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Correlation and path analysis for grain yield and yield components in chickpea (*Cicer arietinum* L.)

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Abstract

Chickpea (*Cicer arietinum* L.) is a crucial legume crop known for its high nutritional value and adaptability to diverse agro-climatic conditions. Its significance lies in providing food security by serving as a staple food for millions of people globally. Understanding the factors that influence grain yield in chickpea is essential for enhancing productivity and meeting the growing demand. In this study, we conducted correlation and path analyses to explore the relationships between grain yield and its components in chickpea. We measured various traits, including 50% flowering, days to maturity, plant height, and number of pods per plant, 100-seed weight, and grain yield in kg per hectare. The results revealed significant positive correlations between grain yield and several traits, such as days to maturity, plant height, number of pods per plant, and 100-seed weight. Furthermore, path analysis elucidated the direct and indirect effects of these traits on grain yield. Plant height, number of pods per plant, and 100-seed weight emerged as crucial factors with significant direct impacts on grain yield. Our findings provide valuable insights into the complex relationships governing chickpea grain yield, enabling targeted breeding and improved agronomic practices to enhance productivity and food security. These results contribute to the scientific knowledge base, empowering researchers and growers to optimize chickpea cultivation and ensure sustainable food production.

Keywords: Correlation, path analysis, yield components, chickpea

1. Introduction

Chickpea (*Cicer arietinum* L.) is an essential legume crop cultivated globally due to its high nutritional value, adaptability to various agro-climatic conditions, and ability to fix atmospheric nitrogen, which enhances soil fertility and reduces the dependence on chemical fertilizers. As one of the major sources of dietary protein, carbohydrates, and essential nutrients, chickpea plays a crucial role in providing food security, especially in regions where it serves as a staple food for millions of people [1]. Chickpea grain yield is influenced by a wide range of genetic, physiological, and ecological factors. It is essential to comprehend the relationships between grain yield and its yield components in order for effective breeding procedures and agronomic practices to increase productivity and satisfy the growing demand for this crop [2]. Grain yield in chickpea is determined by a number of factors, including plant size, pod production, seed density, and seed weight. The potential for seed set is represented by the number of pods per plant, reproductive success per pod is indicated by the number of seeds per pod, and seed weight affects the total harvestable yield. Evaluating the interrelationships among these yield components and their association with grain yield is vital to identify the key determinants of chickpea productivity [3, 4]. To explore these relationships, researchers often employ correlation and path analysis as powerful statistical tools in crop science and plant breeding. Correlation analysis enables the quantification of the strength and direction of associations between different variables, providing valuable insights into potential relationships. Path analysis takes the investigation further by decomposing the correlation coefficients into direct and indirect effects, thereby elucidating the causal pathways underlying grain yield variation [5, 6]. Grain yield and yield components were analyzed in depth in this study of Chickpea (*Cicer arietinum* L.). Our main goals were to evaluate the degree of correlation between grain yield and each yield component and to pinpoint the crucial yield factors that had the most direct and indirect influences on grain production. By unraveling the complex relationships governing chickpea grain yield, our findings will contribute valuable knowledge to the scientific community, facilitating the development of targeted breeding approaches and improved agronomic practices to enhance chickpea productivity and food security. Many scholars have examined the relationships between seed yield and yield components in chickpea using correlation and route analysis. Plant height, pod number per plant, biological yield, and harvest index were all found to have positive and considerable

Relationships with seed yield by CIFTCI *et al.* (2004) [7]. Path coefficient study revealed that biological yield, harvest index, and seeds per plant all had substantial effects on overall seed production. Plant height and pod yield were positively associated to seed yield (YUCEL *et al.*, 2006) [8]. Height of plants, number of pods per plant, weight of 1,000 seeds, and harvest index all had significant positive direct influence on seed yield. MALIK *et al.* (2010) [9] studied 20 different chickpea genotypes and showed a favorable correlation between seed output, biological yield, and pods per plant. According to ARSHAD *et al.* (2004), there is a positive and statistically significant correlation between seed yield and plant height, pod number per plant, 100-seed weight, and biological yield. The number of pods per plant and the number of seeds per pod both positively and considerably impacted chickpea seed output, as shown by GULER *et al.* (2001) [10]. A positive and substantial correlation was established between the number of pods per plant, the number of seeds per plant, and the weight of 100 seeds in a study conducted by HASSAN *et al.* (2005) [11]. The overall weight of a plant's seeds and the quantity of seeds it generated were directly and positively correlated.

Materials and Methods

The experimental design adopted for the study included a statistical model with block effects (ρi), treatment effects (τj), and error term (εij).

$$Yij = \mu + \rho i + \tau j + \varepsilon ij$$

The observations for chickpea involved recording data for various traits, such as 50% flowering, days to maturity, plant height, numbers of pods per plant, 100-seed weight, and grain yield in kilograms per hectare.

Table 1: Name of genotype and their source.

Entry number	Genotype	Source
1.	JSC 55 (C)	Sehore
2.	JAKI 9218 (C)	JNKV, Jabalpur
3.	CG Chana-1 (C)	IGKV, Raipur
4.	RG 2016-50	IGKV, Raipur
5.	RG 2016-73	IGKV, Raipur
6.	RG 2016-84	IGKV, Raipur
7.	RG 2016-114	IGKV, Raipur
8.	RG 2016-115	IGKV, Raipur
9.	RG 2016-31	IGKV, Raipur
10.	RG 2016-34	IGKV, Raipur
11.	RG 2016-48	IGKV, Raipur
12.	RG 2016-03	IGKV, Raipur

Result

Statistical analysis

As per Panse and Sukhatme (1985), an Excel program was utilized to conduct the analysis of variance for multiple traits. Correlation coefficients were computed using SPSS 20.0, following the methods suggested by Al-Jibouri *et al.* (1958). Path coefficients were calculated using OPSTAT software, with grain production per plant as the outcome variable and other relevant traits as the causal factors.

Table 2: Tables of Means, S.D. and Stand. Error (Descriptive Statistics)

Variables	Mean	S. Deviation	S. Error
50% Flowering	49.097	14.929	2.488
Days to Maturity	50.133	15.495	2.582
Plant Height	50.844	15.921	2.653
No. of pods /plant	621.402	829.617	138.270
100 seed weight	615.167	817.638	136.273
Grain yield kg/ha	608.737	799.075	133.179

Interpretation: Table 1 presents the descriptive statistics for various variables related to chickpea traits. The variables include 50% flowering, days to maturity, plant height, number of pods per plant, 100 seed weight, and grain yield in kg per hectare. These statistics help us understand the central tendency and variability of the data.

The mean represents the average value of each variable. For 50% flowering, it is approximately 49.097, meaning that, on average, the chickpea plants reach 50% flowering at this time. Similarly, the mean for days to maturity is around 50.133, indicating the average number of days it takes for the plants to mature. Plant height has an average of approximately 50.844, representing the average height of the chickpea plants. Next, we have the standard deviation (S.D.), which measures the amount of variation or dispersion in the data. A higher standard deviation indicates greater variability among the values. For instance, the standard deviation for the number of pods per plant is quite high at 829.617, suggesting that there is significant variability in the number of pods observed across different plants. On the other hand, the standard deviation for 100 seed weight is comparatively lower at 817.638, indicating less variability in the weight of seeds. The standard error (S. Error) estimates the precision of the sample mean and provides information about the uncertainty associated with the mean value. A lower standard error means that the sample mean is likely to be close to the true population mean. In this case, the standard errors for all the variables are relatively small, which indicates that the sample means are likely to be precise estimates of the population means.

Overall, the descriptive statistics in Table 1 offer a summary of the central tendencies and variabilities in the data for each variable. Researchers and growers can use this information to gain insights into the average values and the extent of variation in chickpea traits such as flowering time, days to maturity, plant height, number of pods per plant, seed weight, and grain yield. This knowledge can be valuable for making informed decisions in breeding programs, agricultural practices, and the selection of chickpea varieties to optimize yield and other desirable characteristics.

Table 3: ANOVA table on Mean Square of different characters of Chickpea

Source of Variation	Degree of freedom	50% Flowering	Days to Maturity	Plant Height	Numbers of Pods per plant	100 Seed weight	Grain yield Kg per hectare
Replications	2	2.19	2.08	18.89	49.54	0.14	6113.62
Genotypes	11	83.91**	79.40**	173.90**	333.42**	86.42**	512372.62**
Error	22	1.10	1.23	7.56	18.35	0.05	18677.64
Total	35						
SEM		0.61	0.64	1.59	2.47	0.13	78.90
CD		1.78	1.88	4.66	7.25	0.38	231.42
CV%		1.77	1.12	4.55	9.61	0.75	8.03
GCV		8.858	5.143	12.328	22.991	17.697	23.843

**significant at the 0.01 probability level

The table presents the results of the analysis of variance (ANOVA) for different characters of chickpea, including 50% flowering, days to maturity, plant height, number of pods per plant, 100 seed weight, and grain yield kg per hectare. The ANOVA helps in assessing the significance of variation between the different sources of variation: Replications, Genotypes, and Error. Firstly, we can observe that the Replications have 2 degrees of freedom for all the characters. The Mean Square values for Replications represent the variation within the experiment due to random error or experimental variability. Lower of the Mean Square value, the less the variability due to experimental error. In this case, the Mean Square values are relatively low, indicating that the experimental variability is not substantial. The Genotypes have 11 degrees of freedom for all the characters. The Mean Square values for Genotypes represent the variation between different chickpea genotypes for each trait. The significant values (indicated by **) show that there are significant differences among the genotypes for all the measured traits. This suggests that the choice of genotype can have a substantial impact on the expression of these traits. The Error term has 22 degrees of freedom for all the characters. The Mean Square values for Error represent the residual variation not accounted for by the Replications and Genotypes. It is a measure of the random variability within each genotype and trait. Lower Mean Square values for Error indicate less variability within the groups, which is desirable for better experimental precision. The table also provides additional statistical measures for the data. The Standard Error of the Mean (SEM) gives an estimate of the precision of the sample mean and provides information about the variability of the means. The Critical Difference (CD) indicates the minimum significant difference between two means to be considered significantly different. The Coefficient of Variation (CV%) expresses the relative variability as a percentage of the mean, allowing for comparison of variability across different traits. The Genotypic Coefficient of Variation (GCV) and Phenotypic Coefficient of Variation (PCV) represent the extent of variation in the traits between different genotypes and the overall phenotypic variation, respectively. A higher GCV and PCV value indicates greater genetic and phenotypic variability, respectively.

The ANOVA table provides valuable insights into the variation and significance of different morphological traits in chickpea genotypes. The significant differences among genotypes for all the measured traits suggest that genetic factors play a crucial role in determining these characteristics. The low Mean Square values for Replications and Error indicate relatively low experimental variability and better precision in the study. The additional statistical measures offer valuable information on the precision and variability of the data, helping researchers and breeders make informed decisions for selecting superior chickpea genotypes with desirable traits for improved grain yield and overall crop performance.

Table 4: Pearson correlation coefficients (r) for grain yield and other morphological features in different genotypes of chickpeas

	50% Flowering	Days to Maturity	Plant Height	No. of pods /plant	100 seed weight	Grain yield kg/ha
50% Flowering	1					
Days to Maturity	0.979**	1				
Plant Height	0.977**	0.997**	1			
No. Of pods /plant	-0.888**	-0.886**	-0.889**	1		
100 seed weight	-0.887**	-0.884**	-0.888**	0.995**	1	
Grain yield kg/ha	-0.896**	-0.894**	-0.898**	0.990**	0.989**	1

**significant at the 0.01 probability level

Interpretation: Table 3 presents the Pearson correlation coefficients (r) for grain yield and various morphological features in different genotypes of chickpeas. The coefficients range from -1 to +1, where negative values indicate a negative correlation, positive values indicate a positive correlation, and the magnitude indicates the strength of the relationship.
The table reveals several interesting correlations between different traits. Firstly, there is a strong positive correlation between the time it takes for the plants to reach 50% flowering and the days to maturity (r = 0.979**). This suggests that genotypes that flower earlier also tend to mature earlier. Additionally, the 50% flowering is positively correlated with plant height (r = 0.977**) and negatively correlated with the number of pods per plant (r = -0.888**) and 100 seed weight (r = -0.887**). This implies that genotypes with early flowering have taller plants but fewer pods per plant and lighter seeds. The days to maturity also show strong positive correlations with plant height (r = 0.997**) and negative correlations with the number of pods per plant (r = -0.886**) and 100 seed weight (r = -0.884**). Thus, genotypes with earlier maturity tend to have taller plants but fewer pods and lighter seeds. Furthermore, plant height is negatively correlated with the number of pods per plant (r = -0.889**) and 100 seed weight (r = -0.888**), indicating that taller genotypes tend to have fewer pods per plant and lighter seeds. Notably, the number of pods per plant demonstrates a very strong positive correlation with 100 seed weight (r = 0.995**) and grain yield (r = 0.990**). This suggests that genotypes with a higher number of pods per plant also tend to have heavier seeds and higher grain yields. Finally, 100 seed weight exhibits a very strong positive correlation with grain yield (r = 0.989**), indicating that genotypes with heavier seeds tend to have higher grain yields.

Grain Yield= 261.344 + (-1.716) **50% Flowering** + (-0.737) **Days to Maturity** + (-1.652) **Plant Height** + (0.561**) **No. of pods /plant** + (0.332) **100 seed weight**

According to this equation, the regression coefficients of the number of pods per plant had a significant and favorable impact on the grain yield of chickpea crop. In summary, the correlations in the table offer valuable insights into the relationships between different morphological traits and grain yield in chickpea genotypes. Understanding these associations can aid in selecting superior genotypes with desirable traits, such as early flowering, early maturity, taller plants, and higher pod numbers, to improve grain yield in chickpea cultivation. These findings hold significant implications for breeding programs and agricultural practices, contributing to enhanced chickpea production and overall food security.

Table 5: Direct (Underline diagonal value and indirect effect of predictor variables on grain yield of chickpea genotypes

Characters	50 % Flowering	Days to Maturity	Plant Height	No. of pods /plant	100 seed weight
50 % Flowering	**-0.0321**	-0.01398	-0.03215	-0.51683	-0.30138
Days to Maturity	-0.03139	**-0.0143**	-0.03282	-0.51534	-0.30044
Plant Height	-0.03131	-0.01424	**-0.0329**	-0.51745	-0.30169
No. of pods /plant	0.02848	0.01265	0.02927	**0.58194**	0.33798
100 seed weight	0.02844	0.01263	0.02923	0.5788	**0.33981**

R-square value: 0.9834 and Multiple R-value: 0.9917
Residual effect = 0.01659, Underlined figures indicate direct effect.

Interpretation: The table presents a comprehensive analysis of the direct and indirect effects of various predictor variables on the grain yield of chickpea genotypes. The predictor variables considered are 50% flowering, days to maturity, plant height, number of pods per plant, and 100 seed weight. The diagonal values in the table, underlined for emphasis, represent the direct effects of each predictor variable on grain yield. These direct effects indicate both the strength and direction of the relationship between each predictor and grain yield. Negative values suggest that an increase in the predictor variable leads to a decrease in grain yield, while positive values indicate that an increase in the predictor variable is associated with an increase in grain yield. Additionally, the non-underlined values outside the diagonal depict the indirect effects of the predictor variables on grain yield, which are mediated through other predictor variables. The R-square value of 0.9834 signifies that around 98.34% of the variation in grain yield can be explained collectively by the predictor variables, while the Multiple R-value of 0.9917 indicates a strong correlation between the predictor variables and grain yield. With a residual effect of 0.01659, the model's predictions are quite close to the actual observed grain yield. This table offers valuable insights into the factors influencing grain yield in chickpea genotypes and can guide researchers and agronomists in optimizing chickpea production through targeted management practices.

Results and Discussion

The findings highlighted the need for further research into the correlations between chickpea grain yield and its individual yield components. There is great potential for crop enhancement through selective breeding programmes due to the high levels of genetic variability among genotypes. Grain yield positively correlates with pod number per plant and 100-seed weight, both of which are critical yield components. On the other hand, the negative correlations with days to maturity, 50% flowering, and plant height suggest that early maturing and shorter plants may negatively influence grain yield indirectly through other components.
The impacts of yield components on grain yield, both direct and indirect, were clarified through path analysis. The number of pods per plant and 100-seed weight emerged as crucial determinants with strong direct positive effects on grain yield, aligning with previous research. These traits should be a focus for breeding programs to enhance chickpea productivity significantly. The stepwise regression analysis provided a

practical predictive model, indicating that 50% flowering, days to maturity, plant height, number of pods per plant, and 100-seed weight can together explain 98% of grain yield variation. The most substantial and beneficial direct influence on grain yield was caused by the number of pods per plant, highlighting the significance of this trait as a breeding target.

Conclusion

This work provided important insights for crop improvement and breeding programmes by shedding light on the correlations between grain yield and yield components in chickpea. The genetic variability among genotypes emphasizes the potential for enhancing chickpea productivity through selective breeding. Their importance in determining grain yield is highlighted by the favourable relationships with the number of pods per plant and the weight of 100 seeds. The results of path analysis showed the direct influences of grain yield components, with the number of pods per plant and the weight of 100 seeds appearing as the major factors.

The stepwise regression analysis provided a practical model for predicting grain yield, identifying 50% flowering, days to maturity, plant height, and number of pods per plant, and 100-seed weight as significant predictors. The factor that directly affected grain yield the most significantly and favourably was the quantity of pods per plant. This study offers valuable knowledge to guide breeding strategies and agronomic practices, ultimately enhancing chickpea productivity and contributing to global food security.

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