

**STUDY ON CHARACTER ASSOCIATION AND GENETIC
PARAMETERS OF CHICKPEA (*Cicer arietinum* L.)**

ABSTRACT

Present study was conducted with an objective of knowing degree of variability and association studies among 64 chickpea genotypes including both *desi* and *kabuli* for 13 quantitative and six quality traits during *Rabi* 2021-22. High PCV and GCV estimates was observed for total number of seeds per plant followed by number of pods per plant, biological yield, tannic acid, 100 seed weight and seed yield. Low estimates were found for phenological traits like days to first flowering, days to 50% flowering, days to maturity and quality parameters like protein content, phytic acid. High heritability and high genetic advance as per cent mean was shown by total number of seeds per plant, plant height, number of primary branches per plant, number of secondary branches per plant and harvest index indicating the influence of additive gene action. Character association studies revealed that number of secondary branches per plant, number of pods per plant, number of seeds per pod, total number of seeds per plant and 100 seed weight showed positive significant correlation with seed yield. Some of the quality parameters like total free amino acid, phytic acid, total flavonoids were also associated positively with seed yield. Path coefficient analysis revealed that days to first flowering, plant height, number of primary branches per plant, number of secondary branches per plant and number of pods per plant showed positive correlation due to their positive direct effect on seed yield. Hence knowledge about these biometrical techniques help in designing the selection procedure for effective exploitation of variability and the association of traits with yield for chickpea improvement.

Key words- Chickpea, Correlation, GCV (Genotypic Coefficient of Variation), Genetic advance as per cent mean, Heritability and Path coefficient analysis.

INTRODUCTION

Chickpea (*Cicer arietinum* L.) is a diploid, $2n=2x=16$, autogamous, cool season legume crop and rich source of dietary protein. As a grain legume, it plays an important role in the nutrition of the developing world's rural and urban poor by providing a protein-rich supplement to cereal-based diets, particularly for vegetarians and subsistence farmers who cannot afford meat. Chickpea ranks third among pulses, fifth among grain legumes and 15th among grain crops of the world (Khan *et al.*, 2011). Chickpea is a good source of carbohydrates (52.4-70.9%), proteins (17-26%), fats (3.8-10.2%) and essential minerals (Ca, Fe) (Saxena *et al.*, 2013). Chickpea seed compared with other legumes is relatively devoid of protein antinutrients such as lectins, but it contains phytates, saponins and tannins, trypsin inhibitors decreasing the bioavailability of seed protein. Phytic acid binds with other minerals

and ions thus reducing its bioavailability, but the phytate phosphorous aids in germination of chickpea seed thus it is essential for growth and development. Variation in dark colour in *desi* genotypes is due to difference in tannic acid concentration and is responsible for dark colour formation in seed coat. Phenols bind to proteins and minerals thus reducing biological functioning. Hence quantifying and understanding the mechanism of action of these non-nutritional compounds is an important challenge in future (Singh *et al.*, 2015).

Variability for economically significant characteristics is a basic prerequisite for crop improvement. One of the major constraints to increasing chickpea productivity has been identified as a lack of adequate variability. The extent of genetic variability has been identified as an important factor, which is required for successful hybridization aimed at producing high yielding progenies. Variability estimates denote the magnitude of variation in the concerned traits and the influence of environment on the expression of a trait. Heritability knowledge assists plant breeders in predicting the behaviour of succeeding generations, making desirable selection, and assessing the magnitude of genetic improvement through selection. Genetic advance as per cent mean helps in predicting the nature of genes governing the character. Heritability combined with genetic advance as per cent mean provides a better indicator for selection. Correlation coefficient analysis is a reliable and consistent technique for determining the degree and extent of relationship between important yield contributing traits. It provides basic selection criteria and leads to directional model based on yield and its components in the field experiments. Yet the information it supplies about the nature of association is often incomplete, Path coefficient analysis is an efficient method of partitioning correlation coefficients into unidirectional and alternative routes, allowing for a critical examination of specific factors that result in a given correlation can be successfully used in developing an effective programme of selection. The present study aimed with these objectives to measure the magnitude of variation, association for genetic improvement in chickpea.

MATERIAL AND METHODS

Present study comprised of 64 chickpea genotypes including both *desi* and *kabuli*, provided by RARS, Nandyal which are released and advanced breeding lines. Research was conducted at Agricultural College Farm, Bapatla during *Rabi* 2021-22 in 8×8 square lattice design. Data was recorded for three phenological traits (days to first flowering, days to 50% flowering, days to Maturity), 10 quantitative characters (plant height, number of primary

branches per plant, number of secondary branches per plant, number of pods per plant, number of seeds per pod, total number of seeds per pod, biological yield, harvest index, 100 seed weight, seed yield per plot) and six quality parameters (protein content, total free amino acid, phytic acid, tannic acid, total phenolic content, total flavonoid content). Sowing was done in black cotton soils with a row length of 4m and 3rows per genotype with a spacing of 30×10 cm. Data was collected from five randomly selected plants preferably in middle and mean values were indicated, for biochemical analysis seed was ground into fine powder which is sieved and used for analysis. Genetic variability parameters *viz.*, coefficients of variation, heritability and genetic advance were estimated according to Singh and Chaudhary (1977), correlation and path analysis as suggested by Falconer (1964), Dewey & Lu (1959).

RESULTS AND DISCUSSION

ANOVA indicated the presence of ample variation among the selected genotypes for the traits under study was presented in table 1.1. Table 1.2 shows the estimates for PCV are greater than GCV for all the characters indicating the role of environment on the expression of these traits the results were in accordance with Raju *et al.*, (2017), Srivastava *et al.*, (2017) and Mohammed *et al.*, (2019).

High PCV, GCV estimates were observed for total number of seeds per plant (50.09 & 49.65), number of pods per plant (39.50 & 38.85), biological yield (35.41 & 35.29), 100 seed weight (30.85 & 30.66), total free amino acid (mg/g) (24.88 & 24.43), tannic acid (36.47 & 36.14), total phenolic content (mg/g) (21.25 & 20.90), total flavonoid content (mg/g) (24.19 & 23.78) and seed yield (29.92 & 26.70) revealing the presence of wide variation for these traits among the studied genotypes and suggesting selection for these traits will enhance chickpea yield as these are the major yield contributing characters. On the other hand low estimates were observed for days to maturity (6.85 & 6.53), days to 50% flowering (7.79 & 6.79) indicating the less variation for the traits and less scope for selection. Seed yield per plot recorded high PCV (29.92) and GCV (26.70) and the difference between them indicates the role of environment on expression of the trait. The results were in accordance with Thakur *et al.* (2018), Mohan and Thiyagarajan (2019), Brindaban *et al.* (2021), Akanksha *et al.* (2016), Anusha *et al.* (2020) and Mukesh *et al.* (2016).

High heritability accompanied high genetic advance as per cent mean was observed for biological yield (99.33 & 72.46), total number of seeds per plant (98.23 & 101.36), plant height (96.06 & 31.35), number of pods per plant (96.75 & 78.72), harvest index (%) (97.67

& 40.02), 100 seed weight (98.81 & 62.79), total free amino acid (mg/g) (96.43 & 49.473), tannic acid (mg/g) (98.20 & 73.79), total phenolic content (mg/g) (96.72 & 42.34), total flavonoid content (mg/g) (96.66 & 48.17), seed yield per plot (g) (79.65 & 49.09), number of primary branches per plant (78.97 & 22.05), number of secondary branches per plant (77.42 & 27.93) and number of seeds per pod (74.94 & 26.08). It indicates that most likely the heritability is due to additive gene effects and selection may be effective. Protein content reported high heritability and low genetic advance as per cent mean suggesting that the character is governed by non-additive gene action and simple selection may not be effective. The results were in harmony with Raju and Lal (2021), Hemalatha and Lal (2021), Karthikeyan *et al.* (2022), Brindaban *et al.* (2021), Bhanu *et al.* (2017) and Xalxo *et al.* (2021).

Association studies revealed that traits like days to first flowering, days to 50% flowering, days to maturity, plant height (cm), number of primary branches per plant, number of secondary branches per plant, number of pods per plant, number of seeds per pod, total number of seeds per plant and biological yield (g) reported positive significant association with seed yield, suggested these characters are the major yield contributing characters. Quality traits like tannic acid and total phenolic content and harvest index showed negative correlation with seed yield. Similar results were reported by Bhanu *et al.* (2017), Amare *et al.* (2020), Raju and Lal (2021), Pattanayak *et al.* (2021) and Karthikeyan *et al.* (2022).

Path coefficient analysis exhibited traits like days first flowering, plant height, number of primary branches per plant, number of secondary branches per plant, number of pods per plant and biological yield showed direct positive effect and significant association with seed yield suggesting direct selection of these characters may be beneficial in chickpea improvement. Some traits like days to 50% flowering, 100 seed weight, total free amino acid and total flavonoid content showed negative direct effect with positive significant effect indicating positive relation may be due to indirect casual factors, so indirect casual factors are to be considered simultaneously for selection. Residual effect recorded up to 0.609 and 0.417 at phenotypic and genotypic levels respectively. The results were in agreement with Kaur *et al.* (2019), Mohan and Thiyagarajan (2019), Dawane *et al.* (2020), Rathod *et al.* (2020) and Amare *et al.* (2020).

CONCLUSION

The above observations indicate the presence of sufficient variation particularly for the major yield contributing traits like number of pods per plant, total number of seeds per plant and 100 seed weight. High heritability accompanied by high genetic advance as per cent mean for the traits like number of secondary branches per plant, number of pods per plant, number of seeds per pod, total number of seeds per plant, harvest index and 100 seed weight indicating the preponderance of additive gene action in governing the trait. Study of character association among important yield attributing characters and bioactive compounds indicated that number of secondary branches per plant, number of pods per plant, number of seeds per pod, total number of seeds per plant, 100 seed weight showed positive significant correlation with seed yield. Some of the quality parameters like total free amino acid, phytic acid, total flavonoids were also associated positively with seed yield. Traits like tannic acid, phenols were correlated negatively with seed yield. The path coefficient analysis revealed that days to first flowering, plant height, number of primary branches per plant, number of secondary branches per plant, number of pods per plant showed positive correlation due to their positive direct effect on seed yield. Suggesting the importance of direct selection for these traits. Bioactive compounds like total free amino acid and flavonoid content showed negative direct effect and positive association with seed yield indicating indirect effects seem to be the cause of positive correlation so, the indirect causal factors are to be considered simultaneously for selection. Therefore, it can be inferred that simultaneous selection for yield and all quality traits may not be possible and breeding programmes should be refined to break undesirable linkages between traits for simultaneous improvement of yield and quality traits.

REFERENCES

- Akanksha, T., And, A., and Namita, P. 2016. Genetic variability, Correlation and path analysis in yield and yield components in chickpea (*Cicer arietinum* L.) genotypes under late sown condition. *International Journal of Agriculture Sciences*. 8(54): 2884-2886.
- Amare, T., Fikre, A., and Bantayhu, M. 2020. Genetic variability and association analysis of Desi-type chickpea (*Cicer arietinum* L.) advanced lines under potential environment in North Gondar, Ethiopia. *Cogent Food and Agriculture*. 6 (1). 1806668.
- Anusha, T., Reddy, A.T., Jayalakshmi, V and Ahammed, S.K. 2020. Genetic variability studies for yield and quality traits in chickpea (*Cicer arietinum* L.). *International Journal of Current Microbiology and Applied Sciences*. 9 (9): 2995-3000.
- Bhanu, A.N., Singh, M.N., Rajendra, T and Saroj, S.K. 2017. Genetic variability, correlation and path coefficient analysis for quantitative traits in chickpea genotypes. *Indian*

- Brindaban, S., Kumar, V and Mishra, S.P. 2021. Genetic variability , path analysis and relationship among quantitative traits in chickpea (*Cicer arietinum* L .) genotypes. *The Pharma Innovation Journal.* 10(5): 1564-1568.
- Burton, G.W. 1952. Quantitative inheritance in grasses. *Proceedings of 6th Grassland Congress Journal.* 1: 277- 281.
- Dawane, J.K., Jahagirdar, J.E and Shedge, P.J. 2020. Correlation Studies and Path Coefficient Analysis in Chickpea (*Cicer arietinum* L.). *International Journal of Current Microbiology and Applied Sciences.* 9 (10): 1266-1272.
- Dewey, D.R and Lu, K.H. 1959. A correlation and path coefficient analysis of components of crested wheat grass seed production. *Agronomy Journal.* 51 (9): 515-518.
- Falconer, D.S. 1964. *An Introduction to Quantitative Genetics.* Oliver and Boyd Publishing Co. Pvt. Ltd., Edinburgh. 312-324.
- Hemalatha, K and Lal G.M. 2021. Genetic association and path coefficient analysis for seed yield characters of chickpea (*Cicer arietinum* L.). *International Journal of Agriculture Sciences.* 13(8): 10837-10839.
- Karthikeyan, M., Pandey, S., Synrem, G., Sharma, P and Singh, V. 2022. Genetic variability and correlation studies for some quantitative traits in chickpea (*Cicer arietinum* L.). *Pharma Innovation* 11(1):1706-1709.
- Kaur, J and Bhardwaj, N. 2019. Correlation studies for yield and its components in chickpea under low input conditions. *Himachal Journal of Agricultural Research.* 45 (2): 15-19.
- Khan, R., Farhatullah and Khan, H. 2011. Dissection of genetic variability and heritability estimates of chickpea germplasm for various morphological markers and quantitative traits. *Sarhad Journal of Agriculture.* 27 (1): 67-72.
- Mohan, S and Thiyagarajan, K. 2019. Genetic variability, correlation and path coefficient analysis in chickpea (*Cicer arietinum* L.) for yield and its component traits. *International Journal of Current Microbiology and Applied Sciences.* 8(5): 1801–1808.
- Mukesh, K., Kushwaha, S., Dwivedi, V.K and Dhaka, S.S. 2016. Genetic variability and correlation analysis of various traits in chickpea genotypes (*Cicer arietinum* L.) under rainfed condition in western Uttar Pradesh. *International Journal of Advanced Engineering Research and Science.* 3(9): 150–156.
- Pattanayak, S., Lal, G.M., Priyanka, V and Tripathi, A. 2021. To assess the character association and path analysis in chickpea (*Cicer arietinum* L.) germplasm lines grown

under late sown condition. *International Journal of Plant and Soil Science*, 33 (16): 108–114.

- Raju, A.C and Lal, G.M. 2021. Correlation and path coefficient analysis for quantitative traits in chickpea (*Cicer arietinum* L.). *International Journal of Botany and Research*. 11 (2): 15–22.
- Rathod, V. L., Toprope, V.N and Godade, L. P. 2020. Assessment of genetic variability, character association and path analysis in F₂ aegregating population for quantitative traits in chickpea. *International Journal of Current Microbiology and Applied Sciences*. 9 (8): 2485-248
- Saxena, A. K., Sharma, S., Sandhu, J. S., Gupta, S. K. and Kaur. J. 2013. Variability and correlation studies for nutritional and cooking quality traits in chickpea (*Cicer arietinum* L.) *Indian Journal of Genetics*.73(1): 51-56.
- Singh, P.K, Shrivastava, N., Sharma, B and Bhagyawant, S.S. 2015. Effect of domestic processes on chickpea seeds for antinutritional contents and their divergence. *American Journal of Food Science and Technology*. 3 (4): 111-117.
- Singh, R.K and Chaudhary, B.D. 1977. *Biometrical Methods in Quantitative Genetic Analysis*. Kalyani Publishers, New Delhi. 215-218.
- Srivastava, S., Roopa Lavanya, G and Lal, G.M. 2017. Genetic variability and character association for seed yield in chickpea (*Cicer arietinum* L.). *Journal of Pharmacognosy and Phytochemistry*. 6(4): 748-750.
- Thakur, N.R., Toprope, V.N and Sai Phanindra, K. 2018. Estimation of genetic variability, correlation and path analysis for yield and yield contributing traits in chickpea (*Cicer arietinum* L.). *International Journal of Current Microbiology and Applied Sciences*. 7(2): 2298–2304.
- Xalxo, B., Lal, G.M., Debnath, S and Tripathi, A.M. 2021. Determination of Genetic Association of Yield and Quality Traits in (*Cicer arietinum* L.) chickpea. *Journal of Experimental Agriculture International*: 43(5): 75–83.

Table 1.1. Analysis of variance for 19 morphological and biochemical characters studied in 64 genotypes of chickpea (*Cicer arietinum* L.)

Source of Variation	DF	DFE	D50% F	DTM	PH (cm)	NPBP P	NSBPP	NPPP	NSPP	TNSPP	BY (g)	HI (%)	100SW (g)	PC (mg/g)	TFAA (mg/g)	PA (mg/g)	TA (mg/g)	TPC (mg/g)	TFC (mg/g)	SYPP (g)
Mean Sum of Squares																				
Replication	1	2.531	2.258	13.133	5.896	0.016	3.125	0.432	0.020	0.547	1.580	3.082	2.432	0.007	0.188	0.001	0.080	0.004	0.004	7161.801
Treatment	63	29.170**	24.656**	71.868**	123.483**	0.387**	7.928**	931.708**	0.064**	2030.015**	151.520**	146.093**	138.872**	3.664**	10.190**	2.296**	4.521**	0.093**	0.059**	42104.030**
Block adj	14	3.013	2.660	2.508	2.794	0.066*	0.871	20.960	0.009	21.510	0.577	2.669	1.136**	1.493**	0.148	0.334	0.037	0.001	0.001	4490.767
Intra Block Error	49	3.638	3.429	3.577	2.376	0.040	1.044	13.453	0.009	16.781	0.463	2.004	0.699	0.802	0.179	0.246	0.040	0.002	0.001	4634.224
Total	127	38.353	33.002	91.085	134.549	0.508	12.969	966.554	0.102	2068.852	154.140	153.847	143.139	5.959	10.705	2.876	4.678	0.096	0.064	58390.820

** Significant at 1%; * significant at 5%

DFE- Days to first flowering, D50%F- Days to 50% flowering, DTM- Days to maturity, PH- Plant height (cm), NPBP-Number of primary branches per plant, NSBPP- Number of secondary branches per plant, NPPP- Number of pods per plant, NSPP- Number of seeds per pod, TNSPP- Total number of seeds per plant, BY- Biological yield (g), HI- Harvest index (%), 100 SW- 100 Seed weight (g), PC- Protein content (%), TFAA- Total free amino acid (mg/g), PA- Phytic acid (mg/g), TA- Tannic acid (mg/g), TPC- Total phenolic content (mg/g), TFC- Total flavonoid content (mg/g), SYPP- Seed yield per plot (g).

Table 1.2. Estimates of genetic parameters for seed yield and biochemical characters in chickpea (*Cicer arietinum* L.)

S. No.	Character	Mean	Range		Coefficient of Variation		Heritability (Broad Sense) (%)	Genetic Advance as % of Mean
			Minimum	Maximum	PCV (%)	GCV (%)		
1.	Days to first flowering	43.72	37.00	55.00	9.27	8.17	77.66	14.82
2.	Days to 50% flowering	48.05	43.00	58.50	7.79	6.79	76.04	12.20
3.	Days to maturity	89.68	51.50	98.00	6.85	6.53	90.88	12.83
4.	Plant height (cm)	49.97	37.36	67.41	15.84	15.53	96.06	31.35
5.	Number of Primary Branches per Plant	3.45	2.57	4.32	13.55	12.04	78.97	22.05
6.	Number of Secondary Branches per plant	12.04	7.50	16.45	17.51	15.41	77.42	27.93
7.	Number of Pods per Plant	55.12	18.96	117.68	39.50	38.85	96.75	78.72
8.	Number of Seeds per Pod	1.13	1.00	1.70	16.90	14.63	74.94	26.08
9.	Total number of Seeds per Plant	63.91	18.96	185.02	50.09	49.65	98.23	101.36
10.	Biological yield (g)	24.54	9.62	52.62	35.41	35.29	99.33	72.46
11.	Harvest Index (%)	44.17	30.97	65.60	19.89	19.66	97.67	40.02
12.	100 Seed weight (g)	27.15	8.95	45.59	30.85	30.66	98.81	62.79
13.	Protein Content (%)	19.00	15.89	24.45	8.01	6.08	57.67	9.52
14.	Total Free Amino Acid (mg/g)	9.09	4.79	13.80	24.88	24.43	96.43	49.43
15.	Phytic acid (mg/g)	14.28	11.55	16.97	7.94	7.06	79.20	12.95
16.	Tannic acid (mg/g)	4.12	1.44	9.79	36.47	36.14	98.20	73.77
17.	Total Phenolic Content (mg/g)	1.07	0.98	1.43	21.25	20.90	96.72	42.34
18.	Total Flavonoid Content (mg/g)	0.71	0.42	1.02	24.19	23.78	96.66	48.17
19.	Seed Yield per plot (g)	510.32	142.50	892.50	29.92	26.70	79.65	49.09

PCV-Phenotypic Coefficient of Variation ; GCV-Genotypic Coefficient of Variation

Table 1.3. Correlation coefficients for seed yield and yield contributing characters in 64 genotypes of chickpea (*Cicer arietinum* L.)

		DFE	D50%F	DTM	PH (cm)	NPBPP	NSBPP	NPPP	NSPP	TNSPP	BY(g)	HI (%)	100 SW (g)	PC (mg/g)	TFAA (mg/g)	PA (mg/g)	TA (mg/g)	TPC (mg/g)	TFC (mg/g)	SYPP(g)
DFE	G	1.0000	0.9634 **	0.5653 **	0.4965 **	0.0585	0.1355	0.0959	0.0809	0.1093	0.2817 *	-0.0632	0.2796 *	0.0053	0.0540	0.0540	0.0591	-0.0298	0.0968	0.4070 **
	P	1.0000	0.9144 **	0.5437 **	0.4177 **	0.0476	0.085	0.0632	0.0678	0.0823	0.2412 **	-0.0516	0.2397 **	-0.0680	0.0403	0.0330	0.0577	-0.0185	0.0731	0.2743 **
D50%F	G		1.0000	0.4919 **	0.4786 **	0.0211	0.2198	0.1405	0.0237	0.1290	0.2689 *	0.0256	0.1862	-0.0548	0.1095	0.0866	0.0602	-0.0519	0.0893	0.3487 **
	P		1.0000	0.505 **	0.391 **	0.0063	0.1131	0.0924	0.0328	0.0969	0.2312 **	0.0180	0.1569	-0.0784	0.0877	0.0620	0.0551	-0.0333	0.0798	0.2302 **
DTM	G			1.0000	0.0830	-0.0531	-0.0477	0.1489	0.1964	0.1839	0.2099	-0.0788	0.1497	0.0316	0.0695	0.1733	0.1226	-0.0274	0.0266	0.3066 **
	P			1.0000	0.0727	-0.0343	-0.051	0.1225	0.1616	0.1648	0.1967 *	-0.0767	0.1388	0.0103	0.0569	0.1508	0.1088	-0.0242	0.0269	0.246 **
PH	G				1.0000	0.1019	0.3771 **	0.1599	0.0872	0.1570	0.3243 **	-0.2075	0.4084 **	-0.1544	0.2268	0.0680	-0.1788	-0.1073	0.2079	0.4291 **
	P				1.0000	0.1019	0.3197 **	0.1509	0.0535	0.1551	0.3190 **	-0.2005 *	0.3933 **	-0.1152	0.2093 *	0.0714	-0.1766 *	-0.1020	0.2002 *	0.3833 **
NPBPP	G					1.0000	0.0036	-0.1223	0.1400	-0.0674	0.1884	-0.1718	0.0621	-0.0319	0.2588 *	-0.1204	-0.2562 *	0.1196	0.2290	0.0440
	P					1.0000	-0.0331	-0.1118	0.1109	-0.0623	0.1676	-0.1435	0.0611	-0.0369	0.2199 *	-0.0566	-0.2224 *	0.0841	0.2017 *	0.0530
NSBPP	G						1.0000	0.3803 **	0.1782	0.3735 **	0.2362	0.0016	0.0901	0.1625	0.248 *	-0.1304	-0.2139	-0.1309	0.4134 **	0.3206 **
	P						1.0000	0.3416 **	0.1126	0.3338 **	0.215 *	-0.0107	0.0706	0.1578	0.198 *	-0.1445	-0.1967 *	-0.1055	0.3403 **	0.2929 **
NPPP	G							1.0000	0.3102 *	0.9345 **	0.1525	0.1922	-0.1374	-0.1341	0.0857	-0.0061	0.0182	-0.1211	0.0440	0.4725 **
	P							1.0000	0.2804 **	0.9194 **	0.1507	0.1886 *	-0.1307	-0.0903	0.0781	-0.0180	0.0193	-0.1207	0.0483	0.4212 **
NSPP	G								1.0000	0.6321 **	0.0701	0.2769 *	-0.0648	-0.2120	0.0625	0.0431	0.1244	-0.1304	0.0149	0.2812 *
	P								1.0000	0.5801 **	-0.0631	0.2286 **	-0.0488	-0.1652	0.0520	0.0556	0.1078	-0.1089	0.0316	0.1644
TNSPP	G									1.0000	0.1434	0.2491 *	-0.1369	-0.1787	0.0860	0.0478	0.0895	-0.1391	0.0877	0.4789 **
	P									1.0000	0.1431	0.2434 **	-0.1327	-0.1245	0.0804	0.0344	0.0928	-0.1307	0.0838	0.4125 **
BY	G										1.0000	-0.2423	0.3121 *	0.1320	0.1547	-0.0908	-0.2078	-0.0341	0.1689	0.3518 **
	P										1.0000	-0.2485	0.3078 **	0.1016	0.1516	-0.0795	-0.2051 *	-0.0353	0.1657	0.3116 **
HI	G											1.0000	-0.2633 *	0.0348	-0.0499	0.048	0.2866 *	-0.0478	-0.1635	-0.0735
	P											1.0000	-0.2562 **	0.0265	-0.0504	0.0505	0.2809 **	-0.0468	-0.1568	-0.0665
HSW	G												1.0000	0.1887	0.0200	0.2422	-0.3298 **	0.0010	0.2053	0.1609
	P												1.0000	0.1469	0.0196	0.2050 *	-0.3205 **	-0.0003	0.2018 *	0.1483
PC	G													1.0000	-0.0692	0.1130	0.1092	0.1041	0.2358	-0.036
	P													1.0000	-0.0865	0.0174	0.0856	0.0723	0.2081 *	0.0696
TFAA	G														1.0000	-0.1698	-0.0637	0.0181	0.0611	0.0214
	P														1.0000	-0.1364	-0.0649	0.0170	0.0526	0.0141
PA	G															1.0000	0.1248	0.0096	0.2109	0.0617
	P															1.0000	0.0951	0.0090	0.2072 *	0.0241
TA	G																1.0000	0.0530	-0.225	-0.0186
	P																1.0000	0.0503	-0.2203 *	-0.0295
TPC	G																	1.0000	0.0112	-0.0374
	P																	1.0000	0.0058	-0.0433
TFC	G																		1.0000	0.0368
	P																		1.0000	0.0421

		DFD	D50%F	DTM	PH (cm)	NPBPP	NSBPP	NPPP	NSPP	TNSPP	BY(g)	HI (%)	100 SW (g)	PC (mg/g)	TFAA (mg/g)	PA (mg/g)	TA (mg/g)	TPC (mg/g)	TFC (mg/g)	SYPP(g)	
SYPP	G																				1.0000
	P																				

* significant at 5% level, ** significant at 1% level

DFD- Days to first flowering, D50%F- Days to 50% flowering, DTM- Days to maturity, PH- Plant height (cm), NPBPP-Number of primary branches per plant, NSBPP- Number of secondary branches per plant, NPPP- Number of pods per plant, NSPP- Number of seeds per pod, TNSPP- Total number of seeds per plant, BY- Biological yield (g), HI- Harvest index (%), 100 SW- 100 Seed weight (g), PC- Protein content (%), TFAA- Total free amino acid (mg/g), PA- Phytic acid (mg/g), TA- Tannic acid (mg/g), TPC- Total phenolic content (mg/g), TFC- Total flavonoid content (mg/g), SYPP- Seed yield per plot (g).

UNDER PEER REVIEW

Table 1.4. Direct and indirect effects of different traits on seed yield in 64 genotypes of chickpea (*Cicer arietinum* L.)

		DFE	D50%F	DTM	PH (cm)	NPBPP	NSBPP	NPPP	NSPP	TNSPP	BY(g)	HI (%)	100 SW (g)	PC (mg/g)	TFAA (mg/g)	PA (mg/g)	TA (mg/g)	TPC (mg/g)	TFC (mg/g)	SYPP(g)
DFE	G	0.8825	-2.1682	-0.0359	0.2223	0.2034	0.2692	0.2813	0.2056	-0.0707	0.2785	-0.0061	-0.0528	-0.0013	-0.0004	0.2200	0.2023	-0.0012	-0.0216	0.4070**
	P	0.1673	-0.1402	0.0823	0.1170	0.0049	0.0118	0.0129	-0.0020	0.0142	0.0272	0.0029	-0.0005	-0.0085	-0.0048	0.0011	0.0009	-0.0006	-0.0115	0.2743**
D50%F	G	2.3917	-2.2506	-0.0312	0.0215	0.0012	0.1122	0.1190	0.0017	-0.0835	0.0750	0.0025	-0.0352	0.0129	-0.0008	0.0321	0.0023	-0.0021	-0.0199	0.3487**
	P	0.1530	-0.1533	0.0765	0.1096	0.0007	0.0156	0.0188	-0.0010	0.0167	0.0260	-0.0010	-0.0004	-0.0098	-0.0105	0.0021	0.0009	-0.0010	-0.0127	0.2302**
DTM	G	1.4033	-1.1070	-0.0635	0.0037	-0.0031	-0.0244	0.1261	0.0137	-0.1190	0.0585	-0.0075	-0.0283	-0.0074	-0.0005	0.0643	0.0047	-0.0011	-0.0059	0.3066*
	P	0.0910	-0.0774	0.1514	0.0204	-0.0035	-0.0070	0.0250	-0.0047	0.0284	0.0221	0.0043	-0.0003	0.0013	-0.0068	0.0052	0.0017	-0.0008	-0.0042	0.2460**
PH	G	1.2325	-1.0770	-0.0053	0.0449	0.0058	0.1926	0.1355	0.0061	-0.1016	0.0904	-0.0199	-0.0772	0.0362	-0.0017	0.0252	-0.0069	-0.0043	-0.0463	0.4291**
	P	0.0699	-0.0600	0.0110	0.2801	0.0104	0.0442	0.0308	-0.0016	0.0267	0.0359	0.0113	-0.0009	-0.0144	-0.0251	0.0025	-0.0028	-0.0032	-0.0316	0.3833**
NPBPP	G	0.1453	-0.0474	0.0034	0.0046	0.0573	0.0018	-0.1036	0.0098	0.0436	0.0525	-0.0164	-0.0117	0.0075	-0.0019	-0.0446	-0.0099	0.0048	-0.0510	0.0440
	P	0.0080	-0.0011	-0.0052	0.0285	0.1024	-0.0045	-0.0228	-0.0033	-0.0107	0.0189	0.0081	-0.0001	-0.0048	-0.0263	-0.0020	-0.0035	0.0025	-0.0312	0.0530
NSBPP	G	0.3363	-0.4946	0.0030	0.0169	0.0002	0.5107	0.3222	0.0124	-0.2417	0.0658	0.0002	-0.0170	-0.0381	-0.0018	-0.0483	-0.0082	-0.0053	-0.0921	0.3206**
	P	0.0142	-0.0173	-0.0077	0.0896	-0.0033	0.1380	0.0696	-0.0033	0.0575	0.0242	0.0006	-0.0002	0.0197	-0.0237	-0.0050	-0.0031	-0.0033	-0.0537	0.2929**
NPPP	G	0.2382	-0.3162	-0.0094	0.0072	-0.0070	0.1942	0.8473	0.0216	-0.6048	0.0425	0.0184	0.0260	0.0315	-0.0006	-0.0023	0.0007	-0.0049	-0.0098	0.4725**
	P	0.0106	-0.0142	0.0185	0.0423	-0.0114	0.0472	0.2039	-0.0082	0.1583	0.0170	-0.0106	0.0003	-0.0113	-0.0094	-0.0006	0.0003	-0.0038	-0.0076	0.4212**
NSPP	G	0.2008	-0.0534	-0.0125	0.0039	0.0080	0.0910	0.2628	0.0697	-0.4091	0.0195	0.0265	0.0123	0.0497	-0.0005	0.0160	0.0048	-0.0053	-0.0033	0.2812*
	P	0.0114	-0.0051	0.0244	0.0150	0.0114	0.0157	0.0572	-0.0286	0.0999	0.0071	-0.0129	0.0001	-0.0206	-0.0064	0.0019	0.0017	-0.0030	-0.0048	0.1644
TNSPP	G	0.2713	-0.2904	-0.0117	0.0071	-0.0039	0.1908	0.7918	0.0441	-0.6472	0.0400	0.0238	0.0259	0.0419	-0.0006	0.0177	0.0035	-0.0056	-0.0195	0.4789**
	P	0.0138	-0.0149	0.0249	0.0434	-0.0064	0.0461	0.1874	-0.0169	0.1722	0.0161	-0.0137	0.0003	-0.0156	-0.0096	0.0012	0.0015	-0.0041	-0.0132	0.4125**
BY	G	0.6993	-0.6052	-0.0133	0.0146	0.0108	0.1206	0.1292	0.0049	-0.0928	0.2787	-0.0232	-0.0590	-0.0310	-0.0011	-0.0337	-0.0080	-0.0014	-0.0376	0.3518**
	P	0.0404	-0.0354	0.0298	0.0894	0.0171	0.0297	0.0307	-0.0018	0.0246	0.1126	0.0140	-0.0007	0.0127	-0.0182	-0.0028	-0.0032	-0.0011	-0.0262	0.3116**
HI	G	-0.1569	-0.0577	0.0050	-0.0093	-0.0099	0.0008	0.1629	0.0193	-0.1612	-0.0675	0.0957	0.0498	-0.0082	0.0004	0.0178	0.0110	-0.0019	0.0364	-0.0735
	P	-0.0086	-0.0028	-0.0116	-0.0562	-0.0147	-0.0015	0.0385	-0.0067	0.0419	-0.0280	-0.0564	0.0006	0.0033	0.0060	0.0018	0.0044	-0.0015	0.0248	-0.0665

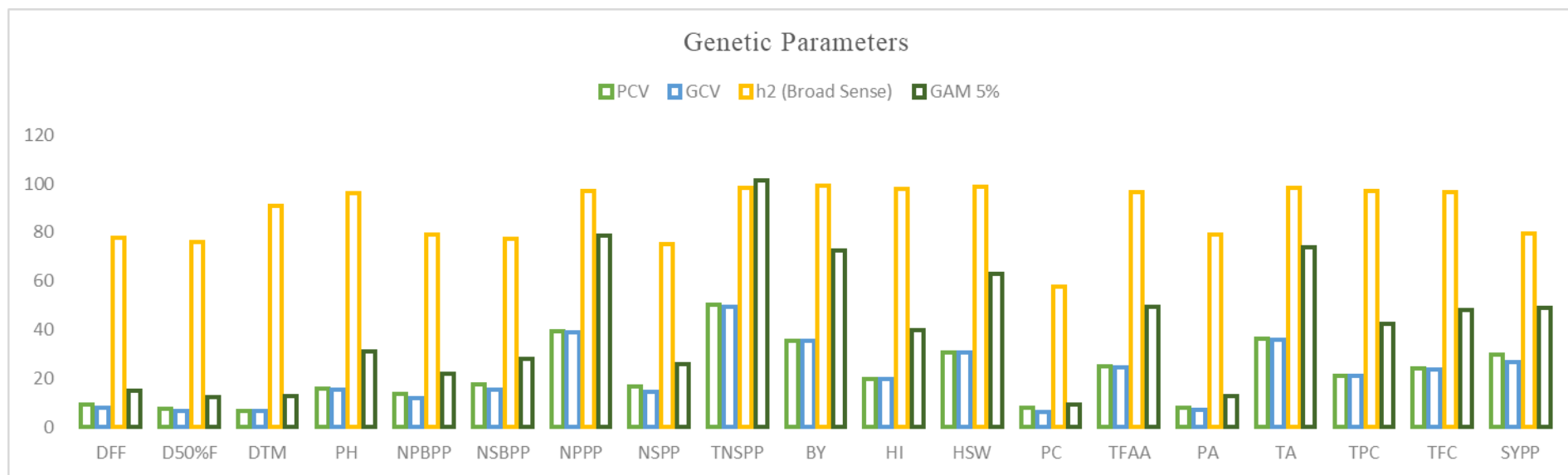
		DFE	D50%F	DTM	PH (cm)	NPBPP	NSBPP	NPPP	NSPP	TNSPP	BY(g)	HI (%)	100 SW (g)	PC (mg/g)	TFAA (mg/g)	PA (mg/g)	TA (mg/g)	TPC (mg/g)	TFC (mg/g)	SYPP(g)
HSW	G	0.6940	-0.4190	-0.0095	0.0183	0.0036	0.0460	-0.1164	-0.0045	0.0886	0.0870	-0.0252	-0.1890	-0.0443	-0.0002	0.0898	-0.0127	0.0000	-0.0457	0.1609
	P	0.0401	-0.0241	0.0210	0.1102	0.0062	0.0098	-0.0266	0.0014	-0.0229	0.0347	0.0144	-0.0022	0.0184	-0.0023	0.0071	-0.0050	0.0000	-0.0318	0.1483
PC	G	0.0132	0.1232	-0.0020	-0.0069	-0.0018	0.0830	-0.1136	-0.0148	0.1157	0.0368	0.0033	-0.0357	-0.2346	0.0005	0.0419	0.0042	0.0042	-0.0525	-0.0360
	P	-0.0114	0.0120	0.0016	-0.0323	-0.0039	0.0218	-0.0184	0.0048	-0.0214	0.0114	-0.0015	-0.0003	0.1250	0.0104	0.0006	0.0013	0.0023	-0.0324	0.0696
TFAA	G	0.1340	-0.2463	-0.0044	0.0102	0.0148	0.1267	0.0726	0.0044	-0.0557	0.0431	-0.0048	-0.0038	0.0162	-0.0073	-0.0630	-0.0025	0.0007	-0.0136	0.0214
	P	0.0068	-0.0134	0.0086	0.0586	0.0224	0.0273	0.0159	-0.0016	0.0138	0.0171	0.0028	0.0000	-0.0108	-0.1198	-0.0047	-0.0010	0.0006	-0.0085	0.0141
PA	G	0.1340	-0.1949	-0.0110	0.0031	-0.0069	-0.0666	-0.0052	0.0030	-0.0310	-0.0253	0.0046	-0.0458	-0.0265	0.0012	0.3708	0.0048	0.0004	-0.0470	0.0618
	P	0.0055	-0.0095	0.0228	0.0200	-0.0058	-0.0200	-0.0037	-0.0016	0.0059	-0.0090	-0.0029	-0.0005	0.0022	0.0164	0.0346	0.0015	0.0003	-0.0322	0.0241
TA	G	0.1466	-0.1354	-0.0078	-0.0080	-0.0147	-0.1092	0.0155	0.0087	-0.0580	-0.0579	0.0274	0.0623	-0.0256	0.0005	0.0463	0.0385	0.0021	0.0501	-0.0186
	P	0.0097	-0.0084	0.0165	-0.0495	-0.0227	-0.0271	0.0039	-0.0031	0.0160	-0.0231	-0.0158	0.0007	0.0107	0.0078	0.0033	0.0157	0.0015	0.0346	-0.0295
TPC	G	-0.0739	0.1167	0.0017	-0.0048	0.0069	-0.0668	-0.1026	-0.0091	0.0900	-0.0095	-0.0046	-0.0002	-0.0244	-0.0001	0.0035	0.0020	0.0403	-0.0025	-0.0374
	P	-0.0031	0.0051	-0.0036	-0.0285	0.0081	-0.0145	-0.0247	0.0028	-0.0225	-0.0040	0.0026	0.0000	0.0091	-0.0022	0.0003	0.0008	0.0310	0.0000	-0.0433
TFC	G	0.2404	-0.2011	-0.0017	0.0093	0.0131	0.2111	0.0373	0.0010	-0.0568	0.0471	-0.0157	-0.0388	-0.0553	-0.0004	0.0782	-0.0087	0.0005	-0.2228	0.0368
	P	0.0122	-0.0123	0.0040	0.0561	0.0202	0.0469	0.0099	-0.0009	0.0144	0.0187	0.0089	-0.0005	0.0257	-0.0064	0.0071	-0.0034	0.0000	-0.1583	0.0421

Diagonal effects-Direct effects, off-diagonal values-indirect values

* Significant at 5% level, ** significant at 1% level

Residual effect P=0.609; G=0.417

DFE- Days to first flowering, D50%F- Days to 50% flowering, DTM- Days to maturity, PH- Plant height (cm), NPBPP-Number of primary branches per plant, NSBPP- Number of secondary branches per plant, NPPP- Number of pods per plant, NSPP- Number of seeds per pod, TNSPP- Total number of seeds per plant, BY- Biological yield (g), HI- Harvest index (%), 100 SW- 100 Seed weight (g), PC- Protein content (%), TFAA- Total free amino acid (mg/g), PA- Phytic acid (mg/g), TA- Tannic acid (mg/g), TPC- Total phenolic content (mg/g), TFC- Total flavonoid content (mg/g), SYPP- Seed yield per plot (g).



DFF- Days to first flowering, D50%F- Days to 50% flowering, DTM- Days to maturity, PH- Plant height (cm), NPBPP-Number of primary branches per plant, NSBPP- Number of secondary branches per plant, NPPP- Number of pods per plant, NSPP- Number of seeds per pod, TNSPP- Total number of seeds per plant, BY- Biological yield (g), HI- Harvest index (%), 100 SW- 100 Seed weight (g), PC- Protein content (%), TFAA- Total free amino acid (mg/g), PA- Phytic acid (mg/g), TA- Tannic acid (mg/g), TPC- Total phenolic content (mg/g), TFC- Total flavonoid content (mg/g), SYPP- Seed yield per plot (g).

Fig. 1.1. Pattern of GCV, PCV, Genetic advance as percent of mean and heritability for various traits in chickpea (*Cicer arietinum* L.)