Research Article

Evaluation of Chickpea (*Cicer arietinum* L.) F_4 derived F_5 MAGIC lines for seed yield and its component traits

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Abstract

An investigation was carried out with 40 genotypes in F_4 derived F_5 MAGIC lines consisting of eight parents: ICC-4958, ICCV-10, JAKI-9218, JG-11, JG-130, JG-16, ICCV-97105, ICCV-00108 during *Rabi* 2012-13 and 2013-14. The genotypes in F_4 and F_5 generations gave minimum, medium and maximum mean values, respectively. For most of the characters the range in the mean performance was quite wide. However, in F_5 generation the upper limit was found quite high, thus giving skewed distribution. The phenotypic and genotypic coefficients of variation were found high in F_5 generation. Seed yield and pod per plant exhibited very high heritability. Also high (plant height, 100 seed weight and secondary branches) to very high (seed yield and pod per plant) genetic advance was recorded. Root length and relative water content of leaf showed very high heritability and genetic advance too. The information was derived on genotypic correlation and path. The values of correlation coefficient at genotypic level were higher than those for phenotypic counterpart. Plant height, primary branches, secondary branches, pod per plant, 100 seed weight and seed yield had direct and positive effect. Root length, relative water content, partitioning coefficient to root, stem, and leaves showed positive and significant correlation. The developmental characters like days to 50% flowering and maturity contributed to grain yield indirectly via, plant height and 100 seed weight.

Keywords: Heritability, Genetic advance, genotypic correlation, phenotypic correlation, Relative water content.

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Introduction

Chickpea is the most important legume in Asia, which contributes 86.73% of global production from 89.89% area. The world area under chickpea is about 11.08 M ha, with a total production of 9.77 M ton, and an average productivity of 882 kg/ha (FAO, 2009). Chickpea remarkably predominates among other pulse crops in terms of both area and production. The year 2009-10 marked significant increase in area under chickpea (8.56 million ha) which is highest in last 10 years. The major chickpea growing countries fall in the arid and semi-arid zones where the crop is largely grown under rain-fed conditions, on residual progressively declining soil moisture and terminal drought stress is a major cause for yield losses. Major chickpea area (95%) is planted in rain-fed condition and is grown in rotation with cereals. Chickpea is the most important *Rabi* pulse crop in India and occupies first position among the pulses grown in country. Breeders have been utilizing the available genetic resources to modify the varieties to meet the ever changing requirements. However in self-pollinated crop the heterosis cannot be exploited directly, hybrid vigor is used to identify superior hybrids as they offer more probability of developing better segregants [1] and [2]. In chickpea beneficial Heterosis for grain filling period, seeds per plant and grain yield were reported by several research workers [3], [4] and [5]. The knowledge of heritability and genetic advance help to identify characters with potential improvement and to decide upon the selection pressure in breeding material. High genetic advance coupled with high heritability offer most effective conditions for selection in chickpea [6] and [7]. The present study was designed to estimate the degree of hybrid vigor, extent of heritability and genetic advance in F_1 hybrids. The information obtained could be used to select superior segregants from better hybrids for stress resistance, better adaptability and productivity.

Materials and Methods

The experiment material comprised of 40 chickpea lines with susceptible check, were laid in RCBD design with three replications, at Pulses Research Sub-station, SKUAST-J, Samba, during 2012-13 and 2013-14 (Fig. 1 and 2). The experiment was sown late by 30 days (first week of December) in comparison to normal sowing date, for subjecting the material to terminal drought stress.

The material was received from ICRISAT, Hyderabad as F_4 bulk of MAGIC population by the A.I.C.R.P. on chickpea, Sub-Station Samba; under ICAR-ICRISAT collaborative work. In this case of chickpea multi-parent advanced generation inter cross (MAGIC) populations are being developed to enhance the genetic base. Eight elite lines/cultivars (ICC 4958, ICCV 10, JAKI 9218, JG 11, JG 130, JG 16, ICCV 97105, and ICCV 00108) were selected by ICRISAT, Hyderabad from Ethiopia, Kenya and India for development of a MAGIC population for *desi* chickpea. Twenty-eight two-way, fourteen four-way and seven eight-way crosses were made to develop this MAGIC population. The seed was collected and sown at the said location, in *Rabi* season of 2013-14 in plant to progeny row, under R.B.D. trial.

Figure 1 Field screening of Chickpea *rabi* 2012-13

Figure 2 Branch of Chickpea bearing pods

Relative water content of leaf

$$RLWC\ (\%) = F_w\text{-}D_w/\ T_w\text{-}D_{wx}\ 100$$

Where, F_w = Fresh weight, T_w = Turgid weight, D_w = Dry weight

$$\text{Partitioning coefficient to root} = \frac{Root\ dry\ weight}{Total\ weight\ of\ the\ plant} \times 100$$

$$\text{Partitioning coefficient to stem} = \frac{Stem\ dry\ weight}{Total\ weight\ of\ the\ plant} \times 100$$

$$\text{Partitioning coefficient to leaves} = \frac{Leaves\ dry\ weight}{Total\ weight\ of\ the\ plant} \times 100$$

$$\text{Partitioning coefficient to pods} = \frac{Pods\ dry\ weight}{Total\ weight\ of\ the\ plant} \times 100$$

$$\text{Heritability} = \frac{Genotypic\ variance}{Phenotypic\ variance} \times 100$$

$$\text{Genetic advance} = k \times h^2 \times \sigma^2_{ph}$$

$$\text{Genetic advance over mean} = \frac{Genetic\ advance}{\overline{X}} \times 100$$

Where,

K = selection differential in terms of standard deviation and it is 1.76 at 10 per cent selection intensity.

h^2 = estimate of heritability coefficient.

σ^2 = phenotypic standard deviation.

$\overline{X}^{ph}$ = mean value of concerned character.

Table 1 Mean, Range and Variance for F_5 generation (morpho-physiological traits) in Chickpea

Parameters → Traits ↓	**Mean**	**Range**	**Variance**
Days to 50% flowering	102.083±1.259	113.000- 98.000	4.760
Days to maturity	151.433±1.144	159.333-149.333	3.930
Primary branches	4.541±1.131	7.000-2.333	3.840
Secondary branches	21.05±3.767	32.667-8.333	42.570
Plant height(cm)	61.052±3.114	73.800-50.800	29.080
Pods per plant	48.166±4.650	75.000-18.333	64.860
Seeds per pod	2.10 ±0.424	3.000-1.333	0.540
Pod length(cm)	1.94±0.123	2.167-1.600	0.050
Seed yield (g)	35.915±1.456	48.761-11.831	6.365
100-seed weight(g)	20.205±4.503	27.372-17.082	6.780
Root length (cm)	21.17±1.256	28.433-15.800	4.730
Root fresh weight (g)	3.271±0.220	3.900-2.600	0.150
Root dry weight (g)	2.242±0.234	2.967-1.533	0.160
Relative Water content (%)	41.670±3.023	55.618-27.741	27.420
Partitioning Coefficient to pods (%)	23.36±1.483	27.900-19.084	6.600
Partitioning Coefficient to roots (%)	33.273±1.630	39.372-29.719	7.970
Partitioning Coefficient to leaves (%)	22.943±1.487	27.808-17.893	6.630
Partitioning Coefficient to stem (%)	23.974±1.446	29.441-17.995	6.270

Results and Discussion

High mean was recorded in the seed yield and its contributing traits. In F_4 generation 20.09 g of seed yield was recorded which increased in the F_5 generation to 35.91 g. This suggested that the selection was quite effective. High yielding lines are considered to be drought resistant and therefore selected in the screening process. Similar findings were also reported by [8], also echoed by the findings of [9]. The important character associated with the yield is pods per plant. In F_4 generation the mean for pods per plant was observed as 19.85 which increased phenomenally up to 48.16 in numbers in F_5 generation. The plant height in F_4 generation was recorded as 49.48 cm but it increased in F_5 generation to 61.05 cm. Similarly, high mean were obtained in case of relative water content of leaf and root length. As these two characters are very important as per the drought tolerance is concerned. The relative water content exhibited higher mean values i.e., 41.67 %. The mean values obtained for root length were 21.17 cm, similar reports were made by [10] and hence it could be used in the breeding programme for improving drought tolerance of the agronomically superior cultivars for the introgression of drought tolerant genes in them. High mean was observed in partitioning coefficient to root (33.27%) which suggested that the maximum photosythates are transported to this region. It means that the plant transfers the photosythates to root in order to escape the drought and survive in the severe conditions.

A wide range was observed in all the characters in both the F_4 and F_5 generations. In F_4 generation the range vary from 97.00-110.00 for days to 50 % flowering while in F_5 it vary from 98.00-113.00. The range increased due to the continuous rainfall during 2013-14 at the time of flowering which delays the flowering in chickpea crop. For seed yield the range in F_4 generation vary from 12.356-34.398 g but the range increased in the F_5 generation to 11.831-48.761 g. This showed that there is the influence of additive genes. Similar observations were recorded in chickpea by [11]. A higher range was recorded in case of pods per plant 9.00-30.00 in F_4 generation that was increased to 18.33-75.00 in F_5 generation except the seeds per pod in both the generation due to less variability.

Table 2 Genetic parameters of segregating population (F_5) of the morpho-physiological traits

Parameters → Traits ↓	**Heritability**	**Phenotypic coefficient of variation**	**Genotypic coefficient of variation**	**Genetic advance**	**Genetic advance over mean (%)**	**Coefficient of variation**
Days to 50% flowering	45.68	2.90	1.96	2.79	2.73	2.14
Days to maturity	26.58	1.53	0.79	1.27	0.84	1.31
Primary branches	02.76	43.03	7.14	0.11	2.44	42.43
Secondary branches	24.29	35.51	17.50	3.75	17.77	30.90
Plant height (cm)	29.12	10.49	5.66	3.84	6.29	8.83
Pods per plant	76.16	34.25	29.89	25.88	53.73	16.72
Seeds per pod	1.18	11.66	1.27	0.01	0.28	11.59
Pod length (cm)	11.20	33.27	0.00	0.16	7.68	35.09
Seed yield (g)	91.95	25.31	24.27	16.84	47.93	7.18
100-seed weight (g)	28.31	15.35	8.17	1.79	8.79	13.00
Root length (cm)	58.25	15.90	12.13	04.04	19.08	10.27
Root fresh weight (g)	18.54	12.92	5.56	0.16	04.94	11.66
Root dry weight (g)	19.23	20.32	08.91	0.18	08.05	18.26
Relative Water content (%)	60.05	19.88	15.41	10.25	24.59	12.57
Partitioning Coefficient to pods (%)	27.81	12.94	06.82	01.73	07.41	10.99
Partitioning Coefficient to roots (%)	18.17	09.38	04.00	01.17	03.51	08.49
Partitioning Coefficient to leaves (%)	36.11	14.09	08.47	02.40	10.48	11.26

Table 3 Genotypic correlation among ten morphological traits in Chickpea during 2013-14

Traits	**Seed yield (g)**	**Days to 50% flowering**	**Days to maturity**	**Plant height (cm)**	**Primary branches**	**Secondary branches**	**Pods per plant**	**Pod length (cm)**	**Seeds per pod**	**100-seed weight (g)**
Seed yield (g)	-	-0.31	-0.72	0.34**	1.10**	0.33**	-0.02	3.14**	0.00	0.38**
Days to 50% flowering		-	0.96**	0.09	-1.08	0.01	-0.18	-2.31	0.00	0.06
Days to maturity			-	-0.31	-1.89	-0.44	0.39**	-3.48	0.00	-0.27
Plant height(cm)				-	0.46**	0.32**	0.53**	-0.31	0.00	0.18*
Primary branches					-	0.46**	0.42**	4.76**	0.00	0.44**
Secondary branches						-	0.33**	-0.90	0.00	0.29
Pods per plant							-	0.22*	0.00	-0.29
Pod length (cm)								-	0.00	0.75**
Seeds per pod									-	0.00
100-seed weight (g)										-

The analysis of variance revealed that there were significant differences between genotypes for all the characters except for number of seeds per pod indicating the presence of genetic variability among the genotypes. Highly significant (P< 0.01) variation for various traits revealed the importance of chickpea germplasm in the crop improvement programme [19] and [2].

Table 4 Genotypic correlation among eight physiological traits in Chickpea during 2013-14

Traits	**Root Length (cm)**	**Root fresh weight (g)**	**Root dry weight (g)**	**Partitioning Coefficient to roots (%)**	**Partitioning Coefficient to stem (%)**	**Partitioning Coefficient to leaves (%)**	**Partitioning Coefficient to pods (%)**	**Relative Water content (%)**
Root length (cm)	-	-0.053	0.048	-0.114	0.197*	0.002	-0.138	-0.022
Root fresh weight(g)		-	0.898**	-0.207	0.274**	0.149	-0.066	0.180*
Root dry weight(g)			-	-0.377	0.057	0.082	0.206*	-0.125
Partitioning Coefficient to roots (%)				-	0.257**	-0.175	-0.111	0.053
Partitioning Coefficient to stem(%)					-	-0.664	-0.590	0.021
Partitioning Coefficient to leaves(%)						-	-0.419	0.241**
Partitioning Coefficient to pods(%)							-	-0.278
Relative Water content (%)								-

Table 5 Phenotypic path coefficient in F_5 generation of Chickpea during 2013-14

Traits	**DF**	**DM**	**PH**	**PB**	**SB**	**PPP**	**PL**	**SPP**	**RL**	**RFW**	**RDW**	**PCR**	**PCS**	**PCL**	**PCP**	**RWC %**	**HSW**	**Cor. With SY**
DF	-**.0172**	-.0591	.0000	-.0010	.0049	.0055	-.0212	-.0182	-.0013	.0147	-.0112	-.0044	-.0353	-.0075	-.0106	.0057	-.0157	-.1721
DM	-.0041	-**.2474**	-.0004	-.0025	-.0139	.0065	-.0329	-.0023	-.0042	-.1024	.0589	-.0204	.0097	-.0212	-.0059	.0056	-.0079	-.3846
PH	.0001	.0164	**.0056**	.0004	.0132	-.0099	.0636	.0048	.0040	.0378	.0015	.0121	-.0079	.0248	.0086	.0015	.0067	.1832
PB	.0014	.0492	.0002	**.0123**	.0049	.0003	.0369	.0079	.0015	.0447	-.0103	-.0027	-.0040	.0147	.0053	.0079	.0061	.1763
SB	-.0016	.0666	.0014	.0012	**.0516**	-.0056	.0162	.0009	.0024	.0777	-.0102	.0189	-.0599	.0361	.0030	.0066	.0003	.2054
PPP	.0019	.0317	.0011	-.0001	.0058	-**.0506**	-.0074	.0126	.0063	-.0208	.0288	.0012	-.0175	.0130	.0016	-.0023	-.0344	-.0292
PL	.0020	.0452	.0020	.0025	.0047	.0021	**.1800**	.0025	.0033	.0642	-.0296	.0259	-.0019	.0240	.0132	.0038	.0027	.3465
SPP	.0029	.0053	.0002	.0009	.0004	-.0058	.0041	**.1095**	.0019	.0240	.0100	.0145	-.0139	.0046	.0021	.0015	-.0377	.1243
RL	.0011	.0526	.0011	.0009	.0061	-.0160	.0295	.0104	**.0200**	.0066	.0036	-.0028	-.0189	.0175	-.0019	.0022	-.0008	.1113
RFW	.0006	-.0589	-.0005	-.0013	-.0093	-.0024	-.0269	-.0061	-.0003	-**.4295**	.2552	-.0235	.0110	.0043	-.0040	-.0050	.0052	-.2917
RDW	.0006	-.0480	.0000	-.0004	-.0017	-.0048	-.0176	.0036	.0002	-.3612	**.3034**	-.0160	.0116	.0030	-.0024	.0011	.0044	-.1332
PCR	-.0006	-.0387	-.0005	.0003	-.0075	.0005	-.0357	-.0122	.0004	-.0773	.0373	-**.1305**	.0490	.0723	-.0155	-.0010	.0044	-.1553
PCS	-.0030	.0120	.0002	.0002	.0154	-.0044	.0017	.0076	.0019	.0235	-.0175	.0319	-**.2007**	.0584	-.0146	-.0029	-.0108	-.1010
PCL	-.0005	-.0219	-.0006	-.0008	-.0078	.0028	-.0180	-.0021	-.0015	.0077	.0038	.0394	.0490	**.2393**	-.0200	-.0058	-.0260	-.2417
PCP	.0032	.0261	.0009	.0012	.0028	-.0014	.0421	.0041	-.0007	.0306	-.0131	.0358	.0520	.0847	**.0564**	.0075	.0271	.3592
RWC %	.0022	.0306	-.0002	-.0021	-.0075	-.0025	-.0150	-.0036	-.0010	-.0475	-.0076	-.0028	-.0130	.0305	-.0094	-**.0452**	-.0162	-.1714
HSW	.0019	.0136	.0003	.0005	.0001	.0122	.0035	-.0290	-.0001	-.0157	.0031	-.0040	.0152	.0437	.0107	.0051	**.1426**	.2037

Bold values shows direct effect; Residual variation = 0.568

Where, DF: days to 50% flowering, DM: days of maturity, PH: Plant height, PB: primary branches, SB: Secondary branches, PPP: Pods per plant, PL: Pod length, RL: Root length, RFW: root fresh weight, RDW: root dry weight, PCR: partitioning coefficient to roots, PCS: partitioning coefficient to stem, PCL: partitioning coefficient to leaves, PCP: partitioning coefficient to pods, RWC: relative water content, HSW: 100 seed weight.

Table 6 Genotypic path coefficient in F_5 generation of chickpea during 2013-14

Traits	DF	DM	PH	PB	SB	PPP	PL	RL	RFW	RDW	PCR	PCS	PCL	PCP	RWC %	HSW	Cor. with SY
DF	**.1757**	-.1420	-.0185	-.2255	-.0021	.0208	.2575	-.0085	-.3392	.1561	-.0061	-.0118	.0113	-.1418	-.0597	.0145	-.3193
DM	.1704	**-.1464**	.0605	-.3923	.1241	.0459	.3878	-.1225	-.3791	.1446	.0229	.0071	-.1508	-.2947	-.1431	-.0577	-.7234
PH	.0169	.0461	**-.1922**	.0971	-.0902	-.0610	.0348	.0330	.3855	-.2220	-.0147	.0008	.0784	.2606	-.0689	.0389	.3430
PB	-.1921	.2773	-.0901	**.2072**	-.1280	-.0489	-.5350	.0361	2.0728	-1.1299	-.0449	.0349	.1761	.5850	-.2092	.0927	1.1093
SB	.0013	.0656	-.0626	.0957	**-.2771**	-.0384	.1006	.0214	-.0120	.3716	.0254	-.0107	.1533	-.0508	-.1121	.0617	.3330
PPP	-.0317	.0583	-.1019	.0881	-.0925	**-.1151**	-.0251	.1156	-.2002	.2657	-.0196	-.0064	-.0025	.0672	.0414	-.0625	-.0211
PL	-.4065	.5103	.0601	.9878	.2505	-.0259	**-.1113**	.1686	.3865	-.5507	-.0446	.0855	.0326	1.3675	.2695	.1579	3.1470
RL	-.0064	.0769	-.0272	.0321	-.0254	-.0570	-.0805	**.2332**	.0494	.0456	-.0070	-.0063	-.0006	-.0638	-.0088	-.0007	.1533
RFW	.0641	-.0597	.0796	-.4616	-.0036	-.0248	.0466	-.0124	**-.9306**	.8378	-.0128	-.0088	-.0317	-.0306	.0700	-.0806	-.5589
RDW	.0294	-.0227	.0458	-.2510	-.1104	-.0328	.0657	.0114	-.8359	**.9327**	-.0233	-.0018	-.0175	.0948	-.0485	-.0603	-.2243
PCR	-.0174	-.0543	.0458	-.1509	-.1139	.0366	.0805	-.0266	.1926	-.3521	**.0617**	-.0082	.0372	-.0514	.0609	.0052	-.2541
PCS	.0649	.0327	.0049	-.2268	-.0927	-.0231	.2983	.0461	-.2558	.0535	.0159	**-.0319**	.1405	-.2718	.0083	-.0212	-.2580
PCL	-.0094	-.1044	.0713	-.1726	.2008	-.0014	.0171	.0007	-.1395	.0771	-.0108	.0212	**-.2115**	-.1930	.0936	-.0676	-.4285
PCP	-.0541	.0938	-.1088	.2634	.0306	-.0168	-.3306	-.0323	.0619	.1922	-.0069	.0188	.0887	**.4603**	-.1082	.0746	.6263
RWC %	-.0270	.0540	.0341	-.1116	.0800	-.0123	-.0772	-.0053	-.1678	-.1166	.0097	-.0007	-.0510	-.1282	**.3884**	-.0666	-.1980
HSW	.0122	.0405	-.0358	.0921	-.0819	.0344	-.0842	-.0008	.3596	-.2693	.0015	.0032	.0685	.1644	-.1239	**.2087**	.3894

Bold values shows direct effect; Residual Variation: 0.5030

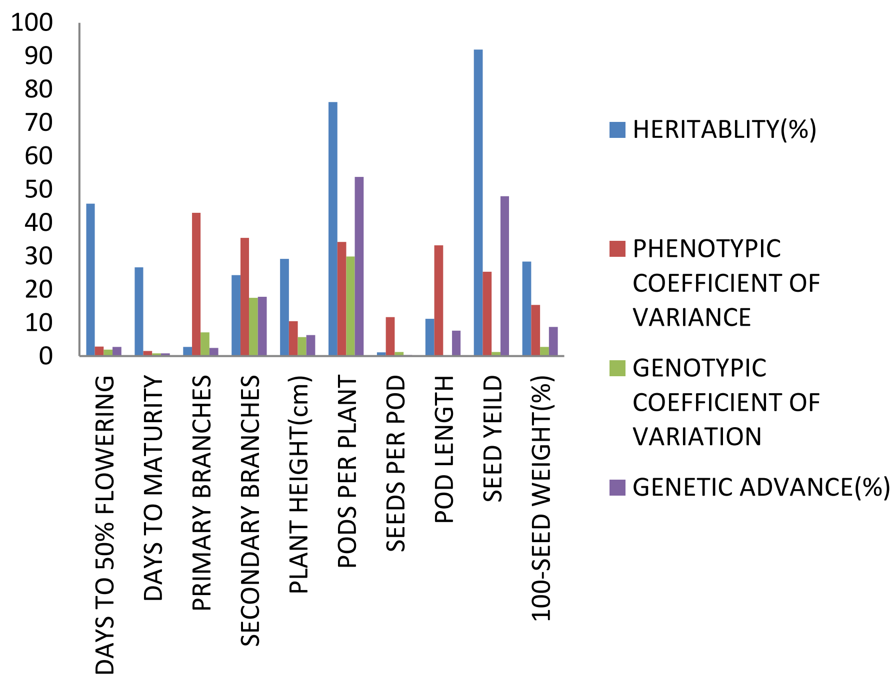

Figure 3 Genetic parameters of segregating population (F_5) for the morphological traits

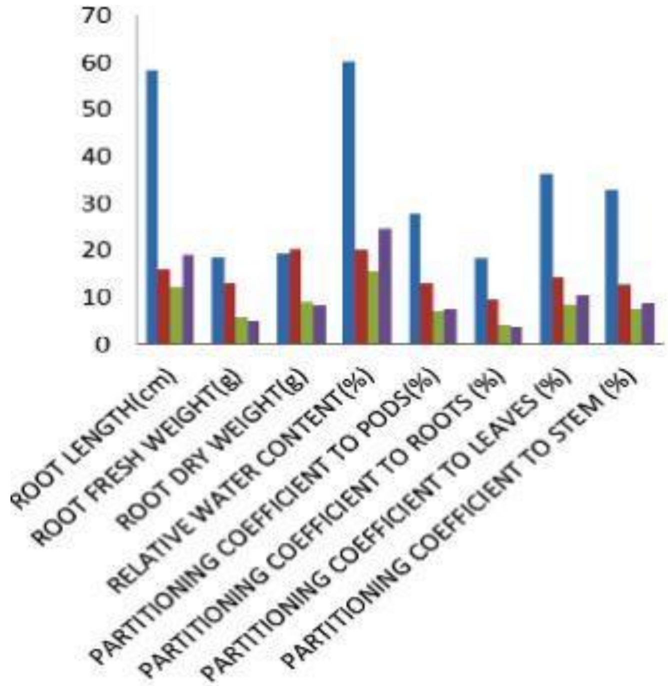

Figure 4 Genetic parameters of segregating population (F_5) for the physiological traits

From the heritability estimates the breeder can determine the appropriate generation at which intensive selection can be practiced. Since heritability in broad sense does not provide information on genetic gain, therefore, heritability along with the estimate of genetic advance would be more useful to the plant breeders. Similar results were in accordance with the findings of [12]. High to very high heritability in broad sense was observed for most of the traits. Seed yield and pods per plant exhibited very high estimates of heritability. Likewise, relative water content of leaf and root length gave high estimates of heritability. High estimates of genetic advance were recorded for pods per plant, seed yield and secondary branches in F_5 generation. Medium to high estimates of genetic advance for root length, relative water content and partitioning coefficient to leaves were observed (Fig. 3 and 4). In this manner, crop improvement, in terms of these traits, could be possible by simple selection because high heritability coupled with high genotypic variation revealed the presence of an additive gene effect [13].[14] suggested that h^2, in combination with genetic advance (GA), was more reliable in predicting the effect of selection. In the present studies, high heritability coupled with high genetic advance for 100-seed weight and number of pods-per-plant indicated additive gene effects to be important for determining these traits. On the other hand, high h^2 was associated with low genetic advance for number of seeds per pod, indicating the influence of dominant and epistemic gene for these traits. These results are supported by the findings of [15].

The genotypic correlation of seed yield per plant and its components were worked out. These correlation studies revealed that, the genotypic correlation coefficients between most of the characters were higher in magnitude. The significant positive correlation was reported between seed yield per plant with number of secondary branches per plant, number of pods per plant and 100 seed weight this was due to the increased additive effect of the genes controlling pods per plant. Similar findings were also reported by [16] and [17]. Similarly strong association between primary and secondary branches per plant and number of pods per plant was noticed through the highly significant positive values of correlation coefficients. This indicates the simultaneous improvement of these characters through selection. The importance of this association was also reported by [18] and [19]. Similarly, days to 50 per cent flowering was strongly associated with days to maturity, plant height and number of primary branches per plant suggesting that maturity period can be predicted by days taken to 50 per cent flowering. A negative correlation of these characters observed with seed yield per plant, number of pods per plant will help in developing early maturity and high yielding varieties.

The direct and indirect contributions of each character as revealed by path coefficient analysis indicated that 100 seed weight had highest direct effect on seed yield per plant followed by number of pods per plant and number of secondary branches per plant. These direct effects are mainly responsible for significant positive association of these characters with seed yield per plant. The number of secondary branches exerted its effect on seed yield through number of pods per plant and 100 seed weight through primary branches per plant which is similar to finding of [20].

Conclusion

The significant differences existed for all the quantitative traits in the segregating generations, suggesting that the genetic improvement in the segregating generations of high degree, which can be further utilized in chickpea breeding programme. The high estimate of heritability in broad sense were observed for major yield contributing traits which indicated that selection can be operated for these traits at any stage of population advancement. The study of genotypic and phenotypic correlations revealed the association of seed yield with pods per plant, plant height, 100 seed weight, of high magnitude in positive direction in both the generations. The pattern of this type of correlation suggested that selection for any of these traits can be taken up by chickpea breeders at any stage of population advancement and it is also suggested that selection for one trait will simultaneously improve the related trait side-by-side. Therefore, it can be concluded that the chickpea breeders should concentrate for the selection of these traits.

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