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Estimation of Heterosis for Seed Yield and Yield Contributing Characters of Desi x Desi Crosses of Chickpea (*Cicer arietinum* L.) under Late Sown Condition

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Authors' contributions

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

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ABSTRACT

Aims: To estimate the relative heterosis & heterobeltiosis for seed yield and it's contributing characters in chickpea. The study was conducted in chickpea for the evaluation of genetic makeup of chickpea genotypes and their further use in chickpea improvement program, information regarding their mean performance and heterosis is very helpful.

Study Design: Randomized block design (RBD) was followed.

Place and Duration of Study: The experiment was conducted at research farm, Rajasthan Agricultural Research Institute, Durgapura (SKNAU, Jobner, Jaipur, Rajasathan) during *rabi*2019-2022.

Methodology: An investigation consisted of eight chickpea genotypes *viz*., RSG-888, CSJD-884, RSG-963, RSG-973, RSG-974, CSJ-515, Avrodhi and HC-5 and crossed in all possible combinationswere raised inrandomized block design (RBD) with three replications in late sown condition December, 2021.

Results: The ANOVA (Analysis of Variance) for different characters revealed that the significant mean square due to generations and parents for all the studied characters under study.The maximum relative heterosis over mid-parent was observed as 49.99 per cent (CSJ-515 × HC-5). Similarly, maximum heterosis over better parent was observed as 35.46 per cent (RSG-973 × HC-5). Therefore, these crosses were observed more heterotic as well as heterobeltiotic for seed yield per plant under late sown environment.

Conclusion: In this study additive and non additive type of gene actions were important in governing all traits studied resulting in high heterosis in selected cross combinations for seed yield per plant and attributed traits.

Keywords: Chickpea; genotypes; diallel; relative heterosis; heterobeltiosis.

1. INTRODUCTION

Chickpea (*Cicer arietinum* L.) is a self-pollinated crop of family *Leguminaceae.* Chickpea commonly known as Gram, Chana and Bengal gram. Chickpea plant is a diploid species with 2n=2x=l6 chromosomes. Chickpea is said to be one of the first grain legumes domesticated by humans in the old world [1]. Chickpea is grown in many tropical, subtropical and temperate regions of the world. India isthe largest chickpea producer as well as consumer inthe world.Chickpea is one of the most important pulsecrops of India due to its multiple functions intraditional farming system and multiple uses in humandiet in the form of green leaves, green seed for vegetables, *sattu,* flour, roasted grain as well as for making local beverage known as *Chhang* [2].

Chickpea is classified into two distinct types: the desi type with pink flowers, anthocyanin pigmentation on stems small, angular, dark coloured seeds and the kabuli type with large, white flowers, lacking anthocyanin pigmentation on stems, smooth coated, beige seeds. This classification overlaps, to a particular extent, with the macrosperma and microsperma races [3]. Chickpea is good source of dietary protein, carbohydrates andminerals like Fe and Zn. The protein content of chickpea seed ranges from 16.7% - 30.6% and 12.6% to 29.0% for desi and *kabuli* types, respectively while the range of Fe content from 3-14 mg/100 g, Zn content from 2.2-20 mg/100 g, Mg content from 107.4-168 mg/100 g and Ca content from 68-269 mg/100 g found in chickpea seeds [4].

The global chickpea area is about 14.84 million hectares with a production of 15.08 million tonnes with an average yield of 1,016 kg/ha [5]. In India, chickpea is cultivated on an area of 9.85 million hectares with production of 11.99 million tonnes and productivity of 1217 kg/ha [6]. In Rajasthan, chickpea occupies about 2.26 million hectares area with production of 2.66 million tonnes with a productivity of 1177 kg/ha [7].

Diallel analysis is one of the most important approaches to know the heterotic effect of the generations. For the evaluation of genetic makeup of chickpea genotypes and their further use in chickpea improvement program, information regarding their mean performance and heterosis is very helpful. The genetic based variability is an essential pre-requisite for a breeding programme aimed at the improvement of any crop. Hybridization, among parents, selected for specific objectives may be an effective tool to increase variability for specific traits. The hybrids with high heterotic effects are more likely to produce segregants with better performance than those with low heterotic effects [8]. The present study was therefore, designed to estimate the heterotic effects in chickpea and then to use these information for further exploitation of the hybrids for variety development.

2. MATERIALS AND METHODS

The 8 parents mentioned above were grown at Research Farm, Rajasthan Agricultural Research Institute (Sri Karan Narendra Agriculture University, Jobner), Durgapura, Jaipur during *Rabi* 2019-20 & 2020-21 were crossed in diallel fashion (excluding reciprocals) in all possible combinations. In *Rabi*2020-21 &2021-22 eight varieties were evaluated in late sown environment with three replications in randomized block design at Agricultural Research Farm, RARI, Durgapura (Jaipur). The rows with 3 m length, row to row and plant to plant distance was kept 30 cm and 10 cm, respectively. Non-experimental rows were planted all around the experiment to eliminate the border effects, if any. All recommended agronomical package of practices were adopted to raise good crop. Observations recorded for days to first flowering, days to 50% flowering, days to first pod formation, days to last pod development, days to maturity, first pod height, plant height, no. of primary branches/plant, no. of secondary branches/plant, pods per plant, seeds per pod, biological yield per plant, seed yield per plant, harvest index and 100-seed weight.

2.1 Statistical Analysis

1 Relative heterosis (Heterosis over mid parent)

Percent relative heterosis of a cross was calculated by the following formula:-

$$\text{Relative heterosis in per cent} = \frac{\overline{\text{F}_1} - \overline{\text{MP}}}{\overline{\text{MP}}} \times 100$$

2 Heterobeltiosis (Heterosis over better parent)

Percent heterobeltiosis of a cross was calculated by the following formula :-

$$\text{Heterobeltiosis in per cent} = \frac{\overline{\text{F}_1} - \overline{\text{BP}}}{\overline{\text{BP}}} \times 100$$

3 Inbreeding depression

Inbreeding depression as per cent increase or decrease in the mean value of F_2 over F_1 was calculated as follows: -

$$\text{Inbreeding depression in per cent} = \frac{\overline{\text{F}_1} - \overline{\text{F}_2}}{\overline{\text{F}_1}} \times 100$$

Where, F_1 and F_2 were the means over replications of a particular cross.

3. RESULTS AND DISCUSSION

The significant mean squares due to parents, genotypes and generations for all the characters in late sown environment. Further analysis showed significant mean square due to generations and parents for all the studied characters. Mean square due to F_1 and F_2 generations were found significant for all the studied characters except harvest index. Earlier scientists *viz*., Sharif et al. [9], Bhardwaj et al. [10] and Hemati et al. [11]also obtained similar result for most of the characters. The genotypic mean squares due to parents vs generation were significant for all the studied characters (Table 1). Significant differences among parents vs generation indicated the presence of heterosis in the hybrid which may be exploited for the development of high yielding chickpea genotypes. The results are in accordance with earlier findings of Parameshwarappa et al. [12], Gadekar and Dodiya [13], Babbar [14]and Sasane et al. [15].

The expression of heterosis, in general, was variable for different yield traits. It was more pronounced for biological yield per plant, seed yield per plant, harvest index, pods per plant, number of primary and secondary branches and 100-seed weight. On the basis of overall range of relative heterosis and heterobeltiosis, the traits like seed yield per plant, harvest index, pods per plant, biological yield per plant and number of primary and secondary branches were found to be the most heterotic traits in late sown environment.

Early flowering in chickpea is desirable, therefore Out of 28 crosses, twenty three and seven crosses exhibited significant negative relative heterosis and heterobeltiosis for days to first flowering. Eighteen and ten crosses exhibited negative and significant relative heterosis and heterobeltiosis for days to 50% flowering. Eighteen and five crosses exhibited

Table 1. Analysis of variance showing mean sum of squares in late sown environment for parents, F_1's and F_2's for yield, yield components

Characters	Source of variation								
	Replications	Genotypes	Parents	Generation	F_1's	F_2's	F_1 *vs* F_2	Parents vs generation	Error
Df	2	63	7	55	27	27	1	1	126
Days to first flowering	1.33	10.43**	16.00**	6.02**	6.03**	2.95**	88.60**	213.76**	0.94
Days to 50% flowering	0.04	10.53**	22.19**	6.25**	6.72**	4.38**	44.02**	164.36**	1.08
Days to first pod formation	0.01	7.98**	10.17**	6.25**	6.72**	4.38**	44.02**	88.05**	1.10
Days to last pod development	0.32	7.51**	5.81**	5.26**	5.06**	4.05**	43.01**	143.39**	0.77
Days to maturity	2.44	9.54**	8.45**	6.59**	9.39**	3.76**	7.29*	179.38**	1.37
First pod height	1.85	12.81**	19.98**	8.80**	9.17**	8.41**	9.57*	182.83**	2.01
Plant height	1.37	51.43**	16.64*	56.27**	45.92**	67.41**	34.96*	28.62*	7.27
No. of primary branches/plant	0.01	0.50**	0.72**	0.34**	0.34**	0.32**	0.96**	7.34**	0.09
No. of secondary branches/plant	0.48	2.63**	2.11**	2.38**	2.38**	2.34**	3.68**	19.58**	0.50
Pods per plant	0.38	43.67**	46.89**	37.34**	37.19**	35.93**	79.41*	369.39**	12.51
Seeds per pod	0.011	0.093**	0.049**	0.094**	0.095**	0.092**	0.11**	0.347**	0.014
Biological yield per plant	2.86	80.42**	67.5**	80.91**	75.78**	88.65**	10.32*	143.99**	2.48
Seed yield per plant	0.23	5.63**	5.87**	5.32**	6.14**	4.59**	2.70**	21.29**	0.34
Harvest index	33.91	68.02**	18.27	73.37**	63.25**	84.66**	41.92	121.95**	12.11
100-seed weight	0.72	4.54**	2.73**	4.31**	4.89**	3.59**	8.26**	29.50**	0.81

**, **Significant at 5 and 1 percent levels, respectively*

Table 2. Estimation of relative heterosis (RH), heterobeltiosis (HB) and inbreeding depression (ID) for yield and other yield contributing traits in late sown environment

Crosses	Days to first flowering			Days to 50% flowering			Days to first pod formation		
	RH	HB	ID	RH	HB	ID	RH	HB	ID
RSG-888 × CSJD-884	-2.91*	-1.96	4*	-1.82	1.25	3.09	-2.70*	-1.22	3.09
RSG-888 × RSG-963	-0.99	0	3.33*	-0.90	1.23	3.03	1.85	3.13*	3.03
RSG-888 × RSG-973	-1.33	0.68	4.05*	-2.70*	-0.61	0.62	0.62	2.53	0.62
RSG-888 × RSG-974	-0.67	2.07	4.05*	-0.92	3.18*	1.23	0	1.25	1.23
RSG-888 × CSJ-515	-0.33	0	7.84**	-2.94*	-2.94*	3.64*	-2.08	0.61	3.64*
RSG-888 × Avrodhi	-4.4**	-0.65	3.95*	-4.90**	-2.94*	0.61	-0.6	0.61	0.61
RSG-888 × HC-5	-6.67**	-3.92*	-0.68	-8**	-5.29**	-2.48	-3.59**	-1.83	-2.48
CSJD-884 × RSG-963	-3.92**	-2	2.04	-0.93	0	1.25	-2.74*	0	1.25
CSJD-884 × RSG-973	-3.63**	-0.68	2.05	-1.55	-0.63	-0.63	-2.75*	0.63	-0.63
CSJD-884 × RSG-974	0.33	4.14*	5.3**	2.21	3.18*	3.70*	-1.52	1.25	3.70*
CSJD-884 × CSJ-515	-3.23*	-2.60	6.67**	0	3.13*	6.06**	-3.51**	-2.37	6.06**
CSJD-884 × Avrodhi	-5.30**	-2.56	7.89**	-2.67*	2.50	6.10**	-2.67*	-2.38	6.1**
CSJD-884 × HC-5	-5.03**	-3.21*	3.31*	-2.94*	3.13*	3.03	-2.65*	-2.37	3.03
RSG-963 × RSG-973	-3.03*	-2.04	0.69	-3.07*	-3.07*	0.63	-0.63	0	0.63
RSG-963 × RSG-974	-4.41**	-2.76	0	-3.13*	-1.27	0	-3.13*	-3.13*	0
RSG-963 × CSJ-515	-7.89**	-6.67**	-0.71	-6.91**	-4.91**	-2.58	-6.91**	-3.13*	-2.58
RSG-963 × Avrodhi	-10.48**	-6**	1.42	-10**	-6.13**	0	-6.71**	-4.38**	0
RSG-963 × HC-5	-7.69**	-4*	0	-10.79**	-6.13**	-0.65	-7.27**	-4.38**	-0.65
RSG-973× RSG-974	-3.42*	-2.76	0.71	-1.88	0	0	-1.26	-0.63	0
RSG-973 × CSJ-515	-4.32**	-2.04	3.47*	-5.11**	-3.07*	1.90	-4.53**	0	1.90
RSG-973 × Avrodhi	-9.62**	-4.08*	1.42	-9.41**	-5.52**	0.65	-5.52**	-2.53	0.65
RSG-973 × HC-5	-7.44**	-2.72	4.20*	-7.29**	-2.45	5.66**	-3.05*	0.63	5.66**
RSG-974 × CSJ-515	-3.01*	0	4.83**	-1.53	2.55	4.97**	-3.30**	0.62	4.97**
RSG-974 × Avrodhi	-7.74**	-1.38	3.50*	-2.99*	3.18*	4.32**	-1.22	1.25	4.32**
RSG-974 × HC-5	-8.14**	-2.76	-0.71	-7.42**	-0.64	-1.28	-5.45**	-2.50	-1.28
CSJ-515 × Avrodhi	-4.08**	-0.65	4.58**	-1.44	0.59	5.85**	0.29	1.79	5.85**
CSJ-515 × HC-5	-4.43**	-1.95	2.65	-4.57**	-1.76	2.99	-2.62*	-1.76	2.99
Avrodhi × HC-5	-9.48**	-8.64**	2.03	-9.24**	-8.47**	0.62	-4.14**	-3.57*	0.62
SE	0.67	0.77	0.80	0.66	0.77	0.86	0.68	0.79	0.88

Table 2 Contd…..

Crosses	Days to last pod development			Days to maturity			First pod height		
	RH	HB	ID	RH	HB	ID	RH	HB	ID
RSG-888 × CSJD-884	-3.14**	-2.26*	-1.39	-4.48**	-3.90**	-1.25	-4.38	-0.98	6.76
RSG-888 × RSG-963	0	0.92	1.37	-3.87**	-3.58**	0.31	-12.38**	-10.9*	5.14
RSG-888 × RSG-973	-1.36	-1.36	1.38	-3.93**	-2.15*	-2.20**	-11.29**	-9.49*	-4.79
RSG-888 × RSG-974	-1.57*	-0.90	0	-3.58**	-3**	-2.79**	-7.25	-4.17	-3.40
RSG-888 × CSJ-515	-0.67	1.36	4.91**	-5.2**	-5.06**	-1.57*	-16.32**	-11.20*	-0.73
RSG-888 × Avrodhi	0.45	1.81*	3.56**	-2.94**	-2.08*	0.91	-4.70	0.39	-4.93
RSG-888 × HC-5	-0.45	0.90	1.79	-1.34	-1.19	1.20	-9.06**	1.30	3.21
CSJD-884 × RSG-963	-1.36	0.46	-2.29*	-3.59**	-3.30**	0.62	-7.53	-5.86	-2.81
CSJD-884 × RSG-973	-1.79*	-0.9	1.37	-1.52	-0.31	0.62	-6.67	-5.30	-1.91
CSJD-884 × RSG-974	-2.45**	-2.23*	0.91	-1.50	-1.50	1.22	-10.68**	-4.32	-1.17
CSJD-884 × CSJ-515	-2.42**	-1.33	5.41**	-4.33**	-3.90**	0	-16.91**	-8.51	-3.20
CSJD-884 × Avrodhi	-1.33	-0.89	4.04**	-0.30	1.20	2.97**	-7.72*	0.84	-0.55
CSJD-884 × HC-5	-2.21**	-1.78*	0.90	-1.94*	-1.50	0	-16.27**	-3.07	-3.74
RSG-963 × RSG-973	-0.46	0.46	2.29*	-1.52	0	0.92	-15.6**	-15.31**	1.28
RSG-963 × RSG-974	-2.95**	-1.38	1.40	-4.49**	-4.20**	-0.63	-17.67**	-13.46**	1.71
RSG-963 × CSJ-515	-5.15**	-2.30*	-0.94	-2.83**	-2.69**	2.15**	-9.91**	-2.69	5.26
RSG-963 × Avrodhi	-4.05**	-1.84*	0.94	-3.24**	-2.09*	-0.61	-7.97*	-1.35	2.73
RSG-963 × HC-5	-2.70**	-0.46	0	-1.04	-0.90	0.90	-3.80	9.15*	2.10
RSG-973× RSG-974	-3.82**	-3.17**	-0.93	-0.61	0.62	1.22	-7.90*	-2.85	1.12
RSG-973 × CSJ-515	-3.77**	-1.81*	1.84	0.76	2.46*	2.40**	-7.25	0.54	3.77
RSG-973 × Avrodhi	-5.36**	-4.07**	0.94	-2.10*	0.62	-0.61	-0.25	7.32	8.59
RSG-973 × HC-5	-4.91**	-3.62**	2.35*	-3.18**	-1.54	-1.88**	-5.89	7.18	-4.42
RSG-974 × CSJ-515	-4.85**	-3.57**	2.78**	-2.54**	-2.10*	0	-8.39*	-5.98	8.05
RSG-974 × Avrodhi	-5.10**	-4.46**	1.4	-1.18	0.30	2.40**	-3.42	-1.59	7.57
RSG-974 × HC-5	-5.10**	-4.46**	0.47	-1.94*	-1.50	0.30	-13.85**	-7.33	12.65**
CSJ-515 × Avrodhi	-6.78**	-6.17**	-1.41	-3.09**	-2.08*	-0.30	-19.28**	-18.71**	1.59
CSJ-515 × HC-5	-2.84**	-2.20*	2.70**	-0.89	-0.89	1.80**	-14.9**	-10.9**	2.73
Avrodhi × HC-5	-2.64**	-2.64**	2.71**	-1.62	-0.60	2.10**	-14.11**	-9.41*	9.22*
SE	0.56	0.65	0.73	0.93	1.08	0.72	0.98	1.13	1.16

Table 2 Contd…..

Crosses	Plant height			No. of primary branches/plant			No. of secondary branches/ plant		
	RH	HB	ID	RH	HB	ID	RH	HB	ID
RSG-888 × CSJD-884	16.87**	16.83**	-0.24	-0.17	-6.05	-13.91*	15.05*	0.72	-7.17
RSG-888 × RSG-963	7.56	6.51	-7.23	29.99**	14.38*	-1.43	33.03**	28**	-2.78
RSG-888 × RSG-973	-3.82	-6.41	-6.35	-7.47	-8.06	-4.39	4.39	-4.03	-10.08
RSG-888 × RSG-974	9.07*	5.47	-8.28*	0.63	-3.03	0.78	7.83	3.54	2.99
RSG-888 × CSJ-515	4.37	-2.01	-2.96	2.43	-3.59	-13.56*	13.98	3.11	4.91
RSG-888 × Avrodhi	13.39**	7.71	-2.62	3.80	0.77	-5.34	19.42**	4.71	-8.65
RSG-888 × HC-5	12.7**	9.08*	4.84	13.43*	2.12	0	40.04**	26.25**	8.87*
CSJD-884 × RSG-963	-7.81	-8.68	0.84	38.31**	28.70**	-0.72	8.37	-1.81	1.84
CSJD-884 × RSG-973	-10.51*	-12.9**	1.63	6.03	-0.81	-15.45**	-4.38	-9.39	-9.16
CSJD-884 × RSG-974	3.63	0.24	-3.35	11.67*	1.52	9.70*	-2.58	-11.55	-3.27
CSJD-884 × CSJ-515	0.82	-5.31	-5.27	25.93**	25.93**	-2.94	7.87	3.97	1.04
CSJD-884 × Avrodhi	-4.02	-8.8*	2.39	28.57**	17.69**	5.88	-12.84*	-13	-2.90
CSJD-884 × HC-5	-6.24	-9.22*	2.87	31.07**	25**	-5.19	23.13**	19.13**	-7.58
RSG-963 × RSG-973	-4.33	-6.01	-1.15	8.76	-4.84	-13.56*	8.58	3.55	-5.53
RSG-963 × RSG-974	9.25*	6.67	-0.69	23.56**	5.30	-9.35*	21.95**	21.68*	0.15
RSG-963 × CSJ-515	-6.98	-11.84**	-3.06	27.36**	18.52**	17.19**	27.39**	19.46*	-3.26
RSG-963 × Avrodhi	-6.97	-10.79*	3.24	17.49**	0.77	-6.11	8.98	-1.09	5.13
RSG-963 × HC-5	3.42	1.07	-1.12	21.47**	18.37*	-10.34	4.13	-2.70	-9.13
RSG-973× RSG-974	-0.97	-1.60	-5.28	6.25	3.03	0	24.47**	18.95*	2.37
RSG-973 × CSJ-515	7.90*	4.01	-3.43	5.17	-1.61	1.64	-1.39	-3.11	-6.43
RSG-973 × Avrodhi	9.68*	7	-0.90	4.72	2.31	-6.02	-9.92	-14.49*	-9.32
RSG-973 × HC-5	8.06*	7.48	-2.05	5.41	-5.65	-17.09**	-1.78	-3.86	-7.23
RSG-974 × CSJ-515	4.84	1.69	-1.29	20**	9.09	0	27.95**	20.23**	-2.91
RSG-974 × Avrodhi	-4.35	-6.10	-6.09	-5.34	-6.06	-4.03	15.94*	5.43	4.81
RSG-974 × HC-5	-10.11*	-10.20*	3.86	22.61**	6.82	1.42	10.10	3.09	-3
CSJ-515 × Avrodhi	-3.01	-4.2	-6.08	2.52	-6.15	-9.02	2.44	-1.09	-8.06
CSJ-515 × HC-5	-7.86*	-10.71*	1.96	37.86**	31.48**	-0.70	-5.04	-5.41	-12.24*
Avrodhi × HC-5	6.68	4.62	-3.01	16.67**	2.31	-3.76	3.93	0.72	-10.43*
SE	1.97	2.28	2.10	0.21	0.24	0.22	0.57	0.66	0.46

Table 2 Contd…..

Crosses	Pods per plant			Seeds per pod			Biological yield per plant		
	RH	HB	ID	RH	HB	ID	RH	HB	ID
RSG-888 × CSJD-884	9.20**	6.03**	-7.60	7.37	2	-1.96	32.33**	-12.75*	8.78
RSG-888 × RSG-963	8.63**	2.31	-13.63	10*	10*	-3.64	9.78	-24.16**	1.53
RSG-888 × RSG-973	7.49**	5.46*	5.50	-16.83**	-17.65**	2.38	50.49**	15.43	0.66
RSG-888 × RSG-974	-1.72	-5.32*	-10.63	9.62*	5.56	0	35.19**	-0.07	-4.73
RSG-888 × CSJ-515	-6.26**	-12.32**	-3.06	6.80	3.77	-10.91	-2.43	-33.33**	-5.68
RSG-888 × Avrodhi	2.51	-0.66	2.05	12.96**	5.17	-3.28	32.98**	1.91	7.20
RSG-888 × HC-5	-2.50	-2.87	-5.77	11.54**	7.41	1.72	30.36**	-2.95	0.95
CSJD-884 × RSG-963	20.54**	16.82**	7.90	17.89**	12*	-7.14	29.77**	19.08**	-14.44**
CSJD-884 × RSG-973	18.64**	13.08**	4.05	18.75**	11.76*	0	52.65**	21.87**	-2.48
CSJD-884 × RSG-974	8.32**	1.43	-12.68	-7.07	-14.81**	-19.57*	2.33	-14.75**	3.07
CSJD-884 × CSJ-515	0.77	-8.30**	0.07	2.04	-5.66	-12	-8.07	-14.09**	2.31
CSJD-884 × Avrodhi	20**	13.02**	3.55	26.21**	12.07**	-1.54	47.55**	17.91**	-1.86
CSJD-884 × HC-5	15.87**	12.92**	-2.44	21.21**	11.11*	-3.33	38.2**	14.13**	-1.86
RSG-963 × RSG-973	6.20**	-1.75	-4.12	2.97	1.96	-3.85	-1.15	-15.26*	-2.99
RSG-963 × RSG-974	8.10**	-1.69	-5.88	-15.38**	-18.52**	-2.27	-15.75**	-24.27**	-3.97
RSG-963 × CSJ-515	24.97**	10.56**	1.93	12.62**	9.43*	-3.45	32.67**	30.08**	-8.48
RSG-963 × Avrodhi	22.93**	12.43**	4.44	-3.70	-10.34*	-7.69	2.49	-12.04*	-9.95
RSG-963 × HC-5	13.04**	6.85**	-0.40	-7.69	-11.11*	-4.17	4.26	-7.20	-7.55
RSG-973× RSG-974	-8.04**	-9.74**	-13.24	2.86	0	0	-3.11	-8.16	9.39
RSG-973 × CSJ-515	-1.73	-6.41**	-5.61	9.62*	7.55	1.75	-8.85	-23.13**	1.65
RSG-973 × Avrodhi	3.20	1.91	-2.06	4.59	-1.72	-1.75	18.82*	18.67*	-13.17
RSG-973 × HC-5	2.93	0.61	-1.14	8.57*	5.56	-5.26	20.25**	15.18	-2.63
RSG-974 × CSJ-515	-1.98	-4.94*	-3.15	2.80	1.85	-3.64	-12.72*	-22.91**	-3.51
RSG-974 × Avrodhi	-1.47	-2.08	-3.51	-3.57	-6.90	5.56	14.11*	8.29	-1.77
RSG-974 × HC-5	11.30**	6.82**	-1.22	9.26*	9.26*	-3.39	34.64**	33.18**	-13.29
CSJ-515 × Avrodhi	5.76**	1.95	-12.27	4.50	0	0	-33.91**	-44.21**	-18.84
CSJ-515 × HC-5	12.67**	5*	-1.92	15.89**	14.81**	8.06	53.74**	34.52**	5.43
Avrodhi × HC-5	10.32**	6.51**	1.67	5.36	1.72	-3.39	-15.94*	-19.39*	2.15
SE	0.93	1.07	3.73	0.07	0.08	0.12	1.00	1.15	1.39

Table 2 Contd…..

Crosses	Seed yield per plant			Harvest index			100-seed weight		
	RH	HB	ID	RH	HB	ID	RH	HB	ID
RSG-888 × CSJD-884	34.57**	-6.83	6.79	-3.11	-11.34	-2.23	-5.99	-8.60	-19.4**
RSG-888 × RSG-963	-6.80	-33.97**	-21.93	11.38	6.99	7.54	0.11	-1.08	-7.84
RSG-888 × RSG-973	43.9**	10.01	4.21	14.54*	13.7	19.33**	8.60*	5.28	1.08
RSG-888 × RSG-974	27.78**	-5.50	-22.57*	-5.66	-5.91	-17.25*	13.6**	10.03*	1.91
RSG-888 × CSJ-515	12.59	-23.49**	-15.20	11.37	9.64	-13.54*	8.84*	5.33	0.74
RSG-888 × Avrodhi	39.96**	5.98	1.84	6	4.07	-5.92	12.26**	4.57	6.86
RSG-888 × HC-5	26.94**	-4.25	4.51	-2.59	-4.45	-25.14**	16.39**	8.91*	14.92**
CSJD-884 × RSG-963	29.83**	24.81**	-5.39	-0.52	-5.43	7.92	19.56**	14.91**	5.91
CSJD-884 × RSG-973	44.11**	24.46**	6.17	-8	-16.37*	-24.49**	11.75**	11.41*	2.30
CSJD-884 × RSG-974	-16.49*	-24.71**	-13.74	-20.01**	-26.97**	-17.20	1.68	1.28	-2.32
CSJD-884 × CSJ-515	-9.36	-12.38*	3.58	28.51**	15.94*	25.13**	13.52**	12.98**	4.81
CSJD-884 × Avrodhi	40.23**	22.55**	-2.58	-7.47	-16.72*	-0.86	13.71**	8.80*	10.88**
CSJD-884 × HC-5	40.23**	23.15**	11.95	0.11	-6.74	13.76	13.91**	9.50*	18.47**
RSG-963 × RSG-973	4.05	-6.97	4.39	29.04**	23.07**	25.11**	16.45**	11.60*	3.57
RSG-963 × RSG-974	-17.69**	-23.03**	-10.18	-3.29	-7.34	-22.68**	3.11	-1.28	-2.80
RSG-963 × CSJ-515	39.95**	30.24**	9.94	5.49	-0.18	17.28*	18.98**	13.82**	12.68**
RSG-963 × Avrodhi	13.23	2.50	-9.82	9.14	3.01	-0.04	13.69**	4.74	-1.29
RSG-963 × HC-5	21.63**	10.67	-7.28	25.56**	22.91**	7.15	0.98	-6.55	-3.14
RSG-973× RSG-974	7.91	2.81	5.78	10.97	10.45	-4.07	6.53	6.43	1.97
RSG-973 × CSJ-515	-13.82*	-27.66**	-6.09	-5.82	-6.60	-30.21**	2.70	2.51	-5.04
RSG-973 × Avrodhi	31.36**	29.55**	-19.39*	10.80	9.59	-5.47	9.98**	5.54	5.2
RSG-973 × HC-5	38.12**	35.46**	-6.96	14.74*	11.73	-4.24	10.82**	6.84	-3.57
RSG-974 × CSJ-515	-6.91	-18.57**	-16.41	6.73	5.34	-10.35	7.32	7.22	6.29
RSG-974 × Avrodhi	13.54	9.63	-14.72	-0.62	-2.17	-12.79	4.53	0.4	6.18
RSG-974 × HC-5	28.24**	24.52**	-18.28*	-4.54	-6.61	-4.17	14.33**	10.33*	-2.64
CSJ-515 × Avrodhi	-25.35**	-36.62**	-22.71*	12.62	12.32	-4.70	-4.10	-7.82	-1.48
CSJ-515 × HC-5	49.99**	27.94**	9.01	-2.17	-5.51	-18.63*	16.12**	12.15**	-0.96
Avrodhi × HC-5	0.37	-0.20	-4.13	19.47**	15.1	-0.75	-5.31	-5.77	7.59
SE	0.38	0.44	0.50	2.47	2.86	2.71	0.64	0.73	0.73

**, **Significant at 5 and 1 percent levels, respectively*

Table 3. Crosses with high relative heterosis and heterobeltiosis for seed yield per plant and related characters under late sown condition in chickpea

Characters	$P_2 \times P_3$		$P_2 \times P_4$		$P_2 \times P_7$		$P_2 \times P_8$		$P_3 \times P_6$		$P_3 \times P_7$		$P_4 \times P_7$		$P_4 \times P_8$		$P_5 \times P_8$		$P_6 \times P_8$	
	RH	HB	RH	HB	RH	HB	RH	HB	RH	HB	RH	HB	RH	HB	RH	HB	RH	HB	RH	HB
Seed yield/plant	+	+	+	+	+	+	+	+	+	+	-	-	+	+	+	+	+	+	+	+
Days to first flowering	+	-	+	-	+	-	+	+	+	+	+	-	+	+	+	-	+	-	+	-
Days to 50% flowering	-	-	-	-	+	-	+	-	+	+	+	+	+	+	+	-	+	-	+	-
Days to first pod formation	+	-	+	-	+	-	+	-	+	+	+	+	+	-	+	-	+	-	+	-
Days to last pod development	-	-	+	-	-	-	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Days to maturity	+	+	-	-	-	-	+	-	+	+	+	+	+	-	+	-	+	-	-	-
First pod height	-	-	-	-	+	-	+	-	+	-	+	-	-	-	-	-	+	-	+	+
Plant height	-	-	+	+	-	+	-	+	-	+	-	+	-	-	-	-	+	+	+	+
No. of primary branches/plant	+	+	-	-	+	+	+	+	+	+	+	-	-	-	-	-	+	-	+	+
No. of secondary branches/plant	-	-	-	-	-	-	+	+	+	+	-	-	-	-	-	-	-	-	-	-
Pods per plant	+	+	+	+	+	+	+	+	+	+	+	+	-	-	-	-	+	+	+	+
Seeds per pod	+	+	+	+	+	+	+	+	+	+	-	-	-	-	+	-	+	+	+	+
Biological yield per plant	+	+	+	+	+	+	+	+	+	+	-	-	+	+	+	-	+	+	+	+
Harvest index	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-
100-seed weight	+	+	+	+	+	+	+	+	+	+	+	-	+	-	+	-	+	+	+	+

P_1: RSG-888, P_2: CSJD-884, P_3: RSG-963, P_4: RSG-973, P_5: RSG-974, P_6: CSJ-515, P_7: Avrodhi, P_8: HC-5

negative and significant relative heterosis and heterobeltiosis for days to first pod formation. Twenty and fifteen crosses exhibited negative and significant relative heterosis and heterobeltiosis for days to last pod development. Seventeen and thirteen crosses exhibited negative and significant relative heterosis and heterobeltiosis for days to maturity. Eighteen and eight crosses exhibited negative and significant relative heterosis and heterobeltiosis for first pod height. Three and seven crosses exhibited negative and significant relative heterosis and heterobeltiosis for plant height. Fifteen and eight crosses exhibited positive and significant relative heterosis and heterobeltiosis fornumber of primary branches per plant. Ten and seven crosses exhibited positive and significant relative heterosis and heterobeltiosis for number of secondary branches per plant. Seventeen and twelve crosses exhibited positive and significant relative heterosis and heterobeltiosis for pods per plant.Thirteen andeight crosses exhibited positive and significant relative heterosis and heterobeltios is for number of seeds per pod. Fifteen and eight crosses exhibited positive and significant relative heterosis and heterobeltiosis for biological yield per plant. Fifteen and nine crosses exhibited positive and significant relative heterosis and heterobeltiosis for seed yield per plant. Six and three crosses exhibited positive and significant relative heterosis and heterobeltiosis for harvest index. Seventeen and eleven crosses exhibited positive and significant relative heterosis and heterobeltiosis for 100-seed weight (Table 2).

Out of 28 hybrids 15 hybrids exhibited significant and positive relative heterosis while 9 hybrids exhibited significant and positive heterobeltiosis for seed yield per plant. Among all the heterotic crosses 10 crosses (CSJD-884 × RSG-963 ($P_2 \times P_3$), CSJD-884 × RSG-973 ($P_2 \times P_4$), CSJD-884 × Avrodhi ($P_2 \times P_7$), CSJD-884 × HC-5 ($P_2 \times P_8$), RSG-963 × CSJ-515 ($P_3 \times P_6$), RSG-963 × Avrodhi ($P_3 \times P_7$), RSG-973 × Avrodhi ($P_4 \times P_7$), RSG-973 × HC-5 ($P_4 \times P_8$), RSG-974 × HC-5 ($P_5 \times P_8$) and CSJ-515 × HC-5 ($P_6 \times P_8$) emerged as good heterotic crosses, on the basis of seed yield per plant and other most heterotic traits in late sown environment (Table 3).

An overall evaluation of relative heterosis forseed yield per plant revealed that the maximum relative heterosis over mid-parent was observed as 49.99 per cent (CSJ-515 × HC-5). Similarly, maximum heterosis over better parent was observed as 35.46 per cent (RSG-973 × HC-5). Therefore, these crosses were observed more heterotic as well as heterobeltiotic for seed yield per plant under latesown environment. Present trend of heterosis are in agreement with the findings of Gupta et al. [16], Ghaffar et al. [17] and Ghasemi et al. [18].

4. CONCLUSION

In present study, diallel analysis on the basis of mean seed yield performance, among all the heterotic crosses 10 crosses CSJD-884 × RSG-963, CSJD-884 × RSG-973, CSJD-884 × Avrodhi, CSJD-884 × HC-5, RSG-963 × CSJ-515, RSG-963 × Avrodhi, RSG-973 × Avrodhi, RSG-973 × HC-5, RSG-974 × HC-5 and CSJ-515 × HC-5emerged as good heterotic crosses, on the basis of seed yield per plant and other most heterotic traits in late sown environment. Thus these crosses may be involved in future breeding programme of chickpea improvement.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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