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Genetic variability, character association and path coefficient analysis for seed yield and its attributing traits in chickpea (*Cicer arietinum* L.)

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Abstract
Present study was conducted to study the genetic variability, correlation and path analysis for seed yield and its attributing traits among 56 genotypes (10 parent + 45 crosses +1 check entry Radha) during rabi 2021-2022 at the Research Farm of BRD P. G. College, Deoria. The experiment was carried out using a randomized block design (RBD) with three replications. The analysis of variance (ANOVA) showed significant differences for nearly all the traits being investigated, suggesting that there is a substantial amount of variation among the different genotypes for traits such as DFF, DFP, and DTM, PHT (cm), PBP, SI, and SYP (g). The highest GCV along with a high genetic advance was observed for the trait, SHC per seed, followed by HI (%), while SHI and PP demonstrate the important role of genetics in the expression of these traits. Meanwhile, the traits SHC and SHI showed high PCV values, indicating that the environment also plays a crucial role in character expression. The highest heritability was noted for the traits SBP, followed by SYP (g), and SI (g). Furthermore, almost all traits displayed high heritability values, suggesting that selection for these traits would be beneficial for genetic enhancement through crossing. Genotypic correlation analysis revealed significant positive correlations between Days to 50% Flowering and other traits including Primary Branches per Plant, Seed Index, and Seed Hydration Index. Significant relationships were also identified between Days to 50% Podding and Seed Germination, Seed Hydration Index, and Days to Maturity. Path coefficient analysis further underscored the direct and indirect effects of various traits on seed yield, providing valuable insights for chickpea breeding programs aimed at improving productivity through indirect selection of highly heritable traits. These results offer critical information for effective selection strategies and boosting yield potential in chickpea breeding.

Keywords: Chickpea, variability, GCV, PCV, heritability, correlation, path

1. Introduction

Chickpeas is commonly known as "Bengal Grams or chickpeas", is an important food grain legume. Chickpea is main source of veg protein, carbohydrates, minerals and vitamins for vegetarians (Jukanti *et al*., 2012) [13]. Assessment of variability between characters and their relationship with yield-contributing characters play a vital role in designing an effective breeding program, especially for plants such as chickpea (Araus *et al*., 2008) [2]. The selection of appropriate parents is a key factor in breeding, and effective selection requires detailed information on the characteristics and extent of variation within a population, the connections between traits and yield, and the environmental factors affecting trait expression (Slafer, 2003) [25]. For chickpea breeding, understanding the variability through genetic component like GVC, PCV, h^2, GA and GA as per cent od mean is prerequisite for making informed decisions. Association between various yield components, such as DFF, DFP, and SYP (g), is decisive as these traits can affect chickpea productivity in different ways. Character association studies provide valuable insights into these relationships, which can guide plant breeders in improving chickpea yield by selecting highly heritable traits which are closely related with yield. Correlation and path analysis are valuable tools for revealing cause an effect relationship between yield and its components, offering breeders a deeper understanding of how traits like DFF, DFP, and Seed Hydration Capacity contribute to overall yield (Tsegaye *et al*., 2012) [27].

Path coefficient analysis, a well-established tool in agricultural breeding, enables the identification of key traits that can serve as effective selection criteria to enhance chickpea yield, as demonstrated by Dewey and Lu (1959) [9]. This comprehensive approach to variability and trait association is integral for optimizing chickpea breeding strategies and improving yield outcomes.

2. Materials and Methods

The 56 genotypes including one commercial check entry Radha (Table 1.) were grown using RBD field experimental design with 3 replications in rabi 2021-2022 at the Research Farm of BRD Post Graduate College, Deoria (Affiliated to Deen Dayal Upadhyaya Gorakhpur University, Gorakhpur (Uttar Pradesh), India.

3. Statistical Analysis

The statistical analysis for the experimental setup was carried out according to the procedure detailed by Panse and Sukhatme (1967) [19]. Genotypic variance was determined using the formula put forth by Burton and Devane (1953) [5]. The coefficients of genotypic and phenotypic variation were established based on Burton's (1952) approach, which offered an estimation of the variation within the population. Heritability in the broad sense (Hbs) was calculated using formula proposed by Burton and Devane (1953) [5]. For estimating genetic advance, the formulas proposed by Lush (1943) [17] and Johnson *et al*. (1955) [12] were utilized. The genetic advance as a percentage of the mean was computed following the method suggested by Robinson and Comstock (1949) [21]. The relationships among various traits at both genotypic and phenotypic levels were examined using the method provided by Searle *et al*. (1971) [22]. Direct and indirect effects were assessed through path coefficient analysis, as described by Wright (1921) and further refined by Dewey and Lu (1959) [9].

4. Results and Discussion

4.1 Analysis of variance

Analysis of variance for Seed yield and its contributing characters shown significant differences between treatments, parents, and hybrids for multiple traits (Table: 2). For DFF, significant differences has been recorded among treatments (94.83**) and hybrids (83.51*), while the parents showed higher significance (155.885). days to 50% podding exhibited significant differences for treatments (41.22**), parents (47.037) and hybrids (40.71**). In Days to maturity, all sources showed significant differences, with treatments (46.50**), parents (15.407), and hybrids (53.84**) (Arshad *et al.*, 2002) [3].

4.2 Genetic variability

The analysis of genetic variability in chickpea demonstrated considerable differences among traits, as exhibited by the magnitude of genotypic coefficient of variation (GCV), phenotypic coefficient of variation (PCV), heritability (h2), and genetic advance as a percentage of the mean (GAM) (Table: 3). Traits like SYP (GCV: 16. 79, PCV: 17. 53, h2 : 91. 81%, GA: 6. 62, GAM: 33. 15), total pods per plant (GCV: 16. 87, PCV: 18. 39, h2: 84. 10%, GA: 18. 32, GAM: 31. 88), SBP (GCV: 15. 98, PCV: 16. 67, h2: 91. 90%, GA: 5. 33, GAM: 31. 56), and HI (%) (GCV: 18. 94, PCV: 21. 08, h2: 80. 69%, GA: 12. 85, GAM: 35. 04) showed elevated GCV and PCV values, along with high heritability and significant genetic advance, suggesting that these traits are mainly determined by additive gene effects and have considerable potential for improvement through selection (Pravalika *et al*. , 2024) [20]. Plant height (GCV: 14. 04, PCV: 15. 15 h2: 85. 98%, GA: 15. 84, GAM: 26. 83) and seed index (GCV: 14. 93, PCV: 15. 78, h2: 89. 50%, GA: 5. 82, GAM: 29. 12) also exhibited high heritability and genetic advance, indicating their usefulness for breeding programs. In contrast, traits such as days to 50% flowering (GCV: 6. 05, PCV: 6. 83, h2: 78. 30%, GA: 9. 04, GAM: 11. 03), chlorophyll concentration (GCV: 11. 18, PCV: 13. 17, h2: 71. 90%, GA: 7. 19, GAM: 19. 53), and seed protein content (GCV: 9. 78, PCV: 10. 58, h2: 85. 30%, GA: 3. 78, GAM: 18. 60) showed moderate heritability and genetic advance, implying a balanced effect of genetic and environmental influences. Traits like seed germination (GCV: 0. 38, PCV: 4. 73, h2: 60. 00%, h2: 0. 06, GAM: 0. 06), swelling index (GCV: 3. 93, PCV: 4. 17, h2: 60. 40%, GA: 0. 08, GAM: 7. 63), and seed hydration index (GCV: 17. 67, PCV: 28. 89, h2: 72. 65%, GA: 0. 03, GAM: 6. 49) showed low GCV and heritability, indicating limited potential for direct selection due to environmental effects. Importantly, seed yield per plant, possessing high heritability (91. 81%) and genetic advance (33. 15%), emerged as a key target for improving productivity. These results imply that traits with high heritability and genetic advance are suitable for selection aimed at developing high-yielding and resilient chickpea genotypes. Similar finding has also been reported by Tripathi et al., (2012) [26], Waseem et al., (2014) [28], Kumar et al., (2020) [16] and Gul et al., 2023 [11].

4.3 Genotypic Correlation coefficient analysis

The analysis of genotypic correlation for chickpea traits uncovered several important relationships among different traits (Table: 4). DFF have positive and significant correlation with DFP (0. 920*), DTM (0. 399*), PBP (0. 364*), SI (0. 854) and SHI (0. 242), while it was negatively correlated with PG (%) (-0. 941) and SHC (-0. 993). Non-significant correlations were noted with PHT (cm) (0. 194), SBP (0. 141), TP (0. 252), Chlorophyll concentration (0. 162), SV (0. 043), and SP (0. 036). DFP (DFP) showed positive and significant correlations with DTM (0. 377*), PBP (0. 943), SBP (0. 361), PP (0. 504), SG (%) (0. 988), and SHI (0. 983), along with a negative correlation with SHI (-0. 988). DTM displayed positive significant correlations with PBP (0. 575), PP (0. 336*), SPP (0. 965), SI (0. 407), Chlorophyll concentration (0. 380*), SHI (0. 955), and SYP (0. 476), while it was negatively correlated with PG (%) (-0. 494). PHT (cm) was significantly correlated with SBP (0. 390*), PP (0. 451), SPP (0. 824), SG (%) (0. 570), Chlorophyll concentration (0. 351*), SV (0. 520), and SYP (0. 312*), and it showed non-significant correlations with PBP (0. 291), BYP (0. 216), HI (0. 259), PG (%) (0. 330*), and SP (0. 137). PBP indicated positive and significant correlations with SBP (0. 551), PP (0. 493), SPP (0. 903), SI (0. 399), SG (%) (0. 690), Chlorophyll concentration (0. 589), SV (0. 525), SHI (0. 925), and SYP (0. 497), while it had a negative significant correlation with SHC (-0. 942). SBP revealed positive and significant correlations with PP (0. 931), PP (0. 938*), SI (0. 528), SG (%) (0. 735), PG (%) (0. 921), Chlorophyll concentration (0. 675), SV (0. 734), SHI (0. 967), and SYP (0. 427), along with a significant negative correlation with SHC (-0. 979). These correlations emphasize essential chickpea genotypic traits that can support the enhancement of chickpea breeding and yield optimization strategies. Our result is in close agreement with the finding of Kumar *et al*., (2014) [15], Shafique *et al.*, (2016) [23], Kulwal *et al.,* (2017) [14], Mohan and Kalaimagal (2019) [18], Chaudhary *et al.,* (2020) [6] and Dawane *et al.*, (2020) [20].

4.4 Phenotypic Correlation coefficient analysis

Phenotypic correlation estimates of chickpea traits highlighted several significant relationships across various genotypes **(Table: 5)**. DFF exhibited positive and significant correlations with DFP (0.676**) and DTM (0.322*), while showing non-significant negative correlations with rest of traits. DFP demonstrated significant positive correlations with DTM (0.306*) and PBP (0.306*), and non-significant correlations with PHT (cm) (0.024) and SYP (-0.007). DTM showed significant positive correlations with PBP (0.425**) and SYP (0.307**). PHT (cm) was significantly correlated with SBP (0.353*) and PP (0.383**), with non-significant positive correlations to various traits, including SYP (0.273). PBP exhibited significant positive correlations with SBP (0.511**), PP (0.436**), and SYP (0.403**), with non-significant negative correlations with BYP (-0.048). SBP showed significant positive correlations with PP (0.860**), SPP (0.484**), SG (%) (0.639**), and SYP (0.637**), while exhibited non-significant correlations with rest of traits under study. These phenotypic correlations highlight key traits that could aid in chickpea breeding for improved yield and plant development (Bhavani *et al*., 2008; Gaur *et al*., 2014) [4, 10].

4.5 Genotypic Path coefficient analysis

The genotypic path estimates of chickpea traits displayed various direct and indirect effects on seed yield SYP (Table: 6). DFF displayed a negative direct effect on SYP (-0. 205) while showing positive indirect effects via traits such as PG (0. 316), SHC (0. 287), and DFP (0. 134). The indirect effects of DFF were negative through PBP (-0. 075) and SBP (-0. 029). DFP exhibited a positive direct effect (0. 110) on SYP, along with indirect positive effects mediated through SHC (0. 438), SG (%) (0. 339), and PG (%) (0. 339). Negative indirect effects of DFP were noted through SV (-0. 001) and BYP (-0. 012). DTM demonstrated a positive direct effect on SYP (0. 047), with indirect positive effects through traits such as SHC (0. 185), SG (%) (0. 008), and SP (%) (0. 022), while negative indirect effects were noted through SHI (-0. 286) and SI (-0. 069). PHT (cm) contributed a positive direct effect on SYP (0. 104) and indirect positive effects through PP (0. 047), SPP (0. 086), and SV (0. 054). Negative indirect effects were recorded via PBP (-0. 043) and SPC (-0. 008). PBP exhibited a negative direct effect on SYP (-0. 146), while showing indirect positive effects mediated through traits such as SHC (0. 039) and SYP (0. 138), accompanied by negative indirect effects through DFP (-0. 138) and total seeds per pod (-0. 132). SBP presented a negative direct effect on SYP (-0. 042), yet positive indirect effects were mediated through HI (%) (0. 712) and PP (0. 224), underscoring the intricate interaction of traits affecting chickpea seed yield (Singh and Sandhu *et. al*., 2008) [24].

4.6 Phenotypic Path coefficient analysis

The phenotypic path analysis of chickpea traits exhibited different direct and indirect influences on SYP (Table: 7). DFF had an insignificant direct impact on SYP (0. 001) and no significant negative indirect effects. Positive indirect influences of DFF were noted through traits such as DFP (0. 001), DTM (0. 000), PHT (0. 000), and SP (0. 000). DFP exhibited a negative direct effect on SYP (-0. 051), but there were positive indirect effects through SG (%) (0. 003) and Chlorophyll Concentration (0. 001), while negative indirect effects were seen for DFP (-0. 034) and SHC (-0. 003). DTM showed a direct negative effect on SYP (-0. 041), along with positive indirect effects via PHT (0. 003) and Chlorophyll Concentration (0. 003), but negative indirect influences were noted through several traits, including PBP (-0. 018) and SP (-0. 013). PHT (cm) revealed a negative direct effect on SYP (-0. 014), while positive indirect effects were facilitated through SHC (0. 354) and Chlorophyll Concentration (0. 007). Negative indirect influences were recorded via PP (-0. 006) and SP (-0. 004). PBP demonstrated a positive direct effect on SYP (0. 012), with significant positive indirect effects through SHC (1. 052) and SHI (-1. 037), although negative indirect effects were noted through SP (-0. 001) and HI (%) (0. 003). These findings highlight the intricate interconnections among chickpea traits and their role in seed yield per plant (Yadav *et al*., 2015) [30].

Table 1: List of Genotypes used in present study

S. No.	Genotypes name	Parentage	S. No.	Genotypes name	Parentage
1	ICC 1205	Advance breeding line	29	C18	GNG 1958 × BGD 209
2	GOKCE	JG 2001-4-1/KWR 108	30	C19	HC 5 × BGD 209
3	BGD-209	ICCL 84224/Annigiri 1	31	C20	IPC 71 × BGD 209
4	GNG-1958	GNG 365/SAKI 9516	32	C21	IPC 18-131 × BGD 209
5	HC-5	ICC 5435/ ICC 1205	33	C22	JG 24 × BGD 209
6	1PC-71	ICC 1205/ ICC 10945	34	C23	JG 14 × BGD 209
7	IPC 18-131	GNG 1581/ ICC 15614	35	C24	BGD 72 × BGD 209
8	JG-24	(PG5/Narsinghpur Bold)/ JG 74)	36	C25	HC 5 × GNG 1958
9	JG-14	[(GW 5/7//P327/// ICCL 83149]	37	C26	IPC 71 × GNG 1958
10	BGD-72	[(BG 256/ E100YM)/BG 256]	38	C27	IPC 18-131 × GNG 1958
11	Radha (Check)		39	C28	JG 24 × GNG 1958
12	C1	ICC 1205 × GOKCE	40	C29	JG 14 × GNG 1958
13	C2	BGD 209 × GOKCE	41	C30	BGD 72 × GNG 1958
14	C3	GNG 1958 × GOKCE	42	C31	IPC 71 × HC 5
15	C4	HC 5 × GOKCE	43	C32	IPC 18-131 × HC 5
16	C5	IPC 71 × GOKCE	44	C33	JG 24 × HC 5
17	C6	IPC 18-131 × GOKCE	45	C34	JG 14 × HC 5
18	C7	JG 24 × GOKCE	46	C35	BGD 72 × HC 5
19	C8	JG 14 × GOKCE	47	C36	IPC 18-131 × IPC 71
20	C9	BGD 72 × GOKCE	48	C37	JG 24 × IPC 71
21	C10	BGD 209 × ICC 1205	49	C38	JG 14 × IPC 71
22	C11	GNG 1958 × ICC 1205	50	C39	BGD 72 × IPC 71
23	C12	HC 5 × ICC 1205	51	C40	JG 24 × IPC 18-131
24	C13	IPC 71 × ICC 1205	52	C41	JG 14 × IPC 18-131
25	C14	IPC 18-131 × ICC 1205	53	C42	BGD 72 × IPC 18-131
26	C15	JG 24 × ICC 1205	54	C43	JG 14 × JG 24
27	C16	JG 14 × ICC 1205	55	C44	BGD 72 × JG 24
28	C17	BGD 72 × ICC 1205	56	C45	BGD 72 × JG 14

Table 2: Analysis of variance for yield and its contributing characters

Characters with abbreviations	Replications	Treatments	Error
d. f.	2	55	110
Days to 50% flowering (DFF)	20.18	94.14^{**}	20.40
Days to 50% poding (DFP)	72.79	41.03^{**}	35.68
Days to maturity (DTM)	16.77	57.23^{**}	24.44
Plant height (PHT)	23.40	21.94^{**}	33.64
Primary branches per plant (PBP)	3.25	2.84^{**}	0.46
Secondary branches per plant (SBP)	40.62	23.79^{**}	1.93
Total pods per plant (PP)	39.68	35.17^{**}	53.16
Total seeds per pods (SP)	1.02	0.041^{**}	0.03
Seed Index (SI)	9.23	29.82^{**}	3.10
Biological yield /Plant (BYPP)	128.53	72.67^{**}	50.25
Harvest Index (HI)	188.98	179.28^{**}	34.62
Seed germination (SG)	27.11	59.84^{**}	59.46
Pollen Germination (PG)	180.38	65.57^{**}	9.43
Chlorophyl concentration (CC)	45.81	70.52^{**}	19.78
Seed Volume (SV)	1.71	5.42^{**}	1.55
Seed Hydration capacity per seed (SHC)	1.30	1.32^{**}	1.31
Seed Hydration index (SHI)	20.82	20.08^{**}	20.18
Swelling index (SI)	0.02	0.06^{**}	0.01
Seed protein content (SP)	0.42	13.87^{**}	2.03
Seed yield /Plant (SYP)	27.09	36.77^{**}	3.01

*, ** significant at 5 and 1 per cent probability levels, respectively

Table 3: Estimates of genetic parameters for yield and its contributing characters

Traits	Range		Mean	GCV	PCV	Heritability (bs %)	Genetic Advance	Genetic Advance (As % mean)
	Min.	Max.						
Days to 50% flowering	67.33	95.33	81.98	6.05	6.83	78.30	9.04	11.03
Days to 50% poding	86.33	103.33	95.19	1.40	3.89	63.87	0.99	9.04
Days to maturity	117.66	141.33	132.09	2.50	3.31	57.30	5.16	3.90
Plant height	39.83	78.83	59.05	14.04	15.15	85.98	15.84	26.83
Primary branches per plant	4.66	9.97	7.88	11.33	12.36	83.90	1.69	21.39
Secondary branches per plant	9.67	23.6	16.89	15.98	16.67	91.90	5.33	31.56
Total pods per plant	38.81	81.37	57.46	16.87	18.39	84.10	18.32	31.88
Total seeds per pods	1	13	1.46	3.78	9.35	16.30	0.04	3.15
Seed Index	12.97	26.13	19.98	14.93	15.78	89.50	5.82	29.12
Biological yield /Plant	46.37	66.73	55.42	4.93	8.88	30.80	3.13	5.64
Harvest Index	22.7	52.55	36.67	18.94	21.08	80.69	12.85	35.04
Seed germination	63.67	98.57	94.41	0.38	4.73	60.00	0.06	0.06
Pollen Germination	76.33	97.67	90.41	4.79	5.17	85.62	8.25	9.12
Chlorophyl concentration	26.93	52.3	36.80	11.18	13.17	71.90	7.19	19.53
Seed Volume	9.4	15	11.67	9.73	11.52	71.50	1.98	16.96
Seed Hydration capacity per seed	0.1	5.1	0.22	32.35	37.11	61.10	0.02	7.02
Seed Hydration index	0.46	20	1.00	17.67	28.89	72.65	0.03	6.49
Swelling index	1.02	1.19	1.08	3.93	4.17	60.40	0.08	7.63
Seed protein content	16.56	25.6	20.32	9.78	10.58	85.30	3.78	18.60
Seed yield /Plant	11.74	1827	52.28	16.79	17.53	91.81	6.62	33.15

Table 4: Estimates of genotypic correlation coefficients between 20 characters in Chickpea.

Traits	DFF	DFP	DTM	PHT	PBP	SBP	PP	SPP	SI	BYP	HI	SG	PG	CC	SV	SHC	HYI	SI	SP	SYP
DFF	1.000	0.920*	0.399*	0.194	0.364*	0.141	0.252	0.522**	-0.020	-0.214	-0.028	-0.941**	-0.036	0.162	0.043	0.854**	-0.993**	0.242	0.036	-0.147
DFP		1.000	0.377*	0.131	0.943**	0.361**	0.504**	0.247	0.176	-0.074	-0.095	0.988**	-0.161	0.027	0.078	0.983**	-0.988**	0.252	0.134	-0.302
DTM			1.000	0.035	0.575**	0.259	0.336*	0.965**	0.407**	-0.249	0.179	-0.494**	0.077	0.380*	0.386**	0.955**	-0.919	0.174	0.476**	-0.027
PHT				1.000	0.291	0.390*	0.451**	0.824**	0.231	0.216	0.259	0.570**	0.330*	0.351*	0.520**	0.111	-0.049	0.137	0.312*	0.330
PBP					1.000	0.551**	0.493**	0.903**	0.399**	-0.096	0.281	0.690**	0.300*	0.589**	0.525**	0.925**	-0.942**	0.134	0.497**	0.166
SBP						1.000	0.931**	0.938*	0.528**	-0.094	0.735**	0.921**	0.206	0.675**	0.734**	0.967**	-0.979**	0.298*	0.427**	0.687**
PP							1.000	0.899**	0.589**	-0.298	0.860**	0.934**	0.376*	0.878**	0.781**	0.973**	-0.974**	0.351*	0.554**	0.781**
SPP								1.000	0.689**	-0.613**	0.748**	0.927**	0.590**	0.922**	0.965**	0.908**	-0.988**	0.314*	0.939**	0.710**
SI									1.000	-0.372*	0.596**	0.948**	0.439**	0.562**	0.521**	0.956**	-0.949**	0.257	0.569**	0.464**
BYP										1.000	-0.322*	-0.937**	-0.121	-0.680**	-0.502**	-0.921**	0.932**	-0.024	-0.589**	-0.050
HI											1.000	0.903**	0.271	0.630**	0.630**	0.916**	-0.919**	0.338*	0.516**	0.945**
SG												1.000	0.947**	0.964*	0.949**	0.971**	-0.943**	0.949**	0.585**	3.967**
PG													1.000	0.394*	0.437**	0.990**	-0.902**	0.081	0.428**	0.289*
CC														1.000	0.515**	0.992**	-0.981**	0.327*	0.639**	0.439**
SV															1.000	0.922**	-0.958**	0.129	0.520**	0.527**
SHC																1.000	-0.368*	0.979**	0.966**	0.915**
HYI																	1.000	-0.928**	-0.911*	-0.978**
SI																		1.000	0.297*	0.315*
SP																			1.000	0.353*
SYP																				1.000

*, ** significant at 5 and 1 per cent probability levels, respectively

Table 5: Estimates of phenotypic correlation coefficients between 20 characters in Chickpea

Traits	DFF	DFP	DTM	PHT	PBP	SBP	PP	SPP	SI	BYP	HI	SG	PG	CC	SV	SHC	HYI	SI	SP	SYP
DFF	1.000	0.676**	0.322*	0.148	0.299	0.128	0.192	0.178	-0.041	-0.142	0.010	-0.113	-0.015	0.179	0.049	0.069	0.075	0.228	0.029	-0.115
DFP		1.000	0.306*	0.024	0.306*	0.139	0.127	-0.004	0.016	-0.159	0.046	0.033	-0.012	0.150	0.047	0.059	0.062	0.135	-0.007	-0.097
DTM			1.000	0.033	0.425**	0.208	0.236	0.148	0.279	-0.137	0.112	-0.066	0.061	0.254	0.177	0.236	0.236	0.156	0.307**	-0.050
PHT				1.000	0.246	0.353*	0.383**	0.283*	0.207	0.112	0.208	0.059	0.262	0.260	0.374*	0.046	0.038	0.120	0.273	0.289
PBP					1.000	0.511**	0.436**	0.310*	0.348*	-0.048	0.224	0.118	0.292*	0.420**	0.414**	0.136	0.135	0.143	0.403**	0.138
SBP						1.000	0.860**	0.484**	0.473**	-0.055	0.639**	0.375*	0.186	0.563**	0.600**	0.242	0.238	0.295*	0.392**	0.637**
PP							1.000	0.559**	0.506**	-0.119	0.706**	0.288	0.329*	0.660**	0.600**	0.31^{5*}	0.306*	0.307**	0.470**	0.698**
SPP								1.000	0.241	-0.169	0.301*	-0.033	0.244	0.428**	0.488**	0.368	0.363*	0.177	0.333**	0.276*
SI									1.000	-0.168	0.507**	0.140	0.358*	0.445**	0.415**	0.270	0.239	0.224	0.502**	0.428**
BYP										1.000	-0.455**	-0.064	-0.128	-0.339**	-0.277	-0.150	-0.149	-0.018	-0.287	-0.052
HI											1.000	0.288*	0.270	0.481**	0.521**	0.261	0.253	0.295*	0.443**	0.891**
SG												1.000	0.077	0.208	0.221	0.117	0.115	0.137	0.068	0.304*
PG													1.000	0.303*	0.335*	0.193	0.179	0.076	0.360**	0.274
CC														1.000	0.418*	0.113	0.104	0.311	0.516**	0.350**
SV															1.000	0.148	0.139	0.112	0.432**	0.459**
SHC																1.000	0.999**	0.173	0.211	0.226
HYI																	1.000	0.172	0.198	0.216
SI																		1.000	0.262	0.286*
SP																			1.000	0.338**
SYP																				1.000

*, ** significant at 5 and 1 per cent probability levels, respectively

Table 6: Estimates of genotypic direct and indirect effect of 19 characters on Seed Yield per Plant in chickpea.

Traits	DFF	DFP	DTM	PHT	PBP	SBP	PP	SP	SI	BYPP	HI	SG	PG	CC	SV	SHC	HYI	SI	SP	SYP
DFF	-0.205	-0.251	-0.082	-0.040	-0.075	-0.029	-0.052	-0.107	0.004	0.044	0.006	0.316	0.007	-0.033	-0.009	-0.175	0.287	-0.050	-0.008	-0.147
DFP	0.134	0.110	0.042	0.014	0.104	0.040	0.056	0.027	0.019	-0.008	-0.010	0.339	-0.018	0.003	0.009	0.438	-0.691	0.028	0.015	-0.302
DTM	0.019	0.018	0.047	0.002	0.027	0.012	0.016	0.045	0.019	-0.012	0.008	-0.023	0.004	0.018	0.018	0.185	-0.286	0.008	0.022	-0.027
PHT	0.020	0.014	0.004	0.104	0.030	0.041	0.047	0.086	0.024	0.023	0.027	0.059	0.035	0.037	0.054	0.012	-0.005	0.014	0.033	0.330
PBP	-0.053	-0.138	-0.084	-0.043	-0.146	-0.081	-0.072	-0.132	-0.058	0.014	-0.041	-0.247	-0.044	-0.086	-0.077	-0.194	0.299	-0.020	-0.073	0.166
SBP	-0.006	-0.015	-0.011	-0.016	-0.023	-0.042	-0.039	-0.052	-0.022	0.004	-0.031	-0.234	-0.009	-0.028	-0.031	-0.099	0.149	-0.012	-0.018	0.687**
PP	0.060	0.121	0.081	0.109	0.118	0.224	0.240	0.360	0.142	-0.071	0.207	0.728	0.090	0.211	0.188	0.690	-1.026	0.084	0.133	0.781**
SP	-0.049	-0.023	-0.091	-0.078	-0.085	-0.117	-0.142	-0.095	-0.065	0.058	-0.071	-0.381	-0.056	-0.125	-0.110	-0.624	0.944	-0.030	-0.089	0.710**
SI	0.003	-0.030	-0.069	-0.039	-0.068	-0.090	-0.100	-0.117	-0.170	0.063	-0.101	-0.483	-0.075	-0.096	-0.089	-0.468	0.653	-0.044	-0.097	0.464**
BYPP	-0.036	-0.012	-0.042	0.036	-0.016	-0.016	-0.050	-0.102	-0.062	0.167	-0.054	-0.690	-0.020	-0.114	-0.084	-0.504	0.773	-0.004	-0.098	-0.050
HI	-0.027	-0.092	0.174	0.250	0.272	0.712	0.832	0.724	0.577	-0.312	0.968	4.454	0.262	0.611	0.611	0.725	-4.082	0.328	0.500	0.945**
SG	-0.004	0.008	-0.001	0.002	0.005	0.015	0.008	0.011	0.008	-0.011	0.012	0.003	0.003	0.008	0.009	0.032	-0.047	0.006	0.002	3.967**
PG	-0.004	-0.018	0.009	0.037	0.034	0.023	0.042	0.066	0.049	-0.014	0.030	0.106	0.112	0.044	0.049	0.234	-0.336	0.009	0.048	0.289*
CC	0.000	0.000	0.001	0.001	0.002	0.002	0.002	0.004	0.002	-0.002	0.002	0.008	0.001	0.003	0.001	0.004	-0.005	0.001	0.002	0.439**
SV	0.000	-0.001	-0.003	-0.004	-0.004	-0.006	-0.006	-0.009	-0.004	0.004	-0.005	-0.025	-0.003	-0.004	-0.008	-0.014	0.020	-0.001	-0.004	0.527**
SHC	0.025	0.116	0.115	0.003	0.039	0.069	0.084	0.193	0.080	-0.088	0.082	0.346	0.061	0.041	0.053	0.029	-0.011	0.046	0.057	0.915**
HYI	-0.024	-0.106	-0.103	-0.001	-0.034	-0.060	-0.072	-0.168	-0.065	0.078	-0.071	-0.293	-0.051	-0.033	-0.045	-0.006	0.017	-0.041	-0.047	-0.978**
SI	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	-0.001	0.000	0.000	0.000	0.000	0.001	0.000	0.000	0.315*
SP	-0.001	-0.003	-0.011	-0.008	-0.012	-0.010	-0.013	-0.023	-0.014	0.014	-0.012	-0.014	-0.010	-0.015	-0.013	-0.047	0.067	-0.007	-0.024	0.353*

R SQUARE = 0.966 RESIDUAL EFFECT = 0.184

Table 7: Estimates of phenotypic direct and indirect effect of 19 characters on seed yield per plant in chickpea.

Traits	DFF	DFP	DTM	PHT	PBP	SBP	PP	SP	SI	BYPP	HI	SG	PG	CC	SV	SHC	HYI	SI	SP	SYP
DFF	0.001	0.001	0.001	0.000	0.003	0.004	0.002	0.000	0.001	0.001	0.001	0.000	0.001	0.000	0.001	0.001	0.001	0.001	0.002	-0.115
DFP	-0.034	-0.051	-0.016	-0.001	-0.016	-0.007	-0.006	0.000	-0.001	0.008	-0.002	-0.002	0.001	-0.008	-0.002	-0.003	-0.003	-0.007	0.000	-0.097
DTM	-0.013	-0.013	-0.041	-0.001	-0.018	-0.009	-0.010	-0.006	-0.011	0.006	-0.005	0.003	-0.003	-0.010	-0.007	-0.010	-0.010	-0.006	-0.013	-0.050
PHT	-0.002	0.000	-0.001	-0.014	-0.004	-0.005	-0.006	-0.004	-0.003	-0.002	-0.003	-0.001	-0.004	-0.004	-0.005	-0.001	-0.001	-0.002	-0.004	0.289
PBP	0.004	0.004	0.005	0.003	0.012	0.006	0.005	0.004	0.004	-0.001	0.003	0.001	0.004	0.005	0.005	0.002	0.002	0.002	0.005	0.138
SBP	0.008	0.008	0.012	0.021	0.030	0.060	0.051	0.029	0.028	-0.003	0.038	0.022	0.011	0.034	0.036	0.014	0.014	0.018	0.023	0.637**
PP	-0.014	-0.009	-0.017	-0.028	-0.032	-0.063	-0.074	-0.041	-0.037	0.009	-0.052	-0.021	-0.024	-0.049	-0.044	-0.023	-0.023	-0.023	-0.035	0.698**
SP	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.276*
SI	0.015	-0.006	-0.100	-0.074	-0.125	-0.170	-0.182	-0.087	-0.359	0.060	-0.182	-0.050	-0.129	-0.160	-0.149	-0.097	-0.086	-0.080	-0.180	0.428**
BYPP	-0.064	-0.071	-0.061	0.050	-0.021	-0.024	-0.053	-0.075	-0.075	0.447	-0.203	-0.029	-0.057	-0.152	-0.124	-0.067	-0.067	-0.008	-0.128	-0.052
HI	0.012	0.054	0.132	0.245	0.264	0.752	0.831	0.354	0.596	-0.535	0.176	0.339	0.318	0.566	0.613	0.307	0.297	0.347	0.522	0.891**
SG	0.001	0.004	0.001	0.001	0.002	-0.001	-0.001	0.000	0.001	0.001	-0.001	-0.003	0.000	-0.001	-0.001	0.0002	0.001	0.000	0.001	0.304*
PG	0.000	0.000	0.001	0.005	0.006	0.004	0.007	0.005	0.007	-0.003	0.006	0.002	0.020	0.006	0.007	0.004	0.004	0.002	0.007	0.274
CC	0.005	0.004	0.007	0.007	0.011	0.015	0.017	0.011	0.012	-0.009	0.013	0.005	0.008	0.026	0.011	0.003	0.003	0.008	0.013	0.350**
SV	0.002	0.002	0.008	0.016	0.018	0.026	0.026	0.021	0.018	-0.012	0.023	0.010	0.015	0.018	0.044	0.007	0.006	0.005	0.019	0.459**
SHC	0.538	0.454	0.830	0.354	0.052	0.878	0.449	0.853	0.090	-0.167	0.024	0.906	0.495	0.877	0.151	0.756	0.750	0.339	0.637	0.226
HYI	-0.575	-0.476	-0.807	-0.291	-0.037	-0.822	-2.355	-0.786	-0.836	0.144	-0.939	-0.881	-0.376	-0.796	-0.068	-0.665	-0.671	-0.320	-0.515	0.216
SI	0.004	0.002	0.003	0.002	0.003	0.005	0.005	0.003	0.004	0.000	0.005	0.002	0.001	0.005	0.002	0.003	0.003	0.018	0.005	0.286*
SP	-0.001	0.000	-0.005	-0.005	-0.007	-0.007	-0.008	-0.006	-0.009	0.005	-0.008	-0.001	-0.006	-0.009	-0.008	-0.004	-0.004	-0.005	-0.018	0.338**

R SQUARE = 0.988 RESIDUAL EFFECT = 0.109

5. Conclusion

Analysis of variance (ANOVA) of chickpea seed yield and attributing traits indicating significant differences among treatments for various characters, such as DFF, Days to DFP, and DTM, with parents showing higher significance for DFF. Few traits such as SHC, HI (%), SHI, PP and SBP exhibited moderate to high GVC value reveals that genetics is playing vital role in the reflecting these characters. Similarly highest PCV was recorded for the traits SHC, SHI, HI, PP and SBP indicating the influence on environments, and during selection these traits must be ignored. Some traits viz., SYP (g), SBP and SI (g) shows highest heritability (h^2bs) coupled with high GA, suggesting selection of these traits could help in genetic improvement, these traits could be easily transferred in the suitable agronomic background. Genotypic correlation analysis indicated significant positive relationships between DFF and several traits, including Days to 50% Podding, Seed Index and Seed Hydration Index, while negative correlations were observed with Pollen Germination and Seed Hydration Capacity per Seed. DFP exhibited significant correlations with DTM, SG (%), and SHI, while DTM was positively correlated with PBP, PP and SYP. Plant Height (PHT) showed significant positive correlations with SBP, PP and SYP, while PBP demonstrated significant correlations with SHI and SYP. SBP is significantly correlated with PP and SYP, highlighting important traits such as Seed Hydration Capacity and Seed Yield per Plant, which play crucial roles in optimizing chickpea breeding strategies. Phenotypic correlation analysis further affirmed these relationships, with significant positive correlations between DFF and DFP, DFP and Primary Branches per Plant and DTM and Seed Yield per Plant, emphasizing the intricate interplay of traits affecting chickpea productivity.

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7. Conflict of Interest Declaration

The authors declare no conflicts of interest.

8. Ethical issues

None.

9. References

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