

Therefore, the present investigation has been undertaken to study the association between different characters and find out the direct and indirect effects of various quantitative characters on seed yield.

Materials and Methods

The experiment material used for present investigation includes 50 chickpea genotypes collected from Pulses Improvement Project, M. P. K. V. Rahuri. The experiment was conducted during *Rabi*, 2022-23 at ZARS, Ganeshkhind, Pune. The experiment was laid out in Randomized Block Design with three replications. Data were recorded on randomly selected five plants per replication of each genotype for eleven yield and yield contributing characters *viz*., days to 50 percent flowering, days to maturity, plant height, plant spread, number of primary branches per plant, number of secondary branches per plant, number of pods per plant, number of seeds per pod, 100-seed weight, protein content and seed yield per plant. The mean data of these five plants were employed for statistical analysis. To understand the association among the characters, genotypic and phenotypic correlation coefficients were worked out by adopting the method described by Singh and Chaudhary (1985) [10]. To establish a cause and effect relationship the first step was used to partition genotypic and phenotypic correlation coefficient into direct and indirect effects by path analysis as suggested by Dewey and Lu (1959) [5] and developed by Wright (1921) [15].

Results and Discussion

The results of correlation between yield components at genotypic level are presented in Table 1. It indicated that days to 50 percent flowering showed significant and positive correlation with days to maturity (0.7252), number of pods per plant (0.4144), plant spread (0.3907), 100-seed weight (0.2016) and number of secondary branches per plant (0.1980). It showed non-significant but positive correlation with plant height (0.0766) and number of seeds per pod (0.0283). Whereas, days to 50 percent flowering showed significantly negative correlation with number of primary branches per plant (-0.1868). Additionally, there was non-significant and negative correlation with protein content (-0.0060).

Days to maturity showed significant and positive correlation with plant spread (0.2991) and number of pods per plant (0.1903). It showed a non-significant positive correlation with both plant height (0.0972) and the number of secondary branches per plant (0.1096). Whereas, days to maturity showed significantly negative correlation with protein content (-0.2221). It also showed a non-significant negative correlation with the number of seeds per pod (-0.0733), primary branches per plant (-0.0512) and 100-seed weight (-0.0115).

Plant height showed significant and positive correlation with 100-seed weight (0.3877), number of primary branches per plant (0.3186) and number of seeds per pod (0.2241). It showed non-significant and positive correlation with plant spread. Plant height, on the other hand, showed significant and negative correlation with both protein content (-0.2164) and number of secondary branches per plant (-0.3417). Additionally, it was non-significantly and negatively correlated with number of pods per plant (-0.0251).Plant spread showed positive and significant correlation with number of pods per plant (0.3616). It showed a non-significant positive correlation with the number of seeds per pod (0.0205) and the number of secondary branches per plant (0.0885). Additionally, there was a non-significant negative correlation found with the number of primary branches per plant (-0.1519), 100-seed weight (-0.0675), and the protein content (-0.0480). Number of primary branches per plant showed significant and positive correlation with 100-seed weight (0.2113), and the number of seeds per pod (0.3502). It showed a non-significant positive correlation with protein content (0.0282), number of pods per plant (0.0508), and number of secondary branches per plant (0.1269).Number of secondary branches per plant was non-significantly and positively correlated with number of pods per plant (0.0650), number of seeds per pod (0.0200), 100-seed weight (0.0079) and protein content (0.1581). Number of pods per plant was significantly and positively correlated with number of seeds per pod (0.5644). Moreover, there was a non-significant positive correlation between number of pods per plant and the 100-seed weight (0.0246) and the protein content (0.0639). The character number of seeds per pod showed non-significant and positive correlation with 100-seed weight (0.1557). It was also non-significantly and negatively correlated with protein content (-0.0374). Protein content and 100-seed weight had a non-significant negative correlation (-0.0062).

It observed that the days to 50 percent flowering, days to maturity, plant height and plant spread of the plant, the number of primary branches per plant and the number of pods per plant had highly significant positive correlation with one another. The similar results was given by Vijayalaxmi *et al.* (2000) [14] who reported that protein content showed negative correlation with 100-seed weight and Malik *et al.* (2010) [7] revealed that the number of pods per plant and seed yield per plant were positively correlated with secondary branches per plant, whereas the 100-seed weight was negatively correlated with both.

The results of path analysis are presented in Table 2. It revealed that the number of pods per plant (0.7100) had the highest positive direct effect on the seed yield per plant followed by 100-seed weight (0.5610) and number of seeds per pod (0.1512). Relatively little positive direct effects on seed yield were shown by the parameters number of secondary branches per plant (0.0295), plant spread (0.0187), days to maturity (0.0186), protein content (0.0109), and number of primary branches per plant (0.0057). Characteristics such as plant height (-0.0227) and days to 50 percent flowering (-0.0419) demonstrated negative direct effects. Number of pods per plant, 100-seed weight, and the number of seeds per pod all showed a significant positive direct effect on the seed yield per plant. Additionally, the correlation between these traits and seed yield was positively significant, indicating a true relationship between yield and these traits. The findings indicate that directly selecting for these traits will help in identifying high-yielding genotypes in chickpeas. Zena *et al*. (2008) [16] reported that number of seeds per pod had highest direct positive effect on seed yield. Borate and Dalvi (2010) [3] reported that number of pods per plant had highest direct positive effect on grain yield. Similar outcomes were noted by Dev *et al*. (2017) [4] for the seeds per pod and pods per plant. Hagos *et al*. (2018) [6] recorded similar results for 100-seed weight. The characters like days to 50 percent flowering (-0.0419) and plant height (-0.0227) demonstrated negative direct effects, however they had significant and positive correlation with seed yield per plant indicating that they played their role via indirect effects. Negative direct effects of days to 50 percent flowering on seed yield per plant were observed by Zena *et al*. (2008) [16], Astereki *et al*. (2017) [2], and Singh *et al*. (2018) [11]. There is a true and perfect relationship between the number of pods per plant and the number of seeds per pod, as evidenced by the high magnitudinal direct effect and the significant positive correlation with seed yield per plant. Residual effect measures the role of other possible independent variables which were not included in the study on the dependent variable i.e. seed yield in this case. In present study residual effect was low (0.1209). It indicates that the characters under investigation are considered sufficient for the variability in seed yield of chickpea. Similar results were reported by Thakur and Sirohi (2009) [12] and Renukadevi and Subbalakshmi (2006) [9].

According to the results of the current studies, the most preferred plant variety should have maximum number of pods per plant, number of seeds per pod, plant height, and 100-seed weight.

When examining the indirect effects of different characters, it was seen that the traits days to 50 percent flowering, plant height, plant spread, number of pods per plant, number of seeds per pod and 100-seed weight all showed a highly significant positive correlation with the seed yield per plant. This was primarily because of indirect effects of all traits mentioned above. However, there was a non-significant but positive correlation between the characters days to maturity, protein content, number of primary branches per plant, secondary branches per plant and seed yield per plant. Days to 50 percent flowering showed significant and positive correlation with seed yield per plant (0.3934), through its positive indirect effect via, number of primary branches per plant and protein content but negative indirect effect through days to maturity, number of pods per plant, plant spread, 100-seed weight, number of secondary branches per plant, plant height and number of seeds per pod. Days to maturity had non-significant and positive correlation with seed yield per plant (0.1097), through its negative indirect effect via protein content, number of seeds per pod, primary branches per plant, and 100-seed weight, but a positive indirect effect through days to 50 percent flowering, plant spread, number of pods per plant, plant height, and number of secondary branches per plant. Plant height and seed yield per plant showed a significant positive correlation (0.2010). The positive indirect effect was primarily caused by 100-seed weight, it was followed by number of primary branches per plant, number of seeds per pod, plant spread, days to maturity, and days to 50 percent flowering. The negative indirect effect was primarily caused by the secondary branches per plant, protein content and pods per plant.

Correlation between plant spread and seed yield per plant was significant positive correlation (0.2284). It showed a negative indirect effect primarily through 100-seed weight then number of primary branches per plant, protein content, number of seeds per pod. Positive indirect effects included days to 50 percent flowering, number of pods per plant, days to maturity, plant height, and secondary branches per plant. Correlation between number of primary branches per plant and seed yield per plant was non-significant and positive (0.2140). Because of its positive indirect effect via, plant height, number of seeds per pod, 100-seed weight, number of secondary branches per plant, number of pods per plant and protein content. It demonstrated a negative indirect effect through days to 50 percent flowering, days to maturity, and plant spread. Correlation between number of secondary branches per plant and seed yield per plant was non-significant and positive (0.0887). Because of its positive indirect effect via, number of primary branches per plant followed by days to 50 percent flowering, protein content, plant spread, days to maturity, number of pods per plant and 100-seed weight but showed negative indirect effect through plant height followed by number of seeds per pod. Correlation between number of pods per plant and seed yield per plant was significant and positive (0.8055), with its positive indirect effect via, number of seeds per pod followed by days to 50 percent flowering, plant spread, days to maturity, number of primary branches per plant, protein content, number of secondary branches per plant and 100-seed weight but showed negative indirect effect through plant height.

Correlation between number of seeds per pod and seed yield per plant was significant and positive (0.6341), it was mediated by positive indirect effect of number of pods per plant followed by number of primary branches per plant, plant height, 100-seed weight and days to 50 percent flowering but showed negative indirect effect through days to maturity, number of secondary branches per plant, plant spread and protein content. Correlation between 100-seed weight and seed yield per plant was found to be positively significant (0.5846). This was because of positive indirect effect of plant height, days to 50 percent flowering, number of primary branches per plant, number of seeds per pod, number of pods per plant, and number of secondary branches per plant. On the other hand, plant spread, days to maturity, and protein content showed negative indirect effects. Correlation between protein content and seed yield per plant was non-significant and positive (0.0521). This was because of positive indirect effect mainly through number of secondary branches per plant followed by number of pods per plant and number of primary branches per plant but showed negative indirect effect through days to maturity followed by plant height, plant spread, number of seeds per pod, days to 50 percent flowering and 100-seed weight.

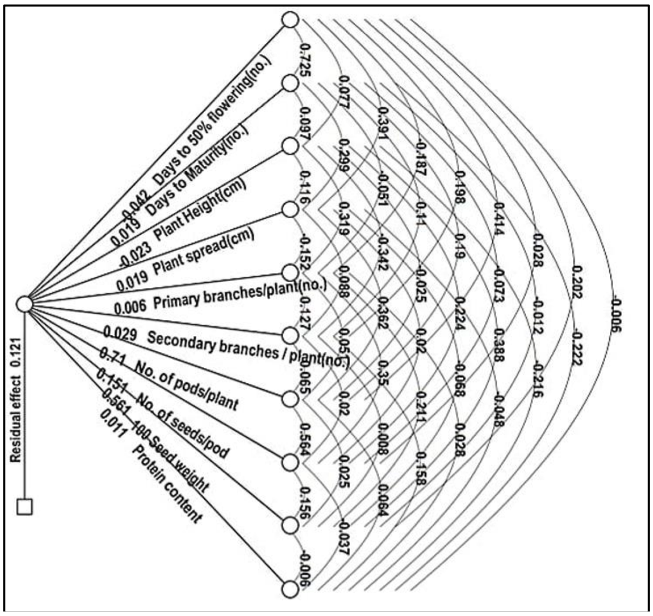

Fig 1: Genotypical path diagram for seed yield per plant in chickpea

Table 1: Genotypic correlation coefficients of 10 characters of 50 genotypes of chickpea on seed yield

Sr. No.	Days to 50 percent flowering (No.)	Days to maturity (No.)	Plant Height (cm)	Plant Spread (cm)	Primary branches per plant (No.)	Secondary branches per plant (No.)	Pods per plant (No.)	Seeds per pod (No.)	100-seed weight (g)	Protein content (%)	Seed yield per plant (g)
	1	2	3	4	5	6	7	8	9	10	11
1.	1	0.7252**	0.0766	0.3907**	-0.1868*	0.1980*	0.4144**	0.0283	0.2016*	-0.0060	0.3934**
2.		1	0.0972	0.2991**	-0.0512	0.1096	0.1903*	-0.0733	-0.0115	-0.2221**	0.1097
3.			1	0.1159	0.3186**	-0.3417**	-0.0251	0.2241**	0.3877**	-0.2164**	0.2010*
4.				1	-0.1519	0.0885	0.3616**	0.0205	-0.0675	-0.0480	0.2284**
5.					1	0.1269	0.0508	0.3502**	0.2113**	0.0282	0.2140**
6.						1	0.0650	0.0200	0.0079	0.1581	0.0887
7.							1	0.5644**	0.0246	0.0639	0.8055**
8.								1	0.1557	-0.0374	0.6341**
9.									1	-0.0062	0.5846**
10.										1	0.0521

*, ** Significant at 5 and 1 percent

Table 2: Direct (diagonal) and indirect (above and below diagonal) path effects of different characters towards grain yield at genotypic level in chickpea

Sr. No.	Days to 50 percent Flowering (No.)	Days to maturity (No.)	Plant height (cm)	Plant spread (cm)	Primary branches per plant (no.)	Secondary branches per plant (cm)	Pods per plant (No.)	Seeds per pod (No.)	100-seed weight (g)	Protein content (%)	Seed yield per plant (g)
	1	2	3	4	5	6	7	8	9	10	11
1	-0.0419	-0.0304	-0.0032	-0.0164	0.0078	-0.0083	-0.0174	-0.0012	-0.0085	0.0003	0.3934**
2	0.0135	0.0186	0.0018	0.0056	-0.0010	0.0020	0.0035	-0.0014	-0.0002	-0.0041	0.1097
3	-0.0017	-0.0022	-0.0227	-0.0026	-0.0072	0.0078	0.0006	-0.0051	-0.0088	0.0049	0.2010*
4	0.0073	0.0056	0.0022	0.0187	-0.0028	0.0017	0.0067	0.0004	-0.0013	-0.0009	0.2284**
5	-0.0011	-0.0003	0.0018	-0.0009	0.0057	0.0007	0.0003	0.0020	0.0012	0.0002	0.2140**
6	0.0058	0.0032	-0.0101	0.0026	0.0037	0.0295	0.0019	0.0006	0.0002	0.0047	0.0887
7	0.2942	0.1351	-0.0178	0.2568	0.0361	0.0462	0.7100	0.4007	0.0175	0.0454	0.8055**
8	0.0043	-0.0111	0.0339	0.0031	0.0529	0.0030	0.0853	0.1512	0.0235	-0.0057	0.6341**
9	0.1131	-0.0065	0.2175	-0.0379	0.1185	0.0044	0.0138	0.0873	0.5610	-0.0035	0.5846**
10	-0.0001	-0.0024	-0.0024	-0.0005	0.0003	0.0017	0.0007	-0.0004	-0.0001	0.0109	0.0521

Conclusions

The Seed yield per plant had significant and positive correlation with days to 50 percent flowering, plant height, plant spread, primary branches per plant, number of pods per plant, number of seeds per pod and 100-seed weight. It also had non-significant positive correlation with days to maturity, number of secondary branches per plant and protein content. In the path analysis, highest positive direct effect on seed yield per plant was observed through number of pods per plant, 100-seed weight and number of seeds per pod. The trait days to maturity, plant spread, primary branches per plant, secondary branches per plant and protein content showed positive direct effect on seed yield per plant. The direct selection to these traits will be beneficial for yield improvement programmes.

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