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Variability and Character Association Studies in Chickpea (*Cicer arietinum*. L)

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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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 were 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,

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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.

Keywords: Chickpea; correlation; GCV (Genotypic Coefficient of Variation); genetic advance as per cent mean; heritability and path coefficient analysis.

1. 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 [1]. Chickpea is a good source of carbohydrates (52.4-70.9%), proteins (17-26%), fats (3.8-10.2%) and essential minerals (Ca, Fe) [2]. 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 [3].

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.

2. MATERIALS 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, Farm is located at an altitude of 5.49 metres above the mean sea level, 15^{o} 54' latitude and 80^{o} 25' longitude and about 8 km away from the Bay of Bengal in the Krishna Agro Climatic Zone of Andhra Pradesh, India, 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 [4], correlation and path analysis as suggested by Falconer [5], Dewey and Lu [6].

3. RESULTS AND DISCUSSION

ANOVA indicated the presence of ample variation among the selected genotypes for the traits under study was presented in Table 1. Table 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., [7], Srivastava et al., [8] and Mohammed et al., [9].

High PCV, GCV estimates were observed for total number of seeds per plant (50.09 and 49.65), number of pods per plant (39.50 and 38.85), biological yield (35.41 and 35.29), 100 seed weight (30.85 and 30.66), total free amino acid (mg/g) (24.88 and 24.43), tannic acid (36.47 and 36.14), total phenolic content (mg/g) (21.25 and 20.90), total flavonoid content (mg/g) (24.19 and 23.78) and seed yield (29.92 and 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 and 6.53), days to 50% flowering (7.79 and 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. [10], Mohan and Thiyagarajan [11], Brindaban et al. [12], Akanksha et al. [13], Anusha et al. [14] and Mukesh et al. [15].

High heritability accompanied high genetic advance as per cent mean was observed for biological yield (99.33 and 72.46), total number of seeds per plant (98.23 and 101.36), plant height (96.06 and 31.35), number of pods per plant (96.75 and 78.72), harvest index (%) (97.67 and 40.02), 100 seed weight (98.81 and 62.79), total free amino acid (mg/g) (96.43 and 49.473), tannic acid (mg/g) (98.20 and 73.79), total phenolic content (mg/g) (96.72 and 42.34), total flavonoid content (mg/g) (96.66 and 48.17), seed yield per plot (g) (79.65 and 49.09), number of primary branches per plant (78.97 and 22.05), number of secondary branches per plant (77.42 and 27.93) and number of seeds per pod (74.94 and 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 [7], Hemalatha and Lal [16], Karthikeyan et al. [17], Brindaban et al. [12], Bhanu et al. [18] and Xalxo et al. [19].

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*. [18], Amare et al. [20], Raju and Lal [7], Pattanayak et al. [21] and Karthikeyan et al. [18].

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

Table 1. Analysis of variance for 19 morphological and biochemical characters studied in 64 genotypes of chickpea (*Cicer arietinum* L.)

Source of Variation	DF	DFF	D50%F	DTM	PH (cm)	NPBPP	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
Treatmentsu adj	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% 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)*

Table 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 3. Correlation coefficients for seed yield and yield contributing characters in 64 genotypes of chickpea (*Cicer arietinum* L.)

		FF	50%F	TM	PH (cm)	PBPP	SBPP	PPP	SPP	NSPP	Y(g)	HI (%)	100 SW (g)	PC (mg/g)	FAA (mg/g)	PA (mg/g)	TA (mg/g)	PC (mg/g)	FC (mg/g)	YPP(g)
DFF	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														1.000	-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

		FF	50%F	TM	PH (cm)	PBPP	SBPP	PPP	SPP	NSPP	Y(g)	HI (%)	100 SW (g)	PC (mg/g)	FAA (mg/g)	PA (mg/g)	TA (mg/g)	PC (mg/g)	FC (mg/g)	YPP(g)
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
SYPP	G																			1.0000
	P																			1.0000

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

Table 4. Direct and indirect effects of different traits on seed yield in 64 genotypes of chickpea (*Cicer arietinum* L.)

		DFF	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)
DFF	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**

		DFF	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)
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
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 Residualeffect P=0.609; G=0.417 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)*

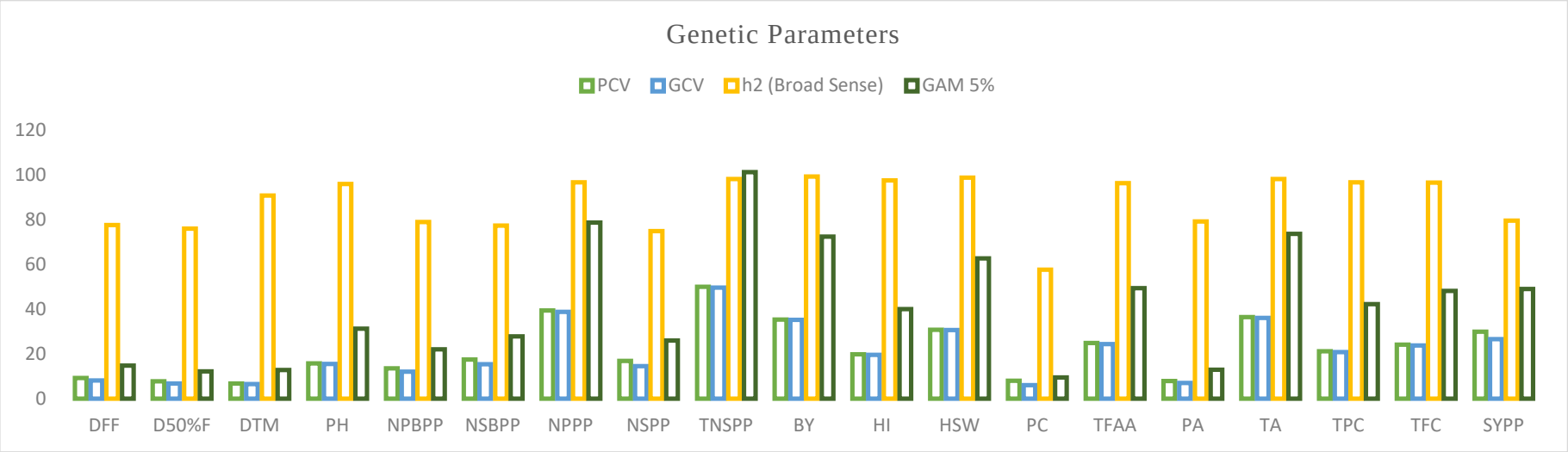

Fig. 1. Pattern of GCV, PCV, Genetic advance as percent of mean and heritability for various traits in chickpea (*Cicer arietinum* L.)

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)

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. [22], Mohan and Thiyagarajan [11], Dawane et al. [23], Rathod et al. [24] and Amare et al. [21].

4. 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. Whereas 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. 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.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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