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Heterosis studies using diallel analysis for yield and its component traits in chickpea (*Cicer arietinum* L.)

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Abstract
The experiment consisting twenty one hybrids of chickpea along with their seven parental lines, conducted at Post Graduate Institute Farm, Mahatma Phule Krishi Vidyapeeth, Rahuri, to assess the extent of heterobeltiosis and standard heterosis over standard check i.e. Phule Vikram for yield and its components. Heterosis in grain yield per plant was reflected through heterosis in number of fruiting branches per plant, number of pods per plant, number of seeds per pod and 100-seed weight. The hybrid GNG-2207 X Digvijay (140.56) expressed the highest heterobeltiosis for grain yield per plant followed by JG-62 x Digvijay (36.17) and JG-62 x JAKI-9218 (36.14). Similarly, Phule Vikram x Digvijay cross combination only gave heterosis over standard check variety for grain yield per plant. Based on per se performance, heterosis, the cross combinations Phule Vikram x Digvijay, Digvijay x WR-315, GNG-2207 x Digvijay and Phule Vikram x JAKI-9218 were found promising for their utilization in chickpea improvement.

Keywords: Heterobeltiosis, Standard heterosis, Chickpea

Introduction

Chickpea is one of the important food legumes in the World. Chickpea is the only cultivated species under the genus '*Cicer*', and has 2n = 2x = 16 chromosomes with relatively small genome size of 738.09 Mbp (Varshney *et al.*, 2013) [11]. It is originated from Middle-East region now known as Turkey (Vavilov, 1926) [12]. In India, the records of chickpea cultivation date back to 2000 BC at Atranjikhera (U.P.) and 300-100 BC at Newasa (Maharashtra). *Macrospora* (Kabuli) and *Microspora* (Desi) are the two distinct types of chickpea with the production share of 25 per cent and 75 per cent, respectively (Soregaon, 2011) [10]. The important chickpea growing countries are India, Pakistan, Turkey, Iran, Mexico, Myanmar, Ethiopia, Australia and Canada. India, a major pulse producing country, accounts roughly 33 per cent of the total world production. Pulses are grown both during *Kharif* and *Rabi* seasons. Out of the total area and production under pulses, the area of *Kharif* and *Rabi* pulses accounts 45 and 55 per cent, respectively. In India, chickpea is cultivated on an area of 10.43 million hectares with production of 11.10 million tonnes and productivity of 1064kg/ha while in Maharashtra it is grown on an area of 18.48 lakh ha with production of 18.91 lakh tonnes and having productivity of 1023 kg/ha (2017-2018). Through, India is the largest producer of this crop; its productivity is low when compared to that in countries like Italy, Turkey, Iran, Sudan etc. The important genetic factors like, photo and thermo sensitivity, low harvest index, flower drop, poor stability of present cultivar, susceptibility to disease and pest, management factors like predominantly cultivated on receding soil moisture and marginal land, inadequate plant protection, low use of organic and inorganic fertilizer and inadequate availability of quality seeds limits the productivity of chickpea in this country. Among the factors listed above susceptibility to major biotic factors namely *Fusarium* wilt, pod borer and abiotic factors namely drought, heat, salt and cold are the most important stresses which need immediate attention of the plant breeder.

Exploitation of heterosis is an important approach towards the improvement of crop. The phenomenon of heterosis is of wide spread occurrence in field of biological sciences. Hybrid vigour was first observed by Koelreuter in 1673 in tobacco and was studied by numerous other workers (Singh, 1996) [9] and the clear approach to the concept of heterosis was made by Shull (1914) [8]. It has been mandatory to exploit heterosis in self pollinated crops like pulses for enhancing productivity. In pulses, a number of researchers has reported and exploited heterosis appreciably for various characters including yield contributing traits (Gupta *et al.*, 2003; Hedge *et al.*, 2007 and Adeyanju, 2009) [3, 4, 1].

The main objective of heterosis in the present study was to know the genetic makeup of parents and to create variability through segregation and recombination in advanced generations of the crosses. Heterosis for yield related traits was reported in many legumes (Singh, 1993) [9]. In practical plant breeding, the heterosis measured over better parent and standard parent or popular cultivar is more realistic and is of more practical importance.

Materials and Methods

The experiment was conducted at Post Graduate Institute Farm, Mahatma Phule Krishi Vidyapeeth, Rahuri. Seven genotypes (JG-62, C-565, GNG-2207, Phule Vikram, Digvijay, JAKI-9218 and WR-315) of chickpea were chosen and were crossed in 7 x 7 half diallel mating design excluding reciprocals. The choice of the genotypes was based on their differences for many agronomic characters. The complete set of 28 genotypes comprising seven parental genotypes and 21 F_1's were evaluated in Randomized Block Design with three replication during rabi season, 2017-18. Each plot consists of single row of three meter length. The inter row and intra row spacing was 30 and 10 cm, respectively. The observations were recorded from randomly selected five competitive individual plants *viz.*, days to 50% flowering, days to maturity, plant height (cm), plant spread (cm), number of primary branches per plant, number of secondary branches per plant, number of fruiting branches per plant, number of pods per plant, number of seeds per plant, number of seeds per pod, 100 seed weight (g) and seed yield per plant (g). All the agronomic practices were followed to raise a good crop. Data in each experiment of all entries was subjected to analysis of variance (Panse and Sukhatme, 1967) [6] for testing the significance of treatments. Heterosis has been estimated over better parent and standard heterosis as per Fonesca and Patterson (1968) [13].

Results and Discussion

Heterosis, a fundamental tool, used for the improvement of crops in the form of F_1 and F_2 populations by improving the various yield contributing characters. The magnitude of heterosis was reported among the crosses, demonstrating potential of hybrid combinations of seven diverse parents for various traits enhancement in the present research. The analysis of variance for grain yield per plant and its attributing traits revealed highly significant differences for all the characters studied. The significant differences were also observed among 21 hybrids for all the characters. This result indicated that parental genotypes were diverse and appropriate for study of heterosis. Significant variances for parents vs. hybrids for grain yield and most other traits indicated presence of heterosis in the population of the hybrids. The degree of heterosis was varied from cross to cross for all the characters.

For day to 50% flowering cross combination, GNG-2207 x JAKI-9218 (-9.52%) showed significantly higher negative heterosis over better parent, followed by GNG-2207 x WR-315 (- 8.99%) and C-565 x JAKI-9218 (-6.63%). Whereas, only single cross combination JG-62 x C-565 (-7.88%) showed significantly higher negative heterosis over standard check. Similarly, for days to maturity cross JG-62 x Phule Vikram (-4.40%) showed significantly higher negative heterosis over better parent followed by Phule Vikram x Digvijay (-4.11%) and JG-62 x WR-315 (-3.97%) while, high heterosis over standard check showed by cross C-565 x Digvijay (-4.69%) followed by JG-62 x Phule Vikram (-4.40%) and Phule Vikram x Digvijay (-4.11%).

For number of pods per plant, cross combination C-565 x GNG-2207 (9.39%) showed heterosis over better parent whereas, Phule Vikram x Digvijay (4.80%) showed heterosis over better parent as well as for standard check. In case of number of seeds per pod, only single cross combination C-565 x GNG-2207 (12.55%) showed heterosis over better parent and standard check. Cross combination Digvijay x JAKI-9218 cross showed highest significant desirable economic heterosis (39.72%) for 100 seed weight followed by Digvijay x WR-315 (29.50%) and JG-62 x Digvijay (14.72%).

Out of 21 crosses 10 manifested heterobeltiosis for grain yield per plant. The range of desirable heterobeltiosis for grain yield was wide 140.56 percent to 5.97 percent. The hybrids GNG-2207 x Digvijay recorded highest heterobeltiosis (140.56%) followed by cross JG-62 x Digvijay (36.17%) and JG-62 x JAKI-9218 (37.14%). But, economic heterosis for seed yield per plant was showed by only single cross combination Phule Vikram x Digvijay (12.80%) (Table-3). Heterobeltiosis and economic heterosis for yield and components traits have been reported in chickpea by Bakhsh, *et al.* (2007) [2], Parameshwarappa, *et al.* (2013) [7]. For yield components traits highest heterobeltiosis were recorded *viz.*, number of primary branches per plant (3.51%), number of fruiting branches per plant (8.10%), number of pods per plant (9.39%), number of seeds per plant (12.55%) and 100-seed weight (12.69%) similar result is also recorded by Kulkarni *et al.* (2004) [5].

A comparative study of five most heterotic crosses for grain yield per plant with their *per se* performances (Table-2) revealed that the cross combination Phule Vikram x Digvijay expressed the highest standard heterosis for number of pods per plant followed by the hybrid Digvijay x WR-315 expressed the high heterobeltiosis for grain yield per plant along with 100 seed weight. The hybrids GNG-2207 x Digvijay, Phule Vikram x JAKI-9218 and JG-62 x Phule Vikram recorded maximum grain yield per plant.

Table 1: ANOVA for yield and its components in chickpea

		Mean sum of squares				
Sources of Variation	**d. f.**	**Days to 50% flowering**	**Days to maturity**	**Plant height (cm)**	**Plant spread (cm)**	**No. of primary branches per plant**
Replications	2	1.58	6.86	13.42	5.43	0.12
Treatments	27	35.02**	52.734**	43.478**	8.964**	0.446**
Parents	6	57.413**	57.857**	55.477**	7.556**	0.533**
Hybrids	20	29.843**	51.849**	38.240**	7.035**	0.377**
Parent Vs. Hybrids	1	4.321	39.683*	76.230*	56.006**	1.314**
Error	54	2.188	6.486	13.747	2.024	0.057
Total	83	12.855	21.540	27.505	4.363	0.185

Mean sum of squares						
Sources of Variation	d. f.	No. of fruiting branches per plant	No. of pods per plant	No. of seeds per plant	100 seed weight (g)	Seed yield per plant (g)
Replications	2	0.396	1.31	63.55	0.363	1.295
Treatments	27	7.890**	428.039**	578.582**	38.856**	116.157**
Parents	6	3.291**	256.489**	299.639**	80.164**	140.185**
Hybrids	20	8.393**	444.455**	617.192**	27.782**	106.506**
Parent Vs. Hybrids	1	27.867**	1129.03**	1480.02**	12.484*	165.013**
Error	54	0.488	3.284	36.653	1.430	0.704
Total	83	2.923	141.41	213.59	13.579	38.276

*, ** Significant at 5 and 1 per cent level, respectively.

Table 2: Per se performance of five superior hybrids based on grain yield per plant

Sr. No.	F_1s	Days to 50% flowering	Days to maturity	Plant height (cm)	Plant spread (cm)	No. of secondary branches per plant
1	Phule Vikram×Digvijay	54.67	109.00	69.00	18.13	15.53
2	Digvijay×WR-315	59.67	121.00	58.00	17.20	12.40
3	GNG-2207×Digvijay	60.33	119.00	55.53	16.33	11.20
4	Phule Vikram×JAKI-9218	56.33	110.33	57.13	16.47	13.20
5	JG-62×Phule Vikram	54.33	108.67	63.53	15.47	10.27
	General Mean	57.06	113.6	60.63	16.72	12.52
	SE (±)	0.85	1.47	2.14	0.82	0.48

Sr. No.	F_1s	No. of fruiting branches per plant	No. of pods per plant	No. of seeds per plant	100 seed weight (g)	Seed yield per plant (g)
1	Phule Vikram×Digvijay	15.13	89.73	103.33	21.95	32.99
2	Digvijay×WR-315	12.40	67.46	77.47	25.05	29.19
3	GNG-2207×Digvijay	10.93	55.53	61.20	21.00	28.43
4	Phule Vikram×JAKI-9218	13.20	77.78	82.80	21.82	28.33
5	JG-62×Phule Vikram	10.07	57.71	68.38	17.93	27.87
	General Mean	12.35	69.364	78.64	21.55	29.36
	SE (±)	0.40	1.04	3.49	0.69	0.48

Table 3: Better and Standard Parent Heterosis (%) in F_1 hybrid for yield and its contributing characters in chickpea

Sr. No.	Crosses	Days to 50% flowering		Days to maturity		Plant height (cm)		Plant spread (cm)		No. of primary branches per plant	
		BPH	SCH	BPH	SCH	BPH	SCH	BPH	SCH	BPH	SCH
1	JG-62×C-565	-3.18	-7.88**	0.93	-4.40*	-5.13	-20.23**	-22.26**	-15.48*	-31.67**	-28.07**
2	JG-62×GNG-2207	-3.70	10.30**	-2.54	1.47	-12.11*	-23.49**	-26.62**	-14.68*	-25.00**	-21.05**
3	JG-62×Phule Vikram	-1.21	-1.21	-4.40*	-4.40*	-16.40**	-16.40**	-15.33*	-7.94	-13.33**	-8.77
4	JG-62×Digvijay	-2.42	-2.42	0.89	-0.59	-9.36	-21.09**	-22.63**	-15.87*	-33.33**	-29.82**
5	JG-62×JAKI-9218	-3.01	-2.42	1.18	0.59	-0.46	-16.30**	-26.64**	-20.24**	-31.67**	-28.07**
6	JG-62×WR-315	-4.92*	5.45*	-3.97*	-0.59	-5.02	-20.13**	-24.09**	-17.46*	-15.00**	-10.53
7	C-565×GNG-2207	-4.23*	9.70**	0.28	4.40*	-1.65	-14.38**	-15.70*	-1.98	-5.26	-2.26
8	C-565×Phule Vikram	-1.21	-1.21	-3.52	-3.52	-20.81**	-20.81**	-25.40**	-25.40**	-33.33**	-33.33**
9	C-565×Digvijay	-3.64	-3.64	-3.27	-4.69**	-19.05**	-29.53**	-24.48**	-27.78**	-9.80	-19.30**
10	C-565×JAKI-9218	-6.63**	6.06**	0.00	-0.59	-1.83	-17.83**	-9.80	-12.30	-13.73*	-21.81**
11	C-565×WR-315	-6.56**	3.64	-2.55	0.88	2.89	-14.67**	-17.72*	-17.06*	-6.00	-17.54**
12	GNG-2207×Phule Vikram	-3.17	10.91**	1.41	5.57*	-9.59	-9.59*	-13.99*	0.00	-1.75	-1.75
13	GNG-2207×Digvijay	-4.23*	9.70**	0.56	4.69*	-4.19	-16.59**	-16.38**	-2.78	-14.04	-14.04*
14	GNG-2207×JAKI-9218	-9.52**	3.64	-0.85	3.23	0.77	-12.27**	-22.87**	-10.32	-15.79**	-15.79**
15	GNG-2207× WR-315	-8.99**	4.24	-0.28	3.81*	-3.63	-16.11**	-20.14**	-7.14	-12.28*	-12.28*
16	Phule Vikram×Digvijay	-0.61	-0.61	-4.11*	-4.11*	-9.49*	-9.49*	7.94	7.94	3.51	3.51
17	Phule Vikram×JAKI-9218	1.81	2.42	-2.93	-2.93	-9.11*	-9.11*	-1.98	-1.98	-12.28*	-12.28*
18	Phule Vikram×WR-315	-2.19	8.48**	1.98	5.57**	-16.20**	-16.20**	-10.63	-9.92	-14.04*	-14.04**
19	Digvijay×JAKI-9218	1.20	1.82	0.88	0.29	-2.53	-15.15**	-3.27	-5.95	-3.92	-14.04**
20	Digvijay×WR-315	-2.19	8.48**	2.83	6.45**	4.74	-8.82*	1.57	2.38	1.96	-8.77
21	JAKI-9218×WR-315	-2.19	8.48**	-1.98	1.47	-1.83	-17.83**	-15.75*	-15.08*	-3.92	-14.04**
	SE (±)	1.20	1.20	2.07	2.07	3.02	3.02	1.16	1.16	0.19	0.19
	CD at 5%	2.42	2.42	4.16	4.16	6.06	6.06	2.32	2.32	0.39	0.39
	CD at 1%	3.22	3.22	5.55	5.55	8.08	8.08	3.10	3.10	0.51	0.51
Sr. No.	Crosses	No. of fruiting branches per plant		No. of pods per plant		No. of seeds per plant		100 seed weight (g)		Seed yield per plant (g)	
		BPH	SCH	BPH	SCH	BPH	SCH	BPH	SCH	BPH	SCH
1	JG-62×C-565	-20.65**	-30.48**	-35.41**	-46.73**	-35.01**	-43.66**	-5.17	-8.27	14.85**	-23.42**
2	JG-62×GNG-2207	-22.63**	-30.00**	-19.22**	-33.37**	-22.78**	-33.06**	12.69	-17.97**	0.55	-32.36**
3	JG-62×Phule Vikram	-28.10**	-28.10**	-32.60**	-32.60**	-27.03**	-27.0**	-7.31	-7.31	-4.70	-4.70
4	JG-62×Digvijay	-26.63**	-35.71**	-37.29**	-48.28**	-36.73**	-45.15**	-16.62**	14.72**	36.17**	-9.21**
5	JG-62×JAKI-9218	-23.91**	-33.33**	-31.37**	-43.40**	-32.47**	-41.45**	-11.33**	8.72	36.14**	-9.23**
6	JG-62×WR-315	-19.07**	-25.24**	-24.80**	-37.97**	-27.71**	-37.32**	10.34	-19.63**	-25.00**	-29.36**
7	C-565×GNG-2207	-10.53*	-19.05**	9.39**	-11.71**	12.55*	-3.46	-10.71**	-13.63**	24.84**	-19.24**
8	C-565×Phule Vikram	-38.10**	-38.10**	-52.54**	-52.54**	-49.92**	-49.92**	-1.26	-1.26	-40.80**	-40.80**

9	C-565×Digvijay	-19.23**	-30.00**	-21.70**	-42.30**	-23.32**	-39.89**	-39.37**	-16.58**	-28.79**	-53.93**
10	C-565×JAKI-9218	-15.82**	-29.05**	-13.51**	-37.06**	-14.16	-37.47**	-18.06**	0.47	24.51**	-19.46**
11	C-565×WR-315	-8.25	-15.24**	-16.09**	-34.17**	-15.61*	-33.20**	-3.97	-7.12	-57.02**	-59.52**
12	GNG-2207×Phule Vikram	-11.90**	-11.90**	-12.19**	-12.19**	-5.31	-5.31	-6.84	-6.84	-6.23*	-6.23*
13	GNG-2207×Digvijay	-13.68**	-21.90**	-19.65**	-35.14**	-23.86**	-34.69**	-21.09**	8.56	140.56**	-2.80
14	GNG-2207×JAKI-9218	-7.37	-16.19**	-11.88**	-28.87**	-14.65*	-26.80**	-16.65**	2.19	19.17**	-22.91**
15	GNG-2207× WR-315	7.22	-0.95	-11.07**	-28.23**	-15.48*	-27.51**	10.01	-19.87**	-62.28**	-64.47**
16	Phule Vikram×Digvijay	8.10	8.10	4.80**	4.80**	10.27	10.27	-17.54**	13.46**	12.80**	12.80**
17	Phule Vikram×JAKI-9218	-5.71	-5.71	-9.16**	-9.16**	-11.64*	-11.64*	-7.98	12.82**	-3.12	-3.12
18	Phule Vikram×WR-315	-28.10**	-28.10**	-35.72**	-35.72**	-36.47**	-36.47**	-2.29	-2.29	-33.21**	-33.21**
19	Digvijay×JAKI-9218	-6.04	-18.57**	-1.52	-27.42**	-14.55*	-33.01**	1.55	39.72**	19.73**	-2.54**
20	Digvijay×WR-315	-4.12	-11.43**	0.42	-21.21**	4.44	-17.33**	-5.87	29.50**	5.97*	-0.19
21	JAKI-9218×WR-315	-21.13**	-27.14**	-14.48**	-32.91**	-15.34*	-32.98**	-18.10**	0.41	-5.81*	-11.28
SE (±)		0.57	0.57	1.47	1.47	4.94	4.94	0.97	0.97	0.68	0.68
CD at 5%		1.14	1.14	2.96	2.96	9.91	9.91	1.95	1.95	1.37	1.37
CD at 1%		1.52	1.52	3.95	3.95	13.19	13.91	2.60	2.60	1.82	1.82

*,** Significant at 5 and 1 per cent level, respectively. BPH- Better Parent Heterosis, SCH- Standard Check (Economic) Heterosis

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