Environment and Ecology 41 (4B) :2656—2665, October—December 2023
Article DOI: https://doi.org/10.60151/envec/CVIX9425
ISSN 0970-0420

Estimation of Genetic Variability Parameters and Character Association in F_2 Generation of Chickpea (*Cicer arietinum* L.) Crosses under Irrigated and Rainfed Conditions

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Received 30 May 2023, Accepted 3 September 2023, Published on 29 November 2023

ABSTRACT

The present study was carried out to estimate genetic variability parameters, heritability (in broad sense), genetic advance as percentage of mean and character association in F_2 generation of five chickpea crosses under irrigated and rainfed conditions for yield and its components traits. The estimates of these parameters will help us to decide selection criteria for improvement of seed yield in chickpea. Significant differences were observed among the crosses and generations for all the characters under both the conditions. The highest range of variation was observed for 100 seed weight followed by seed yield per plant, biological yield per plant, seeds per pod and plant height in irrigated condition, while in rainfed condition the highest range of variation was registered for 100 seed weight followed by days to 50% flowering, fruiting branches per plant, seed yield per plant, days to maturity and harvest index. Hence, selection should be done on characters having wide range of variation under the respective environmental condition. Phenotypic variance was higher than the corresponding genotypic variance for all the characters studied under both the conditions, indicating more contribution of environment in the phenotypic appearance of the traits than their genetic makeup. The high estimates of GCV and PCV were obtained for fruiting branches per plant, pods per plant, seeds per pod, biological yield per plant, seed yield per plant and 100 seed weight in most of the crosses under both the conditions. High heritability coupled with high genetic advance as percentage of mean was observed for pods per plant in most of the crosses under both the conditions. RSG-895 × RSG-888 showed high heritability coupled with high GAM for seed yield per plant and harvest index, CSJD-901 × RSG-931 for seed yield per plant, RSG-888 × ICC-4958 for harvest index under irrigated condition indicated the importance of additive gene action in the inheritance of these characters; hence, selection based on phenotypic performance would be effective for improvement of these characters. Seed yield per plant had positive and significant correlation with fruiting branches per plant, pods per plant, biological yield per plant, harvest index and 100 seed weight under both the conditions and with plant height in rainfed condition only. So selection based on these characters is expected to bring improvement in the seed yield of chickpea.

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Keywords Chickpea, Genetic parameters, Heritability, Genetic advance, Rainfed condition.

INTRODUCTION

Chickpea (*Cicer arietinum* L.) is the third most important pulse crop in the world after dry bean and dry pea. India is the largest producer of chickpea in the world with a 67.0% share in global production followed by Australia (5.9%), Pakistan (4.6%), Myanmar (3.8%), Turkey (3.8%), Ethiopia (3.3%) and Iran (2.3%). The global production of chickpea in 2014 was 13.00 million tons from an area of 13.59 million ha with an average productivity of 956 kg/ha (FAOSTAT 2019). In India, chickpea was grown on 9.69 million ha with production of 11.07 million and productivity of 1142 kg/ha tons in the year 2019-20 (Anonymous 2022).

Chickpea has special significance in the diet of the predominantly vegetarian population of India as it contains more protein (23%), which is complementary with cereals in amino acids profile. Production and productivity of chickpea have been stagnant for the past three decades; one of the main reasons of this is its sensitivity to moisture stress at critical stages as more than 80% area under chickpea is rainfed (Dhiman *et al.* 2006). Significant variation among genotypes for yield and yield components under moisture stress condition in chickpea has been observed by Krishnamurthy *et al.* (2011), Mishra and Babbar (2014).

The effectiveness of the breeding program would depend on the magnitude of variability and heritability in early generation populations for important economic traits (Pal *et al.* 2018). Heritability determines how much of the phenotypic variability has a genetic origin and how much due to influence of environment (Falconer 1981). Genetic advance is another parameter on which effectiveness of selection depends. For the selection to be effective and for making improvement in the crop, moderate to high heritability should be accompanied by sufficient amount of genetic advance (Johnson *et al.* 1955). Further, variability parameters were studied by many workers using fix/stable genetic material. Very few reports are available on segregating material. Therefore, the present study was conducted to estimate genetic variability, heritability, genetic advance and association for yield and yield components in F_2 generation of chickpea crosses under irrigated and rainfed conditions. This will help us to finalize appropriate selection criteria for improvement of seed yield in chickpea.

MATERIALS AND METHODS

The F_2 generation of five chickpea crosses viz., RSG-895 (Medium bold) × RSG-888 (Medium bold), RSG-888 (Medium bold) × ICC-4958 (Bold), IPC-94-94 (Bold) × RSG-888 (Medium bold), CS-JD-901(Medium bold) × RSG-931(Medium bold) and BG-362 (Bold) × RSG-931(Medium bold) along with their parents P_1 and P_2, and F_1 generation were grown in Compact Family Block Design with three replications under both irrigated (two supplemental irrigations) and rainfed (on receding soil moisture) conditions at Research Farm, Agricultural Research Sub Station, Hanumangarh, Rajasthan, India. Seeds were sown in 3 meter long rows. Parents were sown in two rows, F_1s in one row and F_2s was sown in four rows. Row to row and plant to plant distance was kept 30 cm and 10 cm, respectively. Recommended practices were followed to raise a good crop. The data were observed on 10 randomly selected plants in P_1, P_2 and F_1 and on 20 randomly selected plants in the F_2 generation for plant height, fruiting branches per plant, pods per plant, seeds per pod, biological yield per plant, seed yield per plant, harvest index, 100-seed weight and protein content. The observations for days to 50% flowering and days to maturity were recorded on plot basis.

Statistical analysis

The analysis of variance was performed as per Compact Family Block Design for comparison of crosses as well as generations of each cross. Standard statistical procedures (Snedecor and Cochran 1994) were used to obtain means and variances for each generation and character, separately. Goulden (1952) stated that the variation occurring in any segregating generation is the phenotypic variance and the variation occurring in any uniform or non-segregating population is due to environment. Hence, phenotypic variance (V_p), genotypic variance (V_g) and environ-

mental variance (V_e) computed as :

Phenotypic variance (V_p) = V_{F2}
Genotypic variance (V_g) = $V_p - V_e$
Environmental variance (V_e) = $(V_{P1}+V_{P2}+2V_{F1})/4$
Where, V_{P1} = Variance of individuals of the P_1 family
V_{P2} = Variance of individuals of the P_2 family
V_{F1} = Variance of individuals of the F_1 family
V_{F2} = Variance of individuals of the F_2 family

The genotypic and phenotypic coefficients of variation were estimated using the formula suggested by Burton (1952).The estimates of PCV and GCV can be divided in three classes as high (>20%), medium (10-20%) and low (<10 %) as suggested by Burton and Devane (1953). The heritability in broad sense was computed as the ratio of genotypic variance to phenotypic variance as suggested by Allard (1962). Heritability values are categorized as low (<30%), moderate (30-60%) and high (>60%) according to Robinson (1966). The expected genetic advance was estimated by using the method suggested by Johnson *et al.* (1955). The range of genetic advance as percentage of mean is categorized as high (>20%), moderate (10-20%) and low (<10%) as suggested by Johnson *et al.* (1955). Character association was estimated as per the method suggested by Panse and Sukhatme (1954).

RESULTS AND DISCUSSION

Analysis of variance revealed the significant differences among the crosses for all the characters under both the conditions, indicating the presence of sufficient diversity among the crosses, suggesting ample scope of exploiting such variability through selection (Table 1). The mean, genotypic variance, phenotypic variance, genotypic coefficient of variation, phenotypic coefficient of variation, heritability (in broad sense), genetic advance and genetic advance as percentage of mean of F_2 generation in five chickpea crosses under both irrigated and rainfed conditions are presented in Table 2.

Most of the characters studied had exhibited wider range of variation under rainfed conditions than irrigated condition as evident from coefficient of range depicted in Fig.1, indicated that water limited condition imposed larger discrimination among genotypes compared with the irrigated condition. The highest range of variation was observed for 100 seed weight followed by seed yield per plant, biological yield per plant, seeds per pod and plant height in irrigated condition, while in rainfed condition the highest range of variation was registered for 100 seed weight followed by days to 50% flowering, fruiting branches per plant, seed yield per plant, days to maturity and harvest index. Hence, selection should be done on characters having wide range of variation under the respective environmental condition.

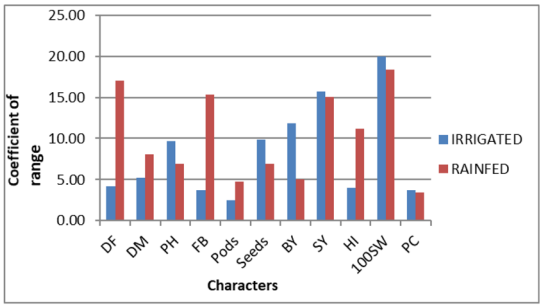

Fig. 1. Coefficient of range for different characters in chickpea under irrigated and rainfed conditions.

Phenotypic variance was higher than the corresponding genotypic variance for all the characters studied under both the conditions (Figs. 2–3). This finding is in agreement with Raju *et al.* (2017), Shivakumar *et al.* (2013) and Rathod *et al.* (2020). Higher difference between genotypic variance and phenotypic variance was recorded for pods per plant, biological yield per plant, harvest index (%), plant height, fruiting branches per plant, seed yield per plant and 100 seed weight while low difference was

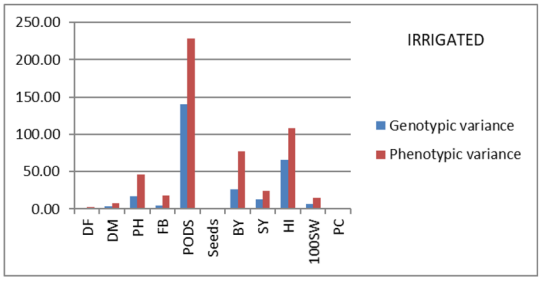

Fig. 2. Genotypic and phenotypic variance for different characters in chickpea under irrigated condition.

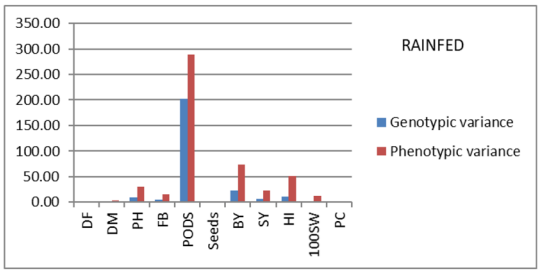

Fig. 3. Genotypic and phenotypic variance for different characters in chickpea under rainfed condition.

registered for the traits like days to 50% flowering, days to maturity, seeds per pod and protein content under both the conditions (Table 2). Higher difference between phenotypic variance and genotypic variance, indicating more contribution of environment in the phenotypic appearance of the traits than their genetic makeup.

In the present study, the magnitude of phenotypic coefficient of variation (PCV) was higher than genotypic coefficient of variation (GCV) for all the characters in all the crosses under both irrigated and rainfed conditions (Table 2), indicated environmental effects on the expression of characters. The high estimates of GCV and PCV were obtained for fruiting branches per plant, pods per plant, seeds per pod, biological yield per plant, seed yield per plant and 100 seed weight in most of the crosses under both the conditions and for harvest index in the crosses RSG-895 × RSG-888 and RSG-888 × ICC-4958 under irrigated condition. Moderate values of GCV and PCV were observed for plant height and harvest index and low values of GCV and PCV were recorded for days to 50% flowering, days to maturity and protein content in most the crosses under both the conditions. These findings were in accordance with the reports of Bala *et al.* (2015), Tiwari *et al.* (2016), Talekar *et al.* (2017), Raval *et al.* (2018) and Rathod *et al*. (2020).

High heritability (broad sense) estimates were obtained for pods per plant in most of the crosses under both the conditions. For days maturity in RSG-895 × RSG-888, for plant height in CSJD-901 × RSG-931, for seed yield per plant in RSG-895 × RSG-888 and CSJD-901 × RSG-931, for harvest index in RSG-895 × RSG-888 and RSG-888 × ICC-4958 under irrigated condition and for days to 50% flowering in IPC-94-94 × RSG-888 under rainfed condition. This result indicates that these traits were highly heritable and less affected by the environment. Such types of results were also reported by Joshi *et al.* (2018), Babbar and Tiwari (2018) and Parmar and Monpara (2019).

High heritability coupled with high genetic

Table 1. Analysis of variance (mean squares) for different characters in chickpea under irrigated (IRG) and rainfed (RF) conditions. *, ** Significant at 5% and 1% level, respectively.

Characters/ Source of variation	df	Days to 50% flowering	Days to maturity	Plant height (cm)	Fruiting branches per plant	Pods per plant	Seeds per pod	Biological yield per plant (g)	Seed yield per plant (g)	Harvest index (%)	100 seed weight (g)	Protein content (%)
Irrigated												
Replications	2	0.070	0.174	0.058	0.258	0.578	0.002	0.365	0.131	0.248	0.098	0.016
Crosses	4	51.708**	88.793**	55.084**	1.455**	24.465**	0.045**	19.267**	7.788**	7.848**	35.574**	0.622**
Error	8	0.096	0.316	0.449	0.172	1.405	0.001	0.318	0.130	0.603	0.086	0.023
Rainfed												
Replications	2	0.037	0.167	0.148	0.043	1.281	0.003	0.478	0.089	0.251	0.030	0.005
Crosses	4	198.05**	147.186**	19.633**	6.927**	52.503**	0.019**	22.987**	18.029**	51.117**	29.679**	0.689**
Error	8	0.081	0.033	0.231	0.106	0.499	0.001	0.271	0.219	0.205	0.165	0.008

Table 2. Mean, variances, coefficient of variation, heritability and genetic advance as percentage of mean (GAM) in F_2 generation in each of five chickpea crosses for different characters under irrigated (IRG) and rainfed (RF) conditions.

Cross/Character	Env	Mean	Variance		Coefficient of variation		Heritability (%)	Genetic advance	GAM (%)
			Genotypic	Phenotypic	Genotypic	Phenotypic			
Days to 50% flowering									
RSG-895 × RSG-888	IRG	93.00	0.92	3.25	1.03	1.94	28.00	1.04	1.12
	RF	83.32	0.15	1.31	0.46	1.37	11.00	0.26	0.31
RSG-888 × ICC-4958	IRG	94.00	0.41	1.22	0.68	1.18	34.00	0.77	0.82
	RF	87.00	0.09	1.22	0.35	1.27	8.00	0.18	0.21
IPC-94-94 × RSG-888	IRG	87.67	2.93	5.24	1.95	2.61	56.00	2.64	3.01
	RF	66.33	2.60	4.16	2.43	3.08	63.00	2.65	4.00
CSJD-901 × RSG-931	IRG	92.04	0.11	1.41	0.36	1.29	8.00	0.20	0.22
	RF	85.87	0.08	1.32	0.33	1.34	6.00	0.14	0.16
BG-362 × RSG-931	IRG	95.33	0.67	1.45	0.86	1.26	46.00	1.14	1.20
	RF	93.63	0.10	1.23	0.34	1.18	8.00	0.18	0.19
Days to maturity									
RSG-895 × RSG-888	IRGs	138.67	8.16	10.94	2.06	2.38	75.00	5.11	3.69
	RF	130.67	0.64	3.07	0.61	1.34	21.00	0.76	0.58
RSG-888 × ICC-4958	IRG	138.00	1.73	4.75	0.95	1.58	37.00	1.66	1.2
	RF	134.03	0.64	3.07	0.60	1.31	21.00	0.76	0.57
IPC-94-94 × RSG-888	IRG	125.00	6.52	15.05	2.04	3.10	43.00	3.44	2.75
	RF	114.00	1.18	4.88	0.95	1.94	24.00	1.09	0.96
CSJD-901 × RSG-931	IRG	134.67	0.81	3.48	0.67	1.38	23.00	0.88	0.65
	RF	128.94	0.65	3.55	0.63	1.46	18.00	0.70	0.54
BG-362 × RSG-931	IRG	134.10	1.00	3.99	0.75	1.49	25.00	1.03	0.77
	RF	132.33	1.50	4.56	0.92	1.61	33.00	1.45	1.10
Plant height (cm)									
RSG-895 × RSG-888	IRG	61.00	26.31	57.20	8.41	12.40	46.00	7.17	11.75
	RF	52.33	3.41	26.36	3.53	9.81	13.00	1.37	2.62
RSG-888 × ICC-4958	IRG	59.23	0.91	42.04	1.61	10.95	2.00	0.27	0.46
	RF	52.82	13.93	29.91	7.06	10.35	47.00	5.30	10.03
IPC-94-94 × RSG-888	IRG	50.23	13.86	41.95	7.41	12.89	33.00	4.4	8.76
	RF	48.05	16.50	34.59	8.45	12.24	48.00	5.82	12.11
CSJD-901 × RSG-931	IRG	56.45	37.35	55.57	10.83	13.21	67.00	10.29	18.23
	RF	50.92	2.80	32.79	3.29	11.25	9.00	1.06	2.08
BG-362 × RSG-931	IRG	60.45	8.68	34.83	4.87	9.76	25.00	3.04	5.03
	RF	55.18	10.61	30.23	5.90	9.96	35.00	3.96	7.18
Fruiting branches per plant									
RSG-895 × RSG-888	IRG	17.68	2.74	13.21	9.36	20.56	21.00	1.57	8.88
	RF	11.28	2.62	8.48	14.34	25.80	31.00	1.86	16.48
RSG-888 × ICC-4958	IRG	16.70	0.35	11.94	3.55	20.69	3.00	0.21	1.26
	RF	13.97	1.69	14.10	9.30	26.88	12.00	0.93	6.66
IPC-94-94 × RSG-888	IRG	16.78	5.03	19.56	13.36	26.36	26.00	2.37	14.12
	RF	13.51	1.97	13.52	10.40	27.21	15.00	1.14	8.44
CSJD-901 x RSG-931	IRG	16.43	5.93	21.83	14.83	28.43	27.00	2.6	15.82
	RF	15.13	7.83	15.75	18.49	26.23	50.00	4.09	27.03
BG-362 × RSG-931	IRG	17.32	10.48	23.64	18.69	28.07	44.00	4.41	25.46
	RF	15.37	13.69	27.49	24.07	34.11	50.00	5.40	35.13

Table 2. Continued.

Cross/Character	Env	Mean	Variance		Coefficient of variation		Heritability (%)	Genetic advance	GAM (%)
			Genotypic	Phenotypic	Genotypic	Phenotypic			
Pods per plant									
RSG-895 × RSG-888	IRG	62.75	158.66	317.78	20.07	28.41	50.00	18.36	29.26
	RF	50.63	112.46	166.54	20.95	25.49	68.00	18.08	35.71
RSG-888 × ICC-4958	IRG	63.28	74.16	137.87	13.61	18.56	54.00	13.06	20.64
	RF	55.72	163.53	245.60	22.95	28.13	67.00	21.63	38.82
IPC-94-94 × RSG-888	IRG	60.17	144.39	208.62	19.97	24.00	69.00	20.53	34.12
	RF	51.00	86.99	140.20	18.29	23.22	62.00	15.12	29.65
CSJD-901 × RSG-931	IRG	61.37	154.78	235.05	20.27	24.98	66.00	20.84	33.96
	RF	55.67	171.79	263.24	23.54	29.14	65.00	21.72	39.02
BG-362 × RSG-931	IRG	61.58	167.13	239.98	20.99	25.16	70.00	22.34	36.28
	RF	51.52	475.68	627.66	42.33	48.63	76.00	39.22	76.13
Seeds per pod									
RSG-895 × RSG-888	IRG	1.68	0.03	0.32	10.11	33.72	9.00	0.11	6.55
	RF	1.78	0.01	0.15	5.90	21.38	8.00	0.06	3.36
RSG-888 × ICC-4958	IRG	1.47	0.23	0.43	32.41	44.54	53.00	0.71	48.3
	RF	1.55	0.09	0.17	19.04	26.80	50.00	0.43	27.74
IPC-94-94 × RSG-888	IRG	1.67	0.21	0.45	27.57	40.37	47.00	0.65	38.92
	RF	1.65	0.12	0.25	21.26	30.54	48.00	0.50	30.30
CSJD-901 × RSG-931	IRG	1.79	0.10	0.26	17.35	28.29	38.00	0.4	22.35
	RF	1.72	0.03	0.17	10.37	24.06	19.00	0.16	9.28
BG-362 × RSG-931	IRG	1.76	0.13	0.36	20.71	34.22	37.00	0.46	26.11
	RF	1.61	0.03	0.20	11.25	27.54	17.00	0.16	9.94
Biological yield per plant (g)									
RSG-895 × RSG-888	IRG	41.11	25.88	74.53	12.37	21.00	35.00	6.22	15.13
	RF	35.68	17.08	62.40	11.58	22.14	27.00	4.39	12.30
RSG-888 × ICC-4958	IRG	48.32	1.19	71.56	2.25	17.51	2.00	0.35	0.72
	RF	39.29	1.02	54.99	2.58	18.87	2.00	0.31	0.79
IPC-94-94 × RSG-888	IRG	43.27	9.48	51.29	7.11	16.55	18.00	2.66	6.15
	RF	35.77	2.30	44.77	4.24	18.71	5.00	0.69	1.93
CSJD-901 × RSG-931	IRG	38.11	53.21	93.46	19.14	25.37	57.00	11.35	29.78
	RF	35.52	14.20	54.17	10.61	20.72	26.00	3.94	11.09
BG-362 × RSG-931	IRG	44.46	40.79	93.26	14.37	21.72	44.00	8.75	19.68
	RF	38.27	80.34	150.93	23.42	32.10	53.00	13.41	35.04
Seed yield per plant (g)									
RSG-895 × RSG-888	IRG	18.63	16.28	26.03	21.66	27.38	63.00	6.62	35.53
	RF	14.60	1.56	15.49	8.56	26.96	10.00	0.81	5.55
RSG-888 × ICC-4958	IRG	20.73	13.28	26.61	17.58	24.88	50.00	5.31	25.62
	RF	19.26	0.24	22.77	2.54	24.78	1.00	0.10	0.52
IPC-94-94 × RSG-888	IRG	19.08	1.90	13.01	7.22	18.90	15.00	1.11	5.82
	RF	16.60	0.15	16.03	2.35	24.12	1.00	0.08	0.48
CSJD-901 × RSG-931	IRG	15.09	20.04	31.23	29.66	37.03	64.00	7.37	48.83
	RF	14.23	5.11	17.84	15.88	29.68	29.00	2.52	17.71
BG-362 × RSG-931	IRG	20.00	11.05	22.00	16.62	23.45	50.00	4.83	24.15
	RF	18.21	26.31	44.27	28.17	36.54	59.00	8.09	44.43
Harvest index (%)									
RSG-895 × RSG-888	IRG	46.45	149.68	199.85	26.34	30.43	75.00	21.84	47.02

Table 2. Continued.

Cross/Character	Env	Mean	Variance		Coefficient of variation		Heritability (%)	Genetic advance	GAM (%)
			Genotypic	Phenotypic	Genotypic	Phenotypic			
Harvest index (%)									
	RF	43.35	26.61	82.12	11.90	20.90	32.00	5.97	13.77
FSG-888 × ICC-4958	IRG	47.85	127.93	168.75	23.64	27.15	76.00	20.34	42.51
	RF	50.12	12.71	62.62	7.11	15.79	20.00	3.26	6.50
IPC-94-94 × RSG-888	IRG	47.08	44.00	73.70	14.09	18.23	60.00	10.61	22.54
	RF	49.14	0.81	41.82	1.84	13.16	2.00	0.27	0.55
CSJD-901 × RSG-931	IRG	44.19	3.03	40.98	3.94	14.49	7.00	0.92	2.08
	RF	40.06	11.18	37.75	8.34	15.34	30.00	3.80	9.49
BG-362 × RSG-931	IRG	46.02	4.98	58.99	4.85	16.69	8.00	1.27	2.76
	RF	48.86	0.66	31.71	1.66	11.53	2.00	0.23	0.47
100 seed weight (g)									
RSG-895 × RSG-888	IRG	17.00	6.29	13.36	14.76	21.50	47.00	3.54	20.82
	RF	16.60	0.14	12.47	2.25	21.28	1.00	0.07	0.42
RSG-888 × ICC-4958	IRG	25.46	7.16	17.28	10.51	16.33	41.00	3.51	13.79
	RF	23.93	0.24	12.61	2.05	14.84	2.00	0.15	0.63
IPC-94-94 × RSG-888	IRG	22.56	13.71	25.41	16.41	22.35	54.00	5.61	24.87
	RF	22.20	0.11	11.60	1.52	15.34	1.00	0.07	0.32
CSJD-901 × RSG-931	IRG	17.14	4.66	8.11	12.59	16.61	57.00	3.34	19.49
	RF	16.50	0.55	11.74	4.48	20.77	5.00	0.35	2.12
BG-362 × RSG-931	IRG	24.22	0.10	8.46	1.29	12.01	1.00	0.06	0.25
	RF	23.56	0.11	10.31	1.38	13.63	1.00	0.07	0.30
Protein content (%)									
RSG-895 x RSG-888	IRG	17.29	0.11	0.69	1.94	4.79	16.00	0.27	1.56
	RF	17.99	0.14	0.75	2.11	4.82	19.00	0.34	1.89
RSG-888 x ICC-4958	IRG	18.38	0.09	0.66	1.61	4.43	13.00	0.22	1.20
	RF	18.57	0.14	0.72	2.02	4.57	20.00	0.35	1.88
IPC-94-94 x RSG-888	IRG	18.25	0.02	0.65	0.68	4.41	2.00	0.03	0.16
	RF	18.38	0.19	0.79	2.34	4.83	24.00	0.44	2.39
CSJD-901 x RSG-931	IRG	18.19	0.50	1.09	3.89	5.74	46.00	0.99	5.44
	RF	18.60	0.16	0.72	2.13	4.55	22.00	0.38	2.04
BG-362 x RSG-931	IRG	18.63	0.04	0.62	1.09	4.23	7.00	0.11	0.59
	RF	19.25	0.36	0.93	3.11	5.00	39.00	0.77	4.00

advance as percentage of mean (GAM) for pods per plant were observed in most of the crosses under both the conditions. RSG-895 × RSG-888 showed high heritability coupled with high GAM for seed yield per plant and harvest index, CSJD-901 × RSG-931 for seed yield per plant, RSG-888 × ICC-4958 for harvest index in irrigated condition. These results indicated the importance of additive gene action in inheritance of these characters, hence simple selection can be used to improve seed yield. Moderate heritability coupled with high GAM in both irrigated and rainfed conditions was observed in BG-362 × RSG-931 for fruiting branches per plant and seed yield per plant, in RSG-888 × ICC-4958 and IPC-94-94 × RSG-888 for seeds per pod. Moderate heritability coupled with high GAM in irrigated condition was observed in RSG-895 × RSG-888 and RSG-888 × ICC-4958 for pods per plant, in CSJD-901 × RSG-931 and BG-362 × RSG-931for seeds per pod, in CSJD-901 ×RSG-931 for biological yield per plant, in RSG-888 × ICC-4958 for seed yield per plant, in IPC-94-94 × RSG-888 for harvest index, in RSG-895 × RSG-888 and IPC-94-94 × RSG-888 for 100 seed weight. In rainfed condition moderate heritability coupled with high GAM was observed in CSJD-901 × RSG-931 for fruiting branches per plant, in BG-362 × RSG-931

Table 3. Phenotypic correlation among different characters in the F_2 populations of chickpea crosses under irrigated (IRG) and rainfed (RF) conditions. *, ** Significant at 5% and 1% level, respectively.

Characters	ENV	Days to 50% flowering	Days to maturity	Plant height (cm)	Fruiting branches per plant	Pods per plant	Seeds per pod	Biological yield per plant (g)	Seed yield per plant (g)	Harvest index (%)	100-seed weight (g)	Protein content (%)
Days to 50% flowering	IRG	-	0.803**	0.720**	0.055	0.056	0.000	0.109	0.107	-0.022	0.140	0.124
	RF	-	0.270**	0.295**	0.122	-0.096	-0.048	-0.022	-0.048	-0.069	0.029	0.539**
Days to maturity	IRG		-	0.687**	0.064	0.093	-0.078	0.040	0.028	-0.015	-0.150	-0.341**
	RF		-	0.501**	0.039	0.058	-0.031	0.118	0.089	-0.078	-0.029	0.243*
Plant height (cm)	IRG			-	0.121	0.119	0.004	0.158	0.091	-0.006	-0.089	-0.157
	RF			-	0.194	0.206*	0.000	0.286**	0.245*	0.018	0.143	0.270**
Fruiting branches per plant	IRG				-	0.699**	0.026	0.669**	0.578**	-0.118	-0.164	-0.070
	RF				-	0.722**	-0.141	0.740**	0.696**	0.102	0.148	0.334**
Pods per plant	IRG					-	-0.060	0.748**	0.675**	0.022	-0.059	-0.022
	RF					-	-0.128	0.811**	0.748**	0.149	-0.034	-0.053
Seeds per pod	IRG						-	-0.166	-0.140	-0.204*	-0.093	-0.025
	RF						-	-0.138	-0.220*	-0.253*	-0.206*	-0.105
Biological yield per plant(g)	IRG							-	0.811**	0.038	0.192	0.189
	RF							-	0.860**	0.124	0.137	0.050
Seed yield per plant (g)	IRG								-	0.286**	0.302**	0.041
	RF								-	0.528**	0.334**	0.164
Harvest index (%)	IRG									-	0.106	-0.036
	RF									-	0.469**	0.165
100 seed weight (g)	IRG										-	0.509**
	RF										-	0.420**
Protein content (%)	IRG											-
	RF											-

for biological per plant. These results indicating the preponderance of additive gene action and selection pressure could profitably be applied on these characters for yield improvement in respective environment. Moderate to high heritability along with high GAM were also reported by Babbar *et al.* (2015), Joshi *et al.* (2018), Gautam *et al.* (2021) and Singh *et al.* (2021).

The phenotypic correlation coefficient for studied characters under irrigated and rainfed conditions are presented in Table 3. Days to 50% flowering had significant positive association with days to maturity and plant height in both the conditions and with protein content in rainfed condition. Days to maturity had significant positive association with plant height in both the condition and with protein content in rainfed condition. Protein content had significant positive association with 100 seed weight in both the conditions, with days to 50% flowering, days maturity, plant height and fruiting branches per plant in rainfed condition and with days to maturity in irrigated condition. Seeds per pod had significant negative association with harvest index in both the conditions, seed yield per plant and 100 seed weight in rainfed condition. Seed yield per plant had positive and significant correlation with fruiting branches per plant, pods per plant, biological yield per plant, harvest index and 100 seed weight under both the conditions and with plant height in rainfed condition. Further, these characters were also significantly positively correlated. So selection based on these characters is expected to bring improvement in the seed yield. These results confirm the findings of earlier workers (Talekar *et al.* 2017, Manasa *et al*. 2019, Rathod *et al.* 2020, Madhuri *et al.* 2020).

CONCLUSION

The highest range of variation was observed for 100 seed weight followed by seed yield per plant, biological yield per plant, seeds per pod and plant height in irrigated condition, while in rainfed condition the highest range of variation was registered by 100 seed weight followed by days to 50% flowering, fruiting branches per plant, seed yield per plant, days to maturity and harvest index. Hence, selection should be

done on characters having wide range of variation under the respective environmental condition. The high estimates of GCV and PCV were obtained for fruiting branches per plant, pods per plant, seeds per pod, biological yield per plant, seed yield per plant and 100 seed weight in most of the crosses under both the conditions and for harvest index in the crosses RSG-895 x RSG-888 and RSG-888 × ICC-4958 under irrigated condition. High heritability coupled with high genetic advance as percentage of mean (GAM) was observed for pods per plant in most of the crosses under both the conditions. RSG-895 x RSG-888 showed high heritability coupled with high GAM for seed yield per plant and harvest index, CSJD-901 x RSG-931 for seed yield per plant, RSG-888 x ICC-4958 for harvest index under irrigated condition, indicated the importance of additive gene action in inheritance of these characters; hence, phenotypic selection would be effective for improvement of these characters. Seed yield per plant had positive and significant correlation with fruiting branches per plant, pods per plant, biological yield per plant, harvest index and 100 seed weight under both the conditions and with plant height in rainfed condition only. Further, these characters were also significantly positively correlated. So selection based on these characters is expected to bring improvement in the seed yield. Further, as per association analysis selection based on fruiting branches per plant, pods per plant, biological yield per plant, harvest index and 100 seed weight under both irrigated and rainfed conditions and on plant height in rainfed condition may bring improvement in seed yield of chickpea.

ACKNOWLEDGMENT

The authors declare no known conflict of interests that could have appeared to influence the work reported in this paper.

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