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RESEARCH PAPER

Deciphering trait association, direct and indirect effects of component traits on yield through correlation and path analysis in chickpea (*Cicer arietinum* L.)

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Abstract: Chickpea (*Cicer arietinum* L.) is a food legume crop belonging to the family Leguminosae (Fabaceae). Increasing crop yield is the primary focus of crop improvement programs, and it is a multifaceted trait that relies on various component traits. A better insight about the association of yield with its component traits can be very helpful in improving the yield. The experiment was carried out during *rabi* 2022-23 at Regional Agricultural Research Station, Vijayapura to dissect the correlation and path analysis to understand the association, direct and indirect effects between the traits. Yield showed positive correlation with SCMR at 60 days (0.128), height of first pod (0.093), hundred seed weight (0.033), plant height (0.023) and days to fifty per cent flowering (0.004). The direct and indirect effects of yield contributing traits among fifty genotypes through path coefficient analysis was analysed. Experimental results indicated that majority of the traits under consideration *viz.,* number of pods per plant (0.8031), NDVI (0.7551), number of primary branches (0.6082), SCMR 60 (0.5948), hundred seed weight (0.4923), height of first pod (0.4299), days to maturity (0.0870) and number of seeds per pod (0.0359) showed positive direct effect on plot yield while days to fifty per cent flowering (-0.7212), SCMR 30 (-0.7196), plant height (-0.6994) and number of secondary branches (-0.3458) exhibited negative effect. The information derived through such analysis helps to derive the traits having positive effect (direct and indirect) and thus gives insights on formulation of selection indices towards enhancing productivity.

Key words: Chickpea, Correlation, Path analysis, Selection index

Introduction

Chickpea (*Cicer arietinum* L.), a self-pollinated true diploid (2n=2x=16), is a cool season legume crop with a genome size of 738 Mbp (Varshney *et al.,* 2013) belonging to the Fabaceae family. It is an important source of protein (19-24%) for millions of people in developing countries and consumed all over the world, especially in Afro-Asian countries. The world's population is increasing faster than ever before, posing tremendous challenge to food supply in the 21st century. Climate change is worsening the problem, which causes environmental stresses, limiting the plant growth and result in lower agricultural productivity (Kaushal and Wani *et al.,* 2016).

Seed yield, being the most important and polygenically controlled complex character, is also governed by many morpho-phenological and physiological changes within the plant. The correlation studies assists in identifying the trait associations to formulate selection criteria to accomplish desired target trait improvement. In general, the genotypic correlation surpasses the phenotypic correlation, highlighting a substantial genetic connection between traits. Correlation analysis was undertaken to understand the association between morpho-phenological, physiological and yield related traits.

Interrelationship among direct and indirect effect of component characters of yield is important in predicting the correlated response to direct selection and in the evaluation of elite genotypes. Path coefficient analysis, introduced by Wright in 1921, is a statistical method that considers the causal relationships between variables. Path coefficient analysis is an important tool for plant breeders in partitioning the total correlation coefficients into direct and indirect effects of independent variables on dependent variable *i.e.,* yield.

Material and methods

The experimental material for this study comprised a total of 50 genotypes, which encompassed a diverse range of genetic sources. These genotypes were carefully selected and included advanced breeding lines; genotypes derived from the Multiparent Advanced Generation Inter Cross (MAGIC) population, as well as those originating from trait-specific donors and previously released varieties. The experiment was carried out at the Regional Agricultural Research Station located in Vijayapura during *rabi* 2022-23.

To ensure a systematic and rigorous approach, the experiment was designed following a Randomized Complete Block Design (RCBD) with two replications. The genotypes were sown with a spacing of 30cm x 10cm, adhering to the recommended package of agricultural practices.

The correlation studies assists in identifying the trait associations to formulate selection criteria to accomplish desired target trait improvement. Hence, knowing the correlation among the related traits with magnitude and direction of association between the traits of interest, helps in achieving breeding objectives in a more efficient way. In this study, correlation analysis was undertaken to understand the association between morpho-phenological, physiological and yield related traits.

In order to gain insights into the factors influencing productivity, path coefficient analysis was used. This statistical method allowed to figure out both direct and indirect effects of various component traits on the overall productivity of the genotypes. This comprehensive approach provided a deeper understanding of the interrelationships among the traits and their impact on crop yield, facilitating informed decision-making for crop improvement and management strategies. In the present investigation, path coefficients were computed for the twelve independent component traits that affect the yield, which is considered as the dependent variable.

Results and discussion

Correlation analysis

In the present investigation, genotypic and phenotypic correlation coefficients among 13 morpho-phenological, physiological and yield related traits (Table 1) were estimated to understand the association between the component traits.

Plot yield showed positive correlation with SCMR at 60 days (r_g= 0.128, r_p= 0.016), height of first pod (r_g= 0.093, r_p= 0.078), hundred seed weight (r_g= 0.033, r_p=0.070), plant height (r_g=0.023) and days to fifty per cent flowering (r_g=0.004, r_p= 0.016), whereas it also showed significant positive correlation with NDVI (r_g= 0.715, r_p= 0.433) and number of pods per plant (r_g = 0.670, r_p= 0.093). It also showed significant negative correlation with number of seeds per pod (r_g = -0.509, r_p = -0.112). Negative correlation was observed between yield and number of primary branches (r_g = -0.021), SCMR at 30 days (r_g = -0.122, r_p = -0.039), number of secondary branches (r_g = -0.191, r_p = -0.229) and days to maturity (r_g = -0.274, r_p = -0.024).Days to fifty per cent flowering exhibited positive significant association with number of seeds per pod (r_g =0.819), days to maturity (r_g = 0.476, r_p = 0.418) and height of first pod (r_g = 0.423, r_p = 0.381). It is significantly negatively correlated with NDVI (r_g = -0.611), SCMR at 30 days (r_g = -0.403, r_p = -0.273) and hundred seed weight (r_g = -0.325, r_p = -0.150).

Positive significant correlation was recorded between height of first pod and days to fifty per cent flowering (r_g = 0.423, r_p = 0.381), SCMR at 30 days (r_g = 0.545, r_p = 0.385), SCMR at 60 days (r_g = 0.317, r_p = 0.247), days to maturity (r_g = 0.808, r_p = 0.230) and plant height (r_g = 0.962, r_p = 0.833). Plant height shows positive significant association with SCMR at 30 days (r_g = 0.635, r_p = 0.387), SCMR at 60 days (r_g = 0.347, r_p = 0.281), days to maturity (r_g = 0.795, r_p = 0.242) and height of first pod (r_g = 0.962, r_p = 0.833), number of seeds per pod (r_g = 0.314, r_p = 0.007) and hundred seed weight (r_g = 0.458, r_p = 0.351). It also showed negative significant correlation with number of secondary branches (r_g = -0.438, r_p = -0.291).

Number of pods per plant showed high positive significant association with plot yield (r_g = 0.670), number of secondary branches (r_g = 0.495, r_p = 0.440), number of seeds per pod (r_g = 0.297) and days to maturity (r_g = 0.066, r_p = 0.243), whereas negative significant association with SCMR at 30 days and NDVI (r_g = -0.407 and r_g = -0.291), respectively. Highly significant positive correlation was observed between number of seeds per pod and days to fifty per cent flowering (r_g = 0.819) similarly between, number of seeds per pod and days to maturity (r_g = 0.381), plant height (r_g = 0.314), number of pods per plant (r_g = 0.297). Number of seeds per pod also showed negative significant correlation with SCMR at 30 days (r_g = -0.592), NDVI (r_g = -0.228), SCMR at 60 days (r_g = -0.999), hundred seed weight (r_g = -0.896), plot yield (r_g = -0.509), number of primary branches (r_g = -0.754) and number of secondary branches (r_g = -0.489).

High significant positive correlation was observed between physiological traits *i.e.,* SCMR at 30 days and NDVI (r_g = 0.401) similarly between SCMR at 30 days and SCMR at 60 days (r_g = 0.487, r_p = 0.213). Days to fifty per cent flowering shows positive significant association with number of seeds per pod, days to maturity and height of first pod. It is significantly negatively correlated with SCMR at 30 days, NDVI and hundred seed weight. These outcomes align with the findings of Banik *et al*. (2017) and Ali *et al*. (2008) where reported that, at both genotypic and phenotypic levels, there was a positive correlation observed between the number of days to flowering and the number of primary branches per plant with seed yield.

Table 1. Estimation of genotypic (above diagonal) and phenotypic (below diagonal) correlation coefficients in chickpea

	DFPF	SCMR30	NDVI	SCMR60	DM	HFP	PH	NPB	NSB	NPPP	NSPP	HSW	PY
DFPF	1.000	-0.403**	-0.611**	-0.083	0.476**	0.423**	0.193	0.119	0.097	0.213	0.819**	-0.325*	0.004
SCMR30	-0.273**	1.000	0.401**	0.487**	-0.067	0.545**	0.635**	0.025	-0.448**	-0.407**	-0.592**	0.624**	-0.122
NDVI	-0.053	0.115	1.000	-0.170	-0.224**	0.175	0.023	0.056	-0.295*	-0.291*	-0.228**	0.259	0.715**
SCMR60	0.017	0.213*	-0.028	1.000	0.574**	0.317*	0.347*	-0.401**	-0.296*	0.120	-0.999**	0.544**	0.128
DM	0.418**	-0.089	-0.197*	0.190	1.000	0.808**	0.795**	-0.195	0.251	0.066**	0.381**	-0.168	-0.274
HFP	0.381**	0.385**	0.162	0.247*	0.230*	1.000	0.962**	-0.098	-0.439**	-0.187	-0.087	0.202	0.093
PH	0.232*	0.387**	0.100	0.281**	0.242*	0.833**	1.000	-0.171	-0.438**	-0.118	0.314*	0.458**	0.023
NPB	-0.129	-0.037	0.078	-0.202*	-0.062	-0.136	-0.206*	1.000	0.494**	-0.192	-0.754**	-0.136	-0.021
NSB	0.012	-0.285**	-0.168	-0.218*	-0.047	-0.367**	-0.291**	0.178	1.000	0.495**	-0.489**	-0.271	-0.191
NPPP	0.171	-0.298**	-0.180	0.072	0.243*	-0.142	-0.083	-0.080	0.440**	1.000	0.297**	-0.271	0.670**
NSPP	-0.029	-0.070	-0.128	0.008	-0.118	-0.031	0.007	-0.112	0.079	0.160	1.000	-0.896**	-0.509**
HSW	-0.150	0.475**	0.199*	0.272**	0.037	0.191	0.351**	-0.129	-0.193	-0.220*	-0.210*	1.000	0.033
PY	0.016	-0.039	0.433**	0.016	-0.024	0.078	-0.017	0.006	-0.229*	0.093	-0.112	0.070	1.000

NOTE: *and ** defines significance at 5 per cent and 1 per cent probability, respectively.

DFPF- Days to fifty per cent flowering, SCMR- SPAD Chlorophyll Meter Reading, NDVI- Normalized Difference Vegetation Index, DM- Days to maturity, HFP- Height of first pod (cm.),PH- Plant height (cm.), NPB- Number of primary branches,NSB- Number of secondary branches, NPPP- Number of pods per plant,NSPP- Number of seeds per pod, PY- Plot yield (g), HSW- Hundred seed weight (g)

Table 2. Genotypic path analysis indicating direct and indirect effect of independent traits on plot yield

	DFPF	SCMR30	NDVI	SCMR60	DM	HFP	PH	NPB	NSB	NPPP	NSPP	HSW
DFPF	-0.7212	0.6932	-0.4619	-0.0494	0.1285	0.6050	-0.1350	0.0725	-0.0335	0.3007	0.0652	-0.1599
SCMR30	0.2907	-0.7196	0.3030	0.2898	-0.0058	0.7799	-0.4439	0.0155	0.1550	-0.1013	-0.0929	0.3074
NDVI	0.4412	-0.6901	0.7551	-0.1011	-0.1066	0.2510	-0.0161	0.0338	0.1019	-0.0009	-0.0799	0.1278
SCMR60	0.0599	-0.8376	-0.1284	0.5948	0.1370	0.4537	-0.2426	-0.2437	0.1024	0.2004	-0.0358	0.2677
DM	-0.0646	0.1143	-0.9252	0.9364	0.0870	0.1546	-0.5558	-0.1188	-0.0868	0.0033	0.2644	-0.0829
HFP	-0.3051	-0.9379	0.1325	0.1888	0.0703	0.4299	-0.6729	-0.0598	0.1517	-0.0006	-0.0031	0.0994
PH	-0.1392	-0.0914	0.0174	0.2063	0.0692	0.3756	-0.6994	-0.1039	0.1516	-0.0004	0.0112	0.2254
NPB	-0.0860	-0.0437	0.0420	-0.2384	-0.0170	-0.1405	0.1194	0.6082	-0.1708	-0.0006	-0.0270	-0.0668
NSB	-0.0698	0.7707	-0.2226	-0.1761	0.0218	-0.6274	0.3066	0.3004	-0.3458	0.1015	-0.0175	-0.1332
NPPP	-0.1534	0.6997	-0.2202	0.0715	0.0928	-0.2676	0.0823	-0.1169	-0.1712	0.8031	0.0464	-0.1332
NSPP	-0.3088	0.4473	-0.6803	-0.5927	0.6410	-0.1241	-0.2191	-0.4574	0.1686	0.2040	0.0359	-0.4227
HSW	0.2343	-0.0737	0.1960	0.3235	-0.0147	0.2886	-0.3203	-0.0825	0.0936	-0.0008	-0.1037	0.4923

NOTE: Diagonal values represent the direct effect of a respective trait on yield per plant. Residual = 0.0317

DFPF- Days to fifty per cent flowering, SCMR- SPAD Chlorophyll Meter Reading,NDVI- Normalized Difference Vegetation Index,DM- Days to maturity, HFP- Height of first pod (cm.), PH- Plant height (cm.),NPB- Number of primary branches,NSB- Number of secondary branches, NPPP- Number of pods per plant, NSPP- Number of seeds per pod, HSW- Hundred seed weight (g)

Path- coefficient analysis

In the present study,the experimental results on direct and indirect effects of morpho-phenological and yield attributing traits on yield per plant are presented in Table 2.Number of pods per plant showed maximum direct effect (0.8031) and indirect effect (0.3007) through days to fifty per cent flowering on plot yield followed by NDVI with the direct effect of 0.7551 and indirect effect of 0.3030 through SCMR 30 on plot yield.

Number of primary branches showed direct effect of 0.6082 and indirect effect of 0.3004 through number of secondary branches on plot yield. SCMR 60 exhibited a direct effect of 0.5948 and indirect effect of 0.9364 through days to maturity on plot yield while direct and indirect effect of hundred seed weight through SCMR 30 on plot yield were 0.4923 and 0.3074, respectively. Height of first pod showed direct effect of 0.4299 on plot yield with indirect effect 0.7799 through SCMR 30. The direct of 0.0870 and indirect of 0.6410 through number of seeds per pod was evident for days to maturity on plot yield. The direct and indirect effects of number of seeds per pod through days to maturity on plot yield were 0.0359 and 0.2644, respectively. Days to fifty per cent flowering, SCMR at 30 days, plant height and number of secondary branches showed negative direct effect of -0.7212, -0.7196, -0.6994 and -0.3458, respectively on plot yield (Fig 1). This analysis had residual effect of 0.0317.

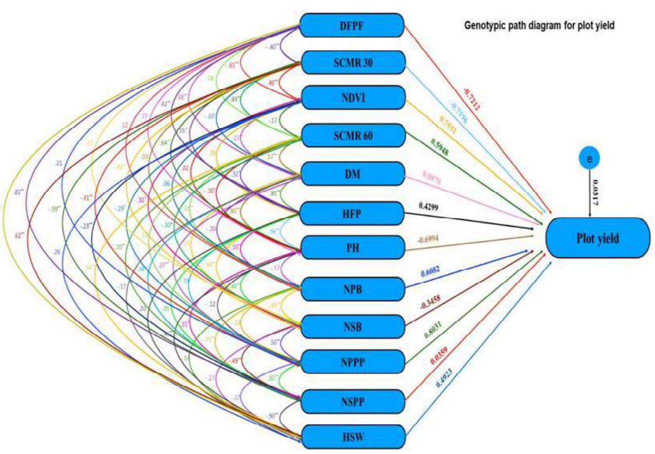

Fig 1. Genotypic path diagram depicting the influence of morpho-phenological, physiological traits on plot yield

These results of the present study are in line with the findings of Gulwane *et al*. (2022) where in100 seed weight had highest direct effect on seed yield per plant followed by number of pods per plant, number of seeds per pod, number of secondary branches per plant and plant height. Similar results on path analysis was observed by Mushtaq *et al.* (2013) where the duration taken for flowering exhibited the highest direct effect on seed yield per plant, followed by the overall plant weight, weight of 100 grains, number of primary branches and plant height. Other studies on path analysis by Dhama *et al.* (2010), Siddika *et al.* (2013), Waseem *et al.* (2014) also revealed similar findings. Thus, considering the potentially significant contribution of these traits to yield, it is recommended to pursue direct selection for these traits to enhance productivity in chickpea. Improving selection efficiency through estimates of trait associations is augmented by analyzing both the direct and indirect effects of component traits on yield.

Conclusion

Correlation, both genotypic and phenotypic levels, estimated to know the direction and magnitude of association among the characters. Plot yield showed significant positive correlation with NDVI and number of pods per plant, whereas it also showed positive correlation with SCMR at 60 days, height of first pod, hundred seed weight, plant height and days to fifty per cent flowering. It also showed significant negative correlation with number of seeds per pod. These findings hold value for the development of selection indices and criterion traits for trait specific breeding programmes. Path analysis has revealed that number of pods per plant had positive and direct effect on plot yield, indicating the importance of the trait towards identifying high yielding genotypes. The majority of the traits, including the number of pods per plant, NDVI, number of primary branches, SCMR 60, hundred seed weight, height of the first pod, days to maturity, and number of seeds per pod, showed a positive direct effect on plot yield, with the exception of days to fifty per cent flowering, SCMR at 30 days, plant height, and number of secondary branches. Thus, such analysis gives information on important criterion traits for yield improvement and to formulate selection index to improve productivity in chickpea.

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