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Genetic Variability, Correlation and Path Coefficient Analysis in Chickpea (*Cicer arietinum* L.) for Yield and its Component Traits

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A B S T R A C T

The present experiment was carried out at field experimentation centre site of the Genetics and Plant Breeding, Naini Agricultural Institute, Sam Higginbottom University of Agriculture, Technology and Sciences, Allahabad to study about genetic variability, correlation and path analysis in fifty chickpea germplasm during *Rabi*, 2017-18. The analysis of variance revealed significant differences among the genotypes for all the characters under the study, indicating a high degree of variability present in the material. The values of PCV were found greater than GCV for all the traits studied indicating environmental factors influencing the characters. High PCV and GCV were observed for effective pods per plant (36.41% and 34.38%) followed by total number of pods per plant (34.85% and 32.70%) and seed index (29.98% and 29.78%) indicated large extent of genetic variability for these traits in the material. High heritability were recorded by seed index (98.61%) followed by harvest index (90.81%), effective pods per plant (89.14%), total number of pods per plant (88.01%), secondary branches per plant (84.42%), primary branches per plant (84.31%) and plant height (81.03%).High heritability along with high genetic advance was observed for the traits, viz., effective pods per plant, total number of pods per plant, seed index, primary branches per plant and secondary branches per plant indicated that the characters were mostly governed by additive gene effects. So direct selection of these characters based on phenotypic expression by simple selection method would be effective due to accumulation of more additive genes leading to further improvement. Grain yield per plant showed positive significant genotypic and phenotypic correlations with biological yield/plant, seed index, harvest index, effective pod/plant, total number of pods/plant and secondary branches per plant whereas significant negative correlations with days to 50% flowering respectively. At the both phenotypic and genotypic levels, biological yield per plant, harvest index, days to maturity, chlorophyll index and plant height had direct positive effect on grain yield per plant had given the highest contribution on yield per plant. So the utmost importance should be given to these characters during the selection for yield improvement in chickpea.

Introduction

Chickpea (*Cicer arietinum* L.) is a self pollinated crop, with 2n = 2x = 16 chromosomes and genome size of 732 Mb. India contributes major share of world's chickpea area (70%) and production (67%) and continues to be the largest chickpea producing nation. In India chickpea is cultivated mostly in as a rainfed crop (68 % area) in all parts of the country (Dixit *et al.,* 2019). During 2017-18, chickpea was cultivated in an area of 10.76 m ha with production of 11.20 million tons and productivity of 1032 kg/ha. The improvement in crop yield depends upon the magnitude of genetic variability available in breeding material and the extent to which the yield component traits are heritable from generation to generation. The genetic variability can thus be a choice for selecting suitable parents; however, the quantitative characters are prone for environmental influence that necessitates the partitioning of overall variances as heritable and non-heritable components for efficient breeding programme (Hamdi, 1992). Absolute variability in different characters cannot be the decisive factor for deciding as to which character is showing the highest degree of variability. The relative values of phenotypic and genotypic coefficient of variation, therefore gives an idea about the magnitude of variability present in a population since the estimate of genotypic and phenotypic coefficient of variation, heritability and expected genetic advance are useful for yield improvement and the above values were estimated to know the scope of improvement in the yield of chickpea genotypes. Yield is a complex character and influenced by many environmental factors, direct selection based on yield may not be rewarding. Therefore a basic understanding of the nature and magnitude of correlation among component traits towards yield is essential. Correlation coefficient and path analysis offers a means of determining the important traits influencing the dependent trait such as seed yield and it also helps in the determination of the selection criteria for simultaneous improvement of various characters along with economic yield. Therefore the present study was undertaken to assess the genetic variability, correlation and path analysis for yield and yield components traits.

Materials and Methods

The experimental materials comprised of fifty germplasm of chickpea were sown on 6th November, 2017 at department of Genetics and Plant Breeding, SHUATS, Prayagraj. The experiment was laid in randomized complete block design with three replications. The plot size was 4.8 m^2 with each row of 4.0 m length. Interrow spacing was kept 30 cm and plant to plant spacing was 10 cm. The recommended packages and practices were followed for raise a healthy crop. Data for 14 quantitative traits were recorded viz. days to 50 % flowering (D50F), days to maturity (DM), chlorophyll index (CHL. Index), Canopy temperature at vegetative stage (CTVS), Canopy temperature at pod filling stage (CTPFS), plant height (PH), number of primary branches per plant (PB), number of secondary branches per plant (SB), number of pods per plant (TPPP), effective pods per plant (EPPP), biological yield per plant (BY), harvest index (HI), seed index (SI) and seed yield per plant (GYPP).

The days to 50% flowering and days to maturity were accounted on a plot basis and rest of the characters was documented from random sample of five plants in each plot. The recommended agronomic practices and crop protection measures were followed during the crop growth period. Biometrical methods were followed to estimate genotypic and phenotypic coefficient of variation (Burton 1952), heritability in broad sense (Lush 1940), genetic advance (Johnson *et al.,* 1955) and

correlation and path coefficient analysis (Singh and Chaudhary, 1979).

Results and Discussion

The analysis of variance revealed significant differences among the genotypes for all the characters under study (Table 1). Thus, it indicated considerable amount of genetic variability among fifty chickpea germplasm.

Estimation of genetic parameters

Estimation of genetic parameters, correlation and path analysis helps to explore important characters during the selection for improving yield of chickpea. Genotypic variances, phenotypic variances, heritability, genotypic coefficient of variation (GCV), phenotypic coefficient of variation (PCV), genetic advance (GA) and genetic advance as percentage of mean, GA (%) for all the yield contributing traits are shown in Table 2. PCV was higher than the corresponding GCV for all the traits indicating that there was an influence of the environment. Highest PCV and GCV were observed for effective pods per plant (36.41% and 34.38%) followed by total number of pods per plant (34.85% and 32.70%) and seed index (29.98% and 29.78%) in Table 2. High GCV for number of pods per plant and 100-seed weight were also earlier reported by Jeena *et al.,* (2005), Younis *et al.,* (2008), Alwani *et al.,* (2010) and Babbar *et al.,*(2012). Similar results were reported by Arora and Jeena (2001), Kumar *et al.,* (2001), Jeena *et al.,* (2005), Meena *et al.,* (2006), Alwani *et al.,* (2010) and Shreelakhsmi *et al.,* (2010).

The high estimates of PCV and GCV for these traits suggested the possibility of yield improvement through selection of these traits. The traits studied showed moderate to high heritability ranging from 45.39% to 98.61%. Among the traits studied the highest heritability was recorded by seed index (98.61%) followed by harvest index (90.81%), effective pods per plant (89.14%), total number of pods per plant (88.01%), secondary branches per plant (84.42%), primary branches per plant (84.31%) and plant height (81.03%) (Table 2). The high heritability values of the considered traits in the present study indicated that those were less influenced by the environment and thus help in effective selection of the traits based on the phenotypic expression by adopting simple selection method and suggested the scope of genetic improvement. Similar results were also reported by Bicer and Sarkar (2008) and Younis *et al.,* (2008).

The information on the magnitude of the inheritance of characters from parents to offspring is provided from heritability estimation, while genetic advance is helpful in finding out the actual gain expected under selection. In the present study, genetic advance as percent of mean estimated the highest for the effective pods per plant (66.86) followed by total number of pods per plant (63.19), seed index (60.94), primary branches per plant (39.38) and secondary branches per plant (32.96) among the yield contributing traits (Table 2). High heritability along with high genetic advance was observed for the traits, viz., effective pods per plant, total number of pods per plant, seed index, primary branches per plant and secondary branches per plant indicated that the characters were mostly governed by additive gene effects (Panse and Sukhatme, 1967) (Table 2).

So direct selection of these characters based on phenotypic expression by simple selection method would be effective due to accumulation of more additive genes leading to further improvement. The present findings are in support with Sharma and Saini (2010) and Sidramappa *et al.,* 2010 and Mohan and Thiyagarajan (2019)

Estimation of correlation coefficient among the traits

Relationships among yield and yield contributing traits were studied through analysis of correlation among them. Phenotypic and genotypic correlation coefficients among the studied traits of 50 chickpea germplasm are presented in Table 3. Correlation analysis among the yield and its contributing characters revealed that the genotypic correlation coefficients in most cases were higher than their phenotypic correlation coefficients indicating the association was largely due to genetic reason (Bhattacharyya *et al.,* 2007). The phenotypic correlation coefficients in some cases were higher than their genotypic correlation, which indicates the suppressing effect of the environment that can alter the expression of characters at the phenotypic level. Grain yield per plant showed positive significant genotypic and phenotypic correlations with biological yield/plant (0.684**, 0.775*), seed index (0.393**, 0.316**), harvest index (0.363**, 0.223**), effective pod/plant(0.299**, 0.368**), total pods/plant (0.270**, 0.351**) and secondary branches per plant (0.239**, 0.197*) whereas significant negative correlations with days to 50% flowering (-0.289**, -0,175*) respectively. Days to 50% flowering exhibited positive significant genotypic and phenotypic correlations with days to maturity (0.815**, 0.566**), canopy temperature at pod filling stage (0.433**, 0.353**), plant height (0.289**, 0.251**) and canopy temperature at vegetative stage (0.291** at genotypic level) and significant negative correlation with biological yield/plant (-0.328**, -0.178**), effective pods/plant (-0.196* at genotypic) and total pods/plant (-0.179* at genotypic level) respectively. Days to maturity registered significant and positive association with secondary branches/plant (0.272**, 0.194*) and plant height (0.238**, 0.175*) at both genotypic and phenotypic level whereas chlorophyll index (0.180*) at genotypic level only. Chlorophyll index showed positive and significant correlations with secondary branches/plant (0.317**, 0.205*) at both genotypic and phenotypic level, but harvest index (0.186*) at genotypic level only whereas significant negative correlations with canopy temperature at pod filling stage (-0.169*) at genotypic level. Canopy temperature at vegetative stage exhibited positive significant genotypic and phenotypic correlations with canopy temperature at pod filling stage (0.470**, 0.272**) respectively. Canopy temperature at pod filling stage and plant height showed non-significant association with all the characters. Number of primary branches/plant exhibited positive significant genotypic and phenotypic association with secondary branches/plant (0.396**, 0.472**) and seed index (0.248**, 0.227**) whereas it had significant and negative association with effective pods/plant (-0.229*) and total pod/plant (-0.228**) at genotypic level only. Number of secondary branches/plant was significant positive genotypic and phenotypic association with total number of pod/plant (0.176*, 0.195*) respectively. Total pod/plant recorded positive significant genotypic and phenotypic correlations with effective pods/plant (0.978**, 0.980**) whereas biological yield/plant (0.259**) showed positive significant correlation only at phenotypic level. Effective pods/plant had positive significant genotypic and phenotypic correlations with biological yield/plant (0.174*, 0.282**) respectively. Positive and significant association of biological yield/plant was observed with seed index (0.328**, 0.249**) whereas significant and negative correlation with harvest index (0.426**, -0.435**) both at genotypic and phenotypic level. Harvest index showed significant positive genotypic and phenotypic association with grain yield/plant (0.363**, 0.223*)

respectively. Seed index exhibited positive significant genotypic and phenotypic correlations with grain yield per plant (0.393**, 0.316**), biological yield per plant (0.328**, 0.249**) and primary branches per plant (0.248**, 0.227**) respectively.

Correlation analysis revealed that grain yield per plant showed significant and positive correlations with biological yield/plant, seed index, harvest index, effective pod/plant, total pods/plant and secondary branches per plant whereas it showed significant negative correlations with days to 50% flowering at both genotypic and phenotypic levels respectively (Table 3). Similar finding were reported by Talebi *et al.,* (2007), Bicer and Sarkar (2008), Hahid *et al.,* (2010), Ali *et al.,* (2011), Babbar *et al.,* (2012) and Kumar *et al.,* (2017), Samyukta *et al.,* (2017) and Agarwal *et al.,* (2018).

Estimation of path coefficient

The results of the path coefficient analysis for phenotypic and genotypic correlations are shown in Table 4. Days to 50% flowering had negative direct effect (-0.026) at genotypic level and positive direct effect (0.017) on grain yield / plant at phenotypic level. It exhibited positive indirect effect via biological yield, total pods per plant, effective pods/plant, seed index, primary branches/plant at genotypic level and days to maturity, canopy temperature at pod filling stage, plant height, canopy temperature at vegetative stage, chlorophyll index, secondary branches/plant at phenotypic level only whereas negative indirect effects were exhibited by harvest index at genotypic and phenotypic level respectively, and days to maturity, chlorophyll index, canopy temperature at vegetative stage, canopy temperature at pod filling stage, plant height, secondary branches/plant at genotypic level and primary branches/plant, total pods/plant, effective pods/plants, biological yield and seed index at only phenotypic level.

Days to maturity had positive direct effect (0.059, 0.020) on grain yield per plant. It exhibited positive indirect effect via days to 50% flowering, chlorophyll index, canopy temperature at vegetative stage, canopy temperature at pod filling stage, plant and secondary branches per plant while it had negative indirect through, total no. of pods/plant, effective pods/plant, biological yield and harvest index. Chlorophyll index recorded positive direct effect (0.038, 0.006) on grain yield per plant. It exhibited positive indirect effect through days to maturity, harvest index, seed index, secondary branches/plant, days to 50% flowering, Primary branches/plant, total pods/plant, canopy temperature at vegetative stage. Direct effect at canopy temperature at vegetative stage on grain yield was positive (0.025, 0.004). It exhibited positive indirect effect via days to 50% flowering, canopy temperature at pod filling stage, days to maturity and chlorophyll index. Direct effect of canopy temperature at pod filling stage on grain yield per plant was positive (0.008, 0.007).

It exhibited positive indirect effect via, days to 50% flowering, Canopy temperature at vegetative stage, days to maturity, secondary branches/plant and effective pods/plant. Direct effect of plant height on grain yield/plant was positive (0.033, 0.013). It exhibited positive indirect effect through days to 50% flowering, days to maturity, total pods/plant and effective pods/plant. Number of primary branches per plant had negative direct effect (-0.007, -0.009) on grain yield/plant. Positive indirect effect were also observed on total pods/plant, effective pods/plant, harvest index, days to 50% flowering, days to maturity, canopy temperature at pod filling stage and plant height.

Table.1 Analysis of variance for fourteen characters in fifty chickpea germplasm

SI. NO.	Characters	Mean Sum of Squares Replication (d. f.=2)	Treatment (d .f.=49)	Error (d. f.=98)
1.	Days to 50% flowering	19.23	76.23**	6.18
2.	Days to maturity	9.15	29.56**	4.45
3.	Chlorophyll index	5.55	40.88**	11.70
4.	Canopy Temperature at Vegetative stage	0.03	6.19**	1.25
5.	Canopy Temperature at pod filling stage	6.82	23.87**	3.25
6.	Plant height (cm)	4.16	150.62**	10.90
7.	Primary branches per plant	0.02	0.45**	0.03
8.	Secondary branches per plant	0.02	2.32**	0.13
9.	Total no. of pods per plant	0.81	522.47**	22.70
10.	Effective pods per plant	0.16	372.94**	14.56
11.	Biological yield per plant	20.27	34.91**	5.80
12.	Harvest index	0.15	39.50**	1.29
13.	Seed index	10.73	135.66**	0.64
14.	Grain yield per plant	2.32	3.64**	0.50

* and ** Significant at 5% and 1% levels of significance, respectively.

Table.2 Estimates of genetic parameters for fourteen quantitative characters in fifty germplasm of Chickpea

SI. NO.	Characters	σ^2g	σ^2p	GCV	PCV	h^2 (bs) %	GA	GA as % of mean
1.	Days to 50% flowering	23.35	29.53	6.58	7.39	79.10	8.85	12.05
2.	Days to maturity	8.37	12.81	2.37	2.94	65.34	4.82	3.95
3.	Chlorophyll index	9.73	21.42	4.96	7.36	45.39	4.33	6.88
4.	Canopy Temperature at Vegetative stage	1.65	2.90	5.89	7.81	56.90	1.99	9.15
5.	Canopy Temperature at pod filling stage	6.86	10.12	8.14	9.88	67.86	4.45	13.82
6.	Plant height (cm)	46.57	57.47	12.98	14.42	81.03	12.65	24.08
7.	Primary branches per plant	0.14	0.17	20.81	22.67	84.31	0.71	39.38
8.	Secondary branches per plant	0.72	0.86	17.41	18.95	84.42	1.62	32.96
9.	Total no. of pods per plant	166.59	189.29	32.70	34.85	88.01	24.94	63.19
10.	Effective pods per plant	119.46	134.02	34.38	36.41	89.14	21.26	66.86
11.	Biological yield per plant	9.70	15.50	13.45	16.99	62.60	5.08	21.91
12.	Harvest index	12.74	14.03	10.23	10.74	90.81	7.01	20.09
13.	Seed index	45.01	45.64	29.78	29.98	98.61	13.72	60.91
14.	Grain yield per plant	1.05	1.54	12.77	15.49	67.91	1.74	21.68

σ^2g=Genotypic variances, **σ^2p**= Phenotypic variances, **GCV**=Genotypic coefficient of variation, **PCV**= Phenotypic coefficient of variation, **h2bs**= heritability in broad sense and **GA**=genetic advance.

Table.3 Genotypic and phenotypic correlation coefficient for yield and yield attributing traits in fifty chickpea germplasm

Characters		Days to 50% flow.	Days to maturity	Chloro phyll index	CT @ VS	CT @ PFS	Plant height	Primary branches plant^{-1}	Secondary branches plant^{-1}	Total no. of Pods plant^{-1}	Effective pods plant^{-1}	Biological yield plant^{-1}	Harvest Index	Seed Index	Grain yield plant^{-1}
Days to 50% flowering	G	**1.000**	0.815 **	0.120	0.291**	0.443**	0.289**	-0.057	0.080	-0.179*	-0.196*	-0.328**	0.003	-0.118	-0.289**
	P	**1.000**	0.566**	0.103	0.158	0.353**	0.251**	-0.028	0.077	-0.139	-0.155	-0.178*	-0.026	-0.109	-0.175*
Days to maturity	G		**1.000**	0.180*	0.036	0.112	0.238**	-0.011	0.272**	-0.045	-0.119	-0.104	-0.018	-0.005	-0.069
	P		**1.000**	0.108	0.035	0.043	0.175*	-0.010	0.194*	-0.036	-0.090	-0.058	-0.006	0.004	-0.029
Chlorophyll index	G			**1.000**	0.052	-0.169*	-0.020	0.067	0.317**	0.076	-0.012	-0.140	0.186*	0.157	0.046
	P			**1.000**	0.004	-0.089	-0.001	0.020	0.205*	0.011	-0.042	-0.112	0.116	0.112	-0.025
CT @ VS	G				**1.000**	0.470**	-0.054	-0.007	-0.032	-0.023	-0.033	-0.121	-0.006	-0.025	-0.106
	P				**1.000**	0.272**	-0.010	0.047	0.0361	-0.044	-0.049	-0.142	0.013	-0.008	-0.134
CT @ PFS	G					**1.000**	-0.059	-0.125	0.024	-0.030	0.026	-0.066	-0.059	-0.122	-0.103
	P					**1.000**	-0.057	-0.084	0.016	0.005	0.050	0.016	-0.066	-0.097	-0.016
Plant height	G						**1.000**	-0.117	-0.078	0.047	0.029	-0.109	-0.022	-0.111	-0.094
	P						**1.000**	-0.111	-0.070	0.035	0.020	-0.105	-0.007	-0.096	-0.097
Pri. branches plant^{-}	G							**1.000**	0.396**	-0.228**	-0.229**	0.068	-0.095	0.248**	-0.011
	P							**1.000**	0.472**	-0.154	-0.156	0.090	-0.125	0.227**	0.007
Sec. branches plant^{-1}	G								**1.000**	0.176*	0.098	0.135	0.094	0.133	0.239**
	P								**1.000**	0.195*	0.128	0.141	0.035	0.123	0.197*
Total no. of Pods plant^{-1}	G									**1.000**	0.978**	0.133	0.149	0.001	0.270**
	P									**1.000**	0.980**	0.259**	0.082	0.001	0.351**
Effective pods plant^{-1}	G										**1.000**	0.174*	0.139	-0.001	0.299**
	P										**1.000**	0.282**	0.077	-0.001	0.368**
Biological yield plant^{-1}	G											**1.000**	-0.426**	0.328**	0.684**
	P											**1.000**	-0.435**	0.249**	0.775**
Harvest Index	G												**1.000**	0.061	0.363**
	P												**1.000**	0.061	0.223**
Seed Index	G													**1.000**	0.393**
	P													**1.000**	0.316**

*, ** Significant at 5% and 1% levels of significance, respectively;

CT@VS= Canopy temperature at vegetative stage; CT@PFS= Canopy temperature at pod filling stage

Table.4 Direct (diagonal) and indirect genotypic and phenotypic effects of different characters on grain yield in chickpea

Characters		Days to 50% flowering	Days to maturity	Chlorophyll index	CT @ VS	CT @ PFS	Plant height	primary branches plant^{-1}	Secondary branches plant^{-1}	Total no. of Pods plant^{-1}	Effective pods plant^{-1}	Biological yield plant^{-1}	Harvest Index	Seed Index	Grain yield plant^{-1}
Days to 50% flowering	G	**-0.026**	-0.021	-0.003	-0.007	-0.011	-0.007	0.002	-0.002	0.005	0.005	0.008	-0.0001	0.003	-0.289
	P	**0.017**	0.010	0.002	0.003	0.006	0.004	-0.0005	0.001	-0.002	-0.003	-0.003	-0.0004	-0.002	-0.175
Days to maturity	G	0.048	**0.059**	0.011	0.002	0.007	0.014	-0.001	0.016	-0.003	-0.007	-0.006	-0.001	-0.0003	-0.069
	P	0.011	**0.020**	0.002	0.001	0.001	0.004	-0.0002	0.004	-0.001	-0.002	-0.001	-0.0001	0.0001	-0.029
Chlorophyll index	G	0.005	0.007	**0.038**	0.002	-0.007	-0.001	0.003	0.012	0.003	-0.0005	-0.005	0.007	0.006	0.046
	P	0.001	0.001	**0.006**	0.000	-0.0005	0.000	0.0001	0.001	0.0001	-0.0003	-0.001	0.001	0.001	-0.025
CT @ VS	G	0.007	0.001	0.001	**0.025**	0.012	-0.001	-0.0002	-0.001	-0.001	-0.001	-0.003	-0.0001	-0.001	-0.107
	P	0.001	0.0001	0.000	**0.004**	0.001	0.000	0.0002	0.0002	-0.0002	-0.0002	-0.001	0.0001	0.000	-0.134
CT @ PFS	G	0.004	0.001	-0.001	0.004	**0.008**	-0.0005	-0.001	0.0002	-0.0002	0.0002	-0.0005	-0.0005	-0.001	-0.103
	P	0.003	0.0003	-0.001	0.002	**0.007**	-0.0004	-0.001	0.0001	0.000	0.0003	0.0001	-0.0005	-0.001	-0.016
Plant height	G	0.010	0.008	-0.001	-0.002	-0.002	**0.033**	-0.004	-0.003	0.002	0.001	-0.004	-0.001	-0.004	-0.094
	P	0.003	0.002	0.000	-0.0001	-0.001	**0.013**	-0.001	-0.001	0.0004	0.0003	-0.001	-0.0001	-0.001	-0.097
Pri. branches plant^{-}	G	0.0004	0.0001	-0.0005	0.000	0.001	0.001	**-0.007**	-0.003	0.002	0.002	-0.0005	0.001	-0.002	-0.011
	P	0.0002	0.0001	-0.0002	-0.0004	0.001	0.001	**-0.009**	-0.004	0.001	0.001	-0.001	0.001	-0.002	0.007
Sec. branches plant^{-1}	G	0.001	0.003	0.003	-0.0003	0.0002	-0.001	0.004	**0.010**	0.002	0.001	0.001	0.001	0.001	0.239
	P	0.001	0.002	0.003	0.0005	0.0002	-0.001	0.006	**0.013**	0.003	0.002	0.002	0.0004	0.002	0.197
Total no. of Pods plant^{-1}	G	0.012	0.003	-0.005	0.002	0.002	-0.003	0.015	-0.012	**-0.068**	-0.066	-0.009	-0.010	-0.0001	0.270
	P	-0.009	-0.002	0.001	-0.003	0.0003	0.002	-0.009	0.012	**0.061**	0.060	0.016	0.005	0.000	0.351
Effective pods plant^{-1}	G	-0.015	-0.009	-0.001	-0.003	0.002	0.002	-0.017	0.007	0.074	**0.076**	0.013	0.011	0.000	0.299
	P	0.007	0.004	0.002	0.002	-0.002	-0.001	0.007	-0.006	-0.045	**-0.046**	-0.013	-0.004	0.000	0.368
Biological yield plant^{-1}	G	-0.337	-0.107	-0.144	-0.124	-0.068	-0.112	0.070	0.139	0.137	0.179	**1.026**	-0.437	0.337	0.684
	P	-0.191	-0.063	-0.121	-0.152	0.018	-0.113	0.097	0.152	0.278	0.302	**1.073**	-0.466	0.268	0.775
Harvest Index	G	0.003	-0.014	0.147	-0.004	-0.047	-0.018	-0.076	0.074	0.118	0.111	-0.338	**0.793**	0.048	0.363
	P	-0.018	-0.004	0.080	0.009	-0.045	-0.005	-0.085	0.024	0.056	0.053	-0.298	**0.685**	0.042	0.223
Seed Index	G	-0.001	0.000	0.001	-0.0001	-0.001	-0.0005	0.001	0.001	0.000	0.000	0.002	0.0003	**0.005**	0.393
	P	-0.001	0.000	0.001	-0.0001	-0.001	-0.001	0.002	0.001	0.000	0.000	0.003	0.001	**0.010**	0.316

G (R SQURE = 0.9964 RESIDUAL EFFECT = 0.0601) **CT@VS**= Canopy temperature at vegetative stage
P (R SQURE = 0.9886 RESIDUAL EFFECT = 0.1070) **CT@PFS**= Canopy temperature at pod filling stage

Fig.1 Histogram showing estimates of Genetic Parameters for fourteen quantitative characters in chickpea

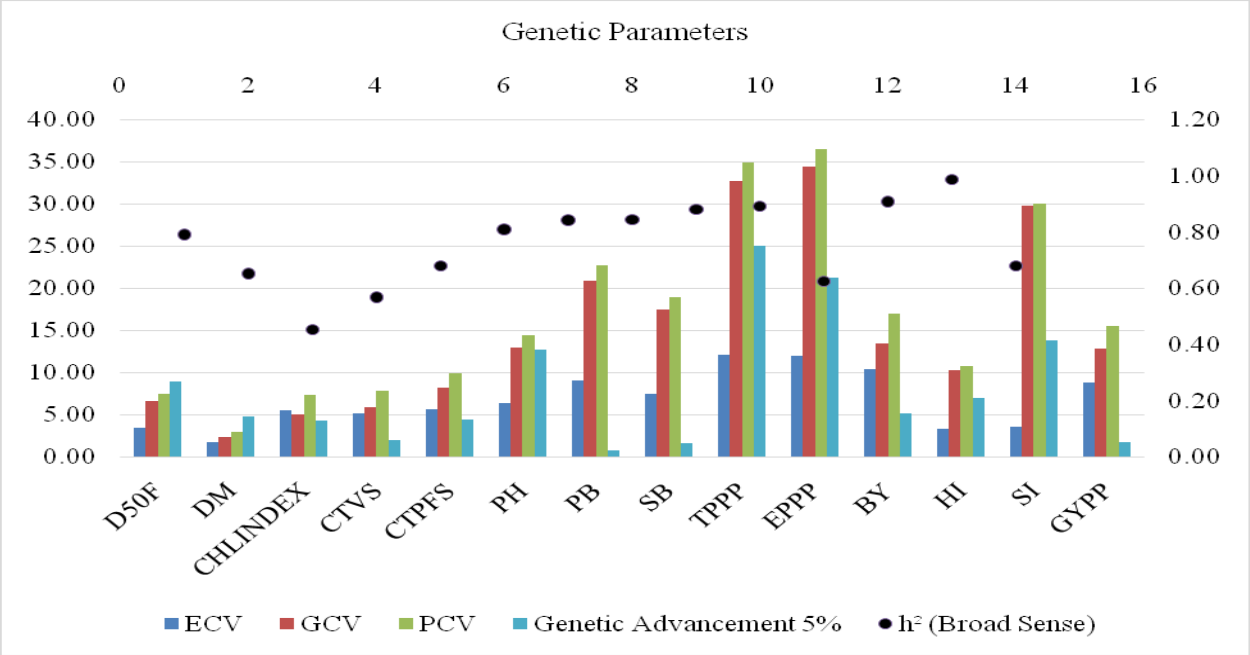
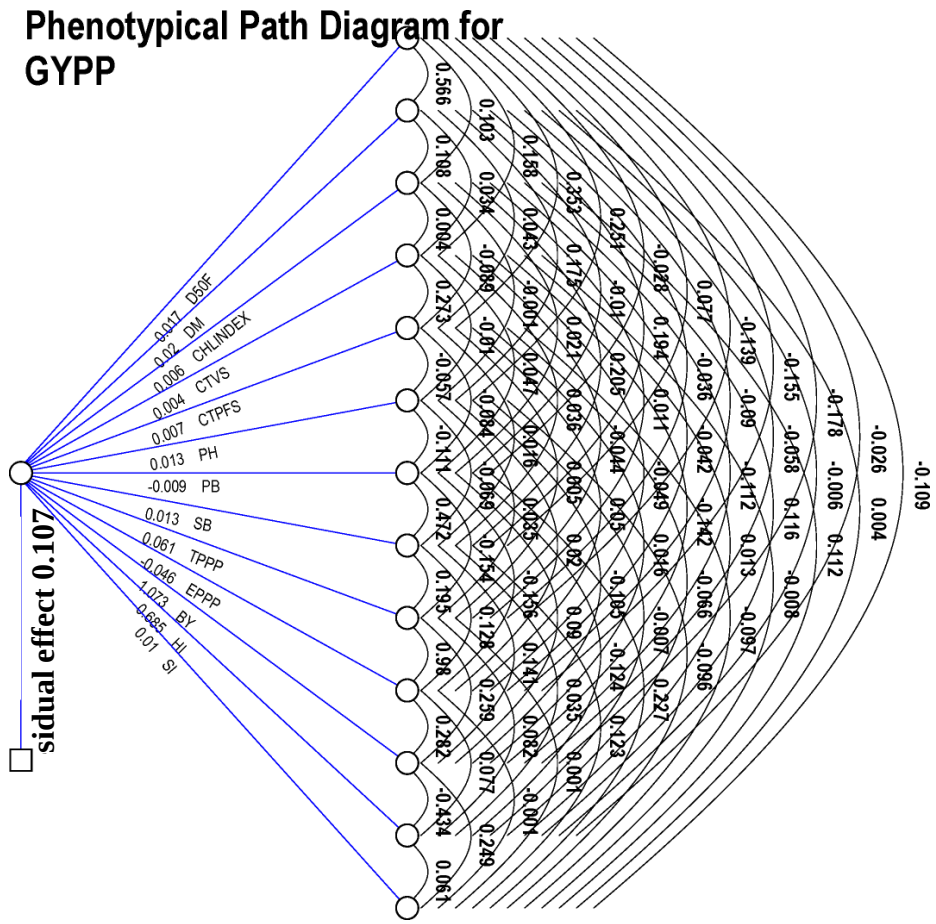


Fig.2 Phenotypic path diagram for grain yield per plant



Number of secondary branches per plant had positive direct effect (0.010, 0.013) on grain yield per plant. It exhibited positive indirect effect through days to 50% flowering, days to maturity, chlorophyll index, canopy temperature at pod filling stage, primary branches/plant, total no. of pods/plant, effective pods/plant, biological yield/plant, harvest index and 100-seed weight. But its indirect effect was negative via plant height.

Total number of pods per plant showed negative direct effect (-0.068) at genotypic level whereas positive effect (0.061) at phenotypic level on grain yield per plant. Positive indirect effect was also observed on canopy temperature at pod filling stage at genotypic and phenotypic level, whereas days to 50% flowering, days to maturity, canopy temperature at vegetative stage, canopy temperature at pod filling stage, Primary branches/plant at genotypic level. Effective pods per plant showed positive direct effect (0.076) at genotypic level where as negative effect (-0.046) at phenotypic level on grain yield/plant. It exhibited positive indirect effect on canopy temperature at pod filling stage, plant height, secondary branches/plant, total pods/plant, biological yield/plant, harvest index at genotypic level and days to 50% flowering, days to maturity, chlorophyll index, canopy temperature at vegetative stage, primary branches/plant at phenotypic level.

Direct effect of biological yield per plant on grain yield/plant was positive (1.026, 1.073). Its indirect effect via, seed index, effective pods/plant, secondary branches/plant, total pods/plant and primary branches/plant were positive. Harvest index showed positive direct effect (0.793, 0.685) on grain yield per plant. It had positive indirect effect via chlorophyll index, effective pods/plant, total pods/plant, secondary branches/plant and seed index at both genotypic and phenotypic level but days to 50% flowering at genotypic level only. Seed index exhibited positive direct effect (0.005, 0.010) on grain yield/plant. It had positive indirect effect via biological yield/plant, primary branches/plant, secondary branches/plant, chlorophyll index and harvest index.

At the both phenotypic and genotypic levels, biological yield per plant, harvest index, days to maturity, chlorophyll index, seed index, plant height and secondary branches per plant had direct positive effect on yield per plant had given the highest contribution on yield per plant (Table 4). The earlier studies for direct effect on grain yield for biological yield and harvest index were reported by Babbar and Patel (2005), Kuldeep *et al.,* (2014), Naveed *et al.,* (2012) and Tadesse *et al.,* (2016) and Kumar *et al.,* (2017) whereas, Talebi *et al.,* (2007), found positive indirect effect on seed yield.

Estimation of genetic parameters, correlation analysis and path coefficient analysis revealed that the biological yield/plant, seed index, harvest index, effective pod/plant, total number of pods/plant and secondary branches per plant were the most reliable traits for yield improvement in chickpea. So the utmost importance should be given to these characters during the selection for yield improvement in chickpea.

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