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Research Note

Heterosis for yield and physiological traits in chickpea (*Cicer arietinum* L.)

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Abstract
Chickpea being a highly self pollinated crop, the scope for exploitation of hybrid vigour will depend on the direction and magnitude of heterosis, biological feasibility and the type of gene action involved. The present investigation was carried out to study heterosis for yield and physiological attributes in chickpea utilising 21F_1s and seven parents from a 7 x 7 diallel set of crosses during *rabi* 2011-12 at Regional Agricultural Research Station, Nandyal - 518 502, A.P., India. Crosses NBeG-3 x Vihar, JG-11 x Vihar and ICCV 05106 x Vihar exhibited significant heterosis for days to first flowering and days to maturity in desirable negative direction. For yield and yield attributes *viz.*, number of branches per plant, number of pods per plant JG-11 x ICCV 05106, JG-11 x KAK-2 and ICCV 05106 x Vihar recorded significantly higher *per se* performance and heterosis over mid parent and better parent. MNK-1 x KAK-2 recorded significantly higher mid parental heterosis and heterobeltosis for physiological attributes like shoot biomass per plant, harvest index and root length. Hence, these promising crosses could be utilized in future breeding programmes for improving earliness, seed yield and drought tolerance in chickpea.

Keywords
Chickpea, diallel, heterosis, shoot biomass, harvest index, root length, yield.

Chickpea (*Cicer arietinum* L.) 2n = 2x = 16, is the third most important food legume globally, occupying an area of 13.2 m ha with a production of 11.6 m t (FAO STAT 2011). In India, chickpea cultivation was done in 9.21 m ha with a production of 8.88 m t and a productivity of 995 kg/ha (DAC Statistics, 2013). But the productivity is low (995 kg/ha) compared to other chickpea producing countries *viz*., Mexico (1809 kg/ha), Australia (1268 kg/ha) and Ethiopia (1265 kg/ha). In recent years, the area under chickpea cultivation has expanded to Southern India. Madhya Pradesh, Uttar Pradesh, Rajasthan, Maharastra, Gujarat, Andhra Pradesh and Karnataka are the major chickpea producing states sharing over 95 % area. In Andhra Pradesh also, the area under chickpea has increased dramatically from 71,000 ha in 1992-93 to 6.47 lakh ha in 2009-10 and the productivity increased from 621 kg/ha to 1309 kg/ha. In Andhra Pradesh, the crop duration of chickpea is short (75-110 days) and the climate is warm. Drought at different crop stages is the most serious constraint of chickpea production and therefore the varieties developed should have comparatively minimum yield losses during low rainfall years.

Chickpea productivity under drought environments could be increased through improving some physiological, morphological and phenological characteristics that have been recognised to be significant in crop adaptation to drought stress during soil drying (Ludlow and Muchnow, 1990 ; Subba Rao *et al*. 1995). Recently chickpea germplasm with deep and prolific root system were identified as a means to improve the drought tolerance through enhanced water uptake (Kashiwagi *et al.*, 2006). Tall and high yielding genotypes are highly suitable for mechanized cultivation, breeding for tallness or incorporation of tallness into high yielding background is another important research priority.

Though heterosis breeding is utilised to achieve substantial enhancement in yield and quality aspects of crop plants, in case of self pollinated crops including chickpea, heterosis *per se* cannot be exploited by way of heterotic hybrids due to biological infeasibility. Utility of heterosis *per se* may not be much useful in chickpea, but cross combinations showing heterotic vigour can be utilised as the source populations for deriving superior progenies. Jinks (1983) outlined the importance of heterosis breeding in self pollinated crops to extract pure breeding lines equalling or outperforming the best F_1s. Therefore, the present investigation was made to generate information on heterosis for yield and physiological attributes in chickpea.

The experimental material comprised of seven diverse lines of chickpea *viz.*, NBeG-3, JG-11, ICCV 05106, MNK-1, ICCV 95333, KAK-2 and Vihar were crossed in a half diallel fashion during Rabi 2010-11 and during *rabi* 2011-12, F_1s and parents were evaluated in a Randomised Block Design with three replications at Regional Agricultural Research Station, Nandyal. Each entry was grown in a single row of 4 m length and JG-11 was grown around the experiment to avoid border effects. A spacing of 30 x 10 cm was followed and standard package of practices were adopted for raising the crop. Observations were recorded on five randomly selected plants in each entry of each replication. Data were recorded on yield and physiological attributes *viz.*, days to first flowering, days to 50 first flowering, days to first podding, days to maturity, plant height, number of branches per plant, number of pods per plant, shoot biomass per plant, root length, seed yield per plant, harvest index and 100 seed weight. Heterosis over mid parent and better parent was calculated as per the standard statistical formulae.

Analysis of variance indicated highly significant differences among the entries for all the twelve characters studied, indicating that there exists substantial variability among the treatments. The *per se* performance of parental genotypes, F_1s and heterosis over mid parent and better parent for twelve yield and physiological attributes are presented in Table 1. Among parents, NBeG-3 for number of branches per plant, number of pods per plant, seed yield per plant, harvest index ; JG-11 for days to first flowering, days to 50 per cent flowering, days to first poding, number of branches per plant, root length, number of pods per plant ; ICCV 05106 for number of pods per plant; MNK-1 for plant height and 100 seed weight; ICCV 95333 for plant height and harvest index and Vihar for number of branches per plant, root length, shoot biomass per plant, exhibited superior *per se* performance. Hence these parents can be utilized in breeding programmes for improvement of respective characters.

Crosses JG-11 x Vihar, ICCV 05106 x ICCV 95333 and ICCV 05106 x KAK-2 for days to first flowering and days to 50 per cent flowering; ICCV 05106 x ICCV 95333 for days to first poding, NBeG-3 x JG-11 for days to maturity, recorded the higher mean values. Hence, these crosses can be utilized for isolating early maturing genotypes in segregating generations. With the development of early maturing genotypes we can avoid yield losses due to terminal drought stress, which was the most serious constraint to chickpea production, particularly in Andhra Pradesh. Among F_1s, JG-11 x MNK-1 and ICCV 95333 x KAK-2 registered significantly superior *per se* performance for root length which can be exploited for isolating desirable recombinants in segregating generations. In the present study, NBeG-3 recorded the highest harvest index followed by ICCV 95333 and JG-11 and the F_1s MNK-1 x KAK- 2 followed by NBeG-3 x ICCV 95333 and NBeG-3 x Vihar registered high harvest indices. Crosses NBeG-3 x ICCV 95333, JG-11 x ICCV 05106, JG-11 x KAK-2 and ICCV 05106 x Vihar could used to isolate superior lines for seed yield in segregating generations, as they were found to be superior with respect to yield and yield attributes.

The direction and magnitude of heterosis varied widely for all the twelve traits studied and in crosses as well. Significant negative heterosis has usually been considered for the phenological traits like days to first flowering, days to 50 per cent flowering, days to first poding and days to maturity. On critical examination of the phenological attributes *viz*., days to first flowering, days to 50 per cent flowering and days to maturity the crosses NBeG-3 x Vihar, JG-11 x Vihar and ICCV 05106 x Vihar exhibited were found significant for days to first flowering and days to maturity in desirable negative direction. Hence, these crosses can be exploited to isolate early maturing genotypes in segregating generations. Heterosis for earliness in Indian bean was reported by Bagade *et al.* 2002 and negative heterobeltiosis for days to maturity was reported in chickpea by Singh *et al.* 2002. For plant height, the per cent deviation of F_1 from mid parent value ranged from -11.49 per cent (JG-11 x ICCV 95333) to 11.62 per cent (NBeG-3 x JG-11). Five combinations *viz.*,NBeG-3 x JG-11, NBeG-3 x Vihar, JG-11 x ICCV 05106, JG-11 x MNK-1 and KAK-2 x Vihar exhibited significant positive heterosis over mid parent and none of the F_1s exhibited significant positive heterobeltiosis for plant height. Singh *et al.*2000 reported heterosis for plant height in chickpea.

Chickpea germplasm with deep and prolific root system can be utilized to improve drought tolerance in the crop through enhanced water uptake. Heterobeltiosis for root length ranged from -16.08 per cent (NBeG-3 X Vihar) to 39.09 per cent (ICCV 95333 x KAK-2). The higher heterosis over mid parent and heterobeltiosis was observed in eleven crosses *viz.,* NBeG-3 x MNK-1, NBeG-3 x ICCV 95333, NBeG-3 x KAK-2, JG-11 x MNK-1, JG-11 x KAK-2, ICCV 05106 x MNK-1, ICCV 05106 x ICCV 95333, ICCV 95333 x KAK-2, MNK-1 x ICCV 95333, MNK-1 x KAK-2 and ICCV 95333 x KAK-2. The magnitude and high incidence of heterosis for this character was indicative of operation of high dominance or epistasis or both (Kashiwagi *et al.* 2005). For shoot biomass per plant, all the twenty one F_1s exhibited significant positive heterosis over mid parent as well as better parent. Cosses *viz.,* NBeG-3 x Vihar, JG-11 x KAK-2, JG-11 x Vihar, ICCV 05106 x Vihar, ICCV 05106 x MNK-1, MNK-1 x ICCV 95333 and ICCV 95333 x Vihar recorded highly significant positive heterosis with high mean values for this trait. Higher magnitude of mid parental heterosis and heterobeltiosis for biomass per plant was reported by Bhardwaj *et al.,* 2010. The magnitude and direction of heterosis for harvest index was medium and positive in a few crosses, while negative in many of the crosses indicating low genetic divergence in the parents for this trait. Only three crosses JG-11 x ICCV 05106, ICCV 05106 x Vihar and MNK-1 x KAK-2 showed highly significant positive heterosis over mid parent as well as better parent for harvest index in chickpea. The results obtained in the present study were in conformity with the reports of Hedge *et al.* 2007 and Bhardwaj *et al.* 2010 for this trait.

Crosses *viz.*, NBeG-3 x JG-11, NBeG-3 x ICCV 95333, NBeG-3 x KAK-2, JG-11 x ICCV 05106, JG-11 x KAK-2, ICCV 05106 x MNK-1, ICCV 05106 x ICCV 95333, ICCV 05106 x Vihar, MNK-1 x KAK-2 and ICCV 95333 x KAK-2 registered significant mid parental heterosis and heterobeltosis for number of branches per plant, number of pods per plant and seed yield per plant. Hence, these cross combinations could be exploited to identify superior pure lines for higher yield in segregating generations of these crosses. Jayalakshmi *et al.*, 2009 observed good amount of heterosis for number number of pods per plant and seed yield per plant in chickpea. In chickpea seed size is an important character especially under rainfed environments, as bold seeded genotypes generally show higher degree of drought tolerance compared to medium seeded genotypes (Kumar *et al.*, 2004). Only three F_1s *viz.*, NBeG-3 x KAK-2, ICCV 05106 x Vihar and KAK-2 x Vihar exhibited significant positive heterosis over mid parent and better parent. Though parental genotypes, MNK-1 and ICCV 95333 recorded higher seed weight, the cross between them showed significant negative heterobeltiosis indicating the poor compatibility of the parents for this trait. Positive heterosis for 100 seed weight in chickpea was reported by Jayalakshmi *et al.* 2009.

From the foregoing results, it can be concluded that JG-11 x ICCV 05106, JG-11 x KAK-2 and ICCV 05406 x Vihar recorded significantly higher *per se* performance and heterosis over mid parent and better parent for yield and yield attributes like number of branches per plant, number of pods per plant. Hence these crosses could be utilized in future breeding programmes for yield improvement in chickpea. MNK-1 x KAK-2 recorded significantly higher mid parental heterosis and heterobeltosis for physiological attributes like shoot biomass per plant, harvest index and root length. Hence, this cross could be effectively utilized in future breeding programmes in order to isolate drought tolerant genotypes in segregating generations.

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Table 1. Estimates of heterosis over mid parent (>MP) and better parent (>BP) for twelve yield and physiological attributes in chickpea.

		Days to first flowering					Days to 50 per cent flowering					Days to first poding					Days to maturity				
S. No.	**Cross**	**P_1**	**P_2**	**F_1**	**>MP**	**>BP**	**P_1**	**P_2**	**F_1**	**>MP**	**>BP**	**P_1**	**P_2**	**F_1**	**>MP**	**>BP**	**P_1**	**P_2**	**F_1**	**>MP**	**>BP**
1	NBeG -3 x JG-11	32	29	35.7	16.94*	11.46	38.7	34.7	39.3	7.27	1.72	45.7	42.7	47.3	7.17*	3.65	91.7	92.3	88.3	-3.99**	-4.33**
2	NBeG-3 x ICCV05106	32	33.7	33	0.51	-1.98	38.7	39.3	39.7	1.71	0.85	45.7	44.7	49	8.49*	7.3	91.7	91.3	91.7	0.18	0
3	NBeG-3 x MNK-1	32	33.3	36	10.2	8	38.7	44.7	39.3	-5.6	-11.94*	45.7	44.7	45.7	1.11	0	91.7	94.7	90.3	-3.04**	-4.58**
4	NBeG-3 x ICCV 95333	32	38.7	37	4.72	-4.31	38.7	45.3	42.7	1.59	-5.88	45.7	45.3	47	3.3	2.92	91.7	92.7	92	-0.18	-0.72
5	NBeG-3 x KAK-2	32	38.3	34.3	-2.37	-10.43	38.7	42.3	41.7	2.88	-1.57	45.7	45.7	44.3	-2.92	-2.92	91.7	92.7	91.3	-0.9	-1.44
6	NBeG-3 x Vihar	32	37.3	30	-13.46*	-19.64**	38.7	47	38	-11.28*	-19.15**	45.7	46.3	47	2.17	1.44	91.7	98.7	92	-3.33**	-6.76**
7	JG-11 x ICCV 05106	29	33.7	32.7	4.26	-2.97	34.7	39.3	37.3	0.9	-5.08	42.7	44.7	46.3	6.11	3.73	92.3	91.3	90.3	-1.63	-2.17
8	JG-11 x MNK-1	29	33.3	39.3	26.2**	18*	34.7	44.7	45.3	14.29**	1.49	42.7	44.7	55.7	27.48**	24.63**	92.3	94.7	92	-1.6	-2.82*
9	JG-11 x ICCV95333	29	38.7	30.3	-10.34	-21.55**	34.7	45.3	35.3	-11.67*	-22.06**	42.7	45.3	47.7	8.33*	5.15	92.3	92.7	91.3	-1.26	-1.44
10	JG-11 x KAK-2	29	38.3	30	-10.89	-21.74**	34.7	42.3	34.3	-10.82*	-18.9**	42.7	45.7	46.7	5.66	2.19	92.3	92.7	89.7	-3.06**	-3.24**
11	JG-11 x Vihar	29	37.3	27.7	-16.58**	-25.89**	34.7	47	34	-16.73**	-27.66**	42.7	46.3	42.7	-4.12	-7.91*	92.3	98.7	91.3	-4.36**	-7.43**
12	ICCV05106 x MNK-1	33.7	33.3	32.3	-3.48	-3.96	39.3	44.7	37.3	-11.11*	-16.42**	44.7	44.7	40.3	-9.7**	-9.7*	91.3	94.7	94.7	1.79	0
13	ICCV05106 X ICCV 95333	33.7	38.7	27.7	-23.5**	-28.45**	39.3	45.3	33.3	-21.26**	-26.47**	44.7	45.3	41.7	-7.41*	-8.09*	91.3	92.7	92	0	-0.72
14	ICCV05106 x KAK-2	33.7	38.3	28	-22.22**	-26.96**	39.3	42.3	35.3	-13.47**	-16.54**	44.7	45.7	43	-4.8	-5.84	91.3	92.7	92.7	0.72	0
15	ICCV05106 x Vihar	33.7	37.3	32	-9.86	-14.29*	39.3	47	37.3	-13.51**	-20.57**	44.7	46.3	43.3	-4.76	-6.47	91.3	98.7	91.3	-3.86**	-7.43**
16	MNK-1 x ICCV 95333	33.3	38.7	40.7	12.96*	5.17	44.7	45.3	43.3	-3.7	-4.41	44.7	45.3	47	4.44	3.68	94.7	92.7	92.7	-1.07	-2.11
17	MNK-1 x KAK-2	33.3	38.3	35.7	-0.47	-6.96	44.7	42.3	39.3	-9.58*	-11.94*	44.7	45.7	47.7	5.54	4.38	94.7	92.7	92.3	-1.42	-2.46*
18	MNK-1 x Vihar	33.3	37.3	42.3	19.81**	13.39*	44.7	47	46	0.36	-2.13	44.7	46.3	52.7	15.75**	13.67	94.7	98.7	94.3	-2.41*	-4.39**
19	ICCV95333 x KAK-2	38.7	38.3	41.7	8.23	7.76	45.3	42.3	45.7	4.18	0.74	45.3	45.7	46.7	2.56	2.19	92.7	92.7	91	-1.8	-1.8
20	ICCV 95333 x Vihar	38.7	37.3	40.7	7.02	5.17	45.3	47	45.7	-1.08	-2.84	45.3	46.3	51.3	12**	10.79	92.7	98.7	93.7	-2.09*	-5.07**
21	KAK-2 x Vihar	38.3	37.3	39.7	4.85	3.48	42.3	47	45.7	2.24	-2.84	45.7	46.3	45.3	-1.45	-2.16	92.7	98.7	94	-1.74	-4.73**
S Em±		1.6	1.6	1.6	0.38	0.43	1.6	1.6	1.6	0.36	0.42	1.2	1.2	1.2	0.28	0.34	0.8	0.8	0.8	0.19	0.21
CD P≤ 0.05		4.6	4.6	4.6	4	4.6	4.4	4.4	4.4	3.8	4.4	3.5	3.5	3.5	3.1	3.5	2.2	2.2	2.2	1.9	2.2
CD P≤ 0.01		6.1	6.1	6.1	5.3	61	5.9	5.9	5.9	5.1	5.9	4.7	4.7	4.7	4.1	4.7	3	3	3	2.6	3

* Significant at P≤ 0.05 level, ** Significant at P≤ 0.01 level

Table 1 Contd. Contd…

S. No.	Cross	Plant height					Number of branches per plant					Root length					Number of pods per plant				
		P_1	P_2	F_1	>MP	>BP	P_1	P_2	F_1	>MP	>BP	P_1	P_2	F_1	>MP	>BP	P_1	P_2	F_1	>MP	>BP
1	NBeG -3 x JG-11	36.1	33.2	38.7	11.62 **	7.09	21	22.3	27.5	27.12**	23.5**	12.2	14.5	16	20.03**	10.55	35.5	36.1	48.7	35.97**	34.96**
2	NBeG-3 x ICCV05106	36.1	40.8	39	1.44	-4.38	21	16.6	18.1	-3.9	-13.97*	12.2	10.2	13.2	17.49**	8.04	35.5	31.5	58.5	74.64**	64.73**
3	NBeG-3 x MNK-1	36.1	49.8	43.4	1.07	-12.83**	21	13.3	21.3	24.51**	1.59	12.2	12.7	17.4	39.22**	36.23**	35.5	20.3	30.8	10.38*	-13.23**
4	NBeG-3 x ICCV 95333	36.1	46.7	40.1	-3.22	-14.17**	21	14.5	29.5	66.23**	40.63**	12.2	13.2	17.4	37.43**	32.19**	35.5	20.1	76.3	174.05**	114.66**
5	NBeG-3 x KAK-2	36.1	36.4	35.2	-2.99	-3.37	21	16.9	24.3	28.52**	15.87**	12.2	11.5	14.5	21.94**	18.57**	35.5	25.6	50.3	64.58**	41.65**
6	NBeG-3 x Vihar	36.1	40	41.3	8.61*	3.32	21	21.3	22.2	4.72	3.91	12.2	15.1	12.6	-7.24	-16.08**	35.5	27.6	52.9	67.54**	48.84**
7	JG-11 x ICCV 05106	33.2	40.8	39.9	7.95*	-2.12	22.3	16.6	29	49.19**	30.21**	14.5	10.2	15.6	26.48**	7.92	36.1	31.5	84.4	149.95**	134.12**
8	JG-11 x MNK-1	33.2	49.8	47.7	15.07**	-4.14	22.3	13.3	21.3	20.06**	-4.21	14.5	12.7	17.5	28.74**	21**	36.1	20.3	44.2	56.8**	22.6**
9	JG-11 x ICCV95333	33.2	46.7	35.3	-11.49**	-24.29**	22.3	14.5	20.2	9.6	-9.43	14.5	13.2	13.2	-4.82	-9.03	36.1	20.1	46.5	65.48**	28.93**
10	JG-11 x KAK-2	33.2	36.4	37.2	6.88	2.15	22.3	16.9	24.9	27.48**	12.02*	14.5	11.5	16.5	27.24**	14.23*	36.1	25.6	88.7	187.59**	145.99**
11	JG-11 x Vihar	33.2	40	38.1	4.1	-4.79	22.3	21.3	23.2	6.27	4.04	14.5	15.1	13	-11.74*	-13.44*	36.1	27.6	88.7	178.7**	145.99**
12	ICCV05106 x MNK-1	40.8	49.8	47.4	4.61	-4.86	16.6	13.3	19.5	30.76**	17.63*	10.2	12.7	15.1	31.68**	18.72**	31.5	20.3	35.3	36.24**	12.1*
13	ICCV05106 X ICCV 95333	40.8	46.7	46.3	5.93	-0.74	16.6	14.5	20.7	32.74**	24.48**	10.2	13.2	15.6	32.93**	17.99**	31.5	20.1	49.3	91.08**	56.6**
14	ICCV05106 x KAK-2	40.8	36.4	37.3	-3.26	-8.47*	16.6	16.9	16.4	-1.73	-2.51	10.2	11.5	13.3	22.66**	15.81*	31.5	25.6	31	8.52	-1.59
15	ICCV05106 x Vihar	40.8	40	41.3	2.19	1.22	16.6	21.3	28	47.63**	31.25**	10.2	15.1	12.8	0.87	-15.3**	31.5	27.6	70.5	138.58**	123.81**
16	MNK-1 x ICCV 95333	49.8	46.7	48.7	0.93	-2.25	13.3	14.5	13.3	-4.41	-8.58	12.7	13.2	18.1	39.88**	37.44**	20.3	20.1	29.2	44.42**	43.7**
17	MNK-1 x KAK-2	49.8	36.4	38.7	-10.24**	-22.33**	13.3	16.9	22.7	50.44**	34.39**	12.7	11.5	15.4	27.17**	21.07**	20.3	25.6	41.8	81.87**	63.07**
18	MNK-1 x Vihar	49.8	40	46.8	4.1	-6.14*	13.3	21.3	11.7	-32.56**	-45.31**	12.7	15.1	14.5	4.37	-3.68	20.3	27.6	25.1	4.66	-9.12
19	ICCV95333 x KAK-2	46.7	36.4	41.9	0.86	-10.24**	14.5	16.9	22.7	44.48**	34.49**	13.2	11.5	18.4	48.54**	39.09**	20.1	25.6	43.3	89.37**	69.05**
20	ICCV 95333 x Vihar	46.7	40	39.6	-8.6**	-15.12**	14.5	21.3	19.9	10.89*	-6.78	13.2	15.1	15	6.02	-0.53	20.1	27.6	43.2	81.09**	56.59**
21	KAK-2 x Vihar	36.4	40	41.3	8.2*	3.32	16.9	21.3	15.2	-20.31**	-28.66**	11.5	15.1	12.7	-4.77	-15.97**	25.6	27.6	37.3	40.05**	35.06**
S Em±		1.1	1.1	1.1	0.25	0.28	0.8	0.8	0.8	0.19	0.21	0.6	0.6	0.6	0.13	0.15	1.1	1.1	1.1	0.26	0.3
CD P≤ 0.05		3	3	3	2.6	3	2.2	2.2	2.2	1.9	2.2	1.6	1.6	1.6	1.4	1.6	3.2	3.2	3.2	2.8	3.2
CD P≤ 0.01		4	4	4	3.5	4	3	3	3	2.6	3	2.1	2.1	2.1	1.8	2.1	4.3	4.3	4.3	3.7	4.3

* Significant at P≤ 0.05 level, ** Significant at P≤ 0.01 level

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Table 1 Contd.

S. No.	Cross	Shoot biomass per plant					Seed yield per plant					Harvest index					100 seed weight				
		P1	P2	F1	>MP	>BP	P1	P2	F1	>MP	>BP	P1	P2	F1	>MP	>BP	P1	P2	F1	>MP	>BP
1	NBeG -3 x JG-11	21.7	20.1	38.9	85.98**	78.99**	13.1	8.8	20.7	89.82**	58.61**	54.9	40.1	51.8	8.98*	-5.76	29.4	23.1	24.3	-7.25	-17.25**
2	NBeG-3 x ICCV05106	21.7	21.3	28.9	34.24**	32.9**	13.1	9.6	11.4	0.56	-12.95**	54.9	41.9	37.5	-22.52**	-31.74**	29.4	27.3	14.2	-50.06**	-51.82**
3	NBeG-3 x MNK-1	21.7	22.6	32.3	45.97**	43.28**	13.1	10.9	12	0.11	-8.25	54.9	46.5	35.6	-29.72**	-35.13**	29.4	56.3	34.7	-18.98**	-38.34**
4	NBeG-3 x ICCV 95333	21.7	18.7	39.4	94.82**	81.23**	13.1	11.2	21.8	79.79**	66.96**	54.9	54.8	54.1	-1.37	-1.52	29.4	36.3	32.9	0.19	-9.28*
5	NBeG-3 x KAK-2	21.7	18.3	37.2	85.75**	70.94**	13.1	8.5	18.2	68.69**	39.07**	54.9	44.1	47.6	-3.84	-13.29**	29.4	29.9	34.4	16.05**	15.02**
6	NBeG-3 x Vihar	21.7	27.6	45.7	84.96**	65.21**	13.1	10.9	25.3	110.89**	93.77**	54.9	37.6	53.9	16.57**	-1.82	29.4	32.3	31.3	1.5	-2.99
7	JG-11 x ICCV 05106	20.1	21.3	40.2	94.04**	88.58**	8.8	9.6	21.5	134.74**	125.07**	40.1	41.9	51.7	26.12**	23.41**	23.1	27.3	24.4	-3.11	-10.68
8	JG-11 x MNK-1	20.1	22.6	41.5	94.61**	83.97**	8.8	10.9	19.8	101.36**	81.79**	40.1	46.5	46.2	6.86	-0.5	23.1	56.3	34.6	-12.92**	-38.63**
9	JG-11 x ICCV95333	20.1	18.7	34	75.46**	69.35**	8.8	11.2	11.6	16.09**	3.49	40.1	54.8	32.7	-31.11**	-40.35**	23.1	36.3	24.5	-17.39**	-32.42**
10	JG-11 x KAK-2	20.1	18.3	47.3	146.36**	135.12**	8.8	8.5	23.1	168.45**	164**	40.1	44.1	47.6	13.14**	7.93	23.1	29.9	24.3	-8.32	-18.85**
11	JG-11 x Vihar	20.1	27.6	44.5	86.55**	61.12**	8.8	10.9	18.4	87.24**	68.63**	40.1	37.6	40.4	4.12	0.92	23.1	32.3	26.4	-4.68	-18.26**
12	ICCV05106 x MNK-1	21.3	22.6	44.3	101.87**	96.2**	9.6	10.9	14.6	43**	34.27**	41.9	46.5	32.1	-27.25**	-30.85**	**27.3**	56.3	41.3	-1.22	-26.64**
13	ICCV05106 X ICCV 95333	21.3	18.7	41.4	106.98**	94.35**	9.6	11.2	14.9	43.22**	32.71**	41.9	54.8	34.7	-28.11**	-36.58**	**27.3**	36.3	38.5	21.13**	6.22
14	ICCV05106 x KAK-2	21.3	18.3	33.7	70.55**	58.4**	9.6	8.5	15.7	73.8**	64**	41.9	44.1	45.1	4.81	2.11	**27.3**	29.9	31.1	8.65	3.93
15	ICCV05106 x Vihar	21.3	27.6	48.7	98.91**	76.12**	9.6	10.9	25.1	145.05**	129.51**	41.9	37.6	50.6	27.35**	20.86**	**27.3**	32.3	29.8	0.11	-7.52
16	MNK-1 x ICCV 95333	22.6	18.7	43.3	109.74**	91.77**	10.9	11.2	16.4	48.87**	46.77**	46.5	54.8	37	-26.84**	-32.38**	56.3	36.3	51.1	10.34**	-9.3**
17	MNK-1 x KAK-2	22.6	18.3	33	61.63**	46.23**	10.9	8.5	19.6	102.93**	80.5**	46.5	44.1	57	25.83**	22.67**	56.3	29.9	36.1	-16.27**	-35.88**
18	MNK-1 x Vihar	22.6	27.6	31.3	24.81**	13.37**	10.9	10.9	11.7	6.94	6.65	46.5	37.6	36.2	-13.8**	-22.02**	56.3	32.3	46.4	4.8	-17.59**
19	ICCV95333 x KAK-2	18.7	18.3	48.7	163.28**	160.23**	11.2	8.5	20.6	109.73**	84.24**	54.8	44.1	41.4	-16.35**	-24.47**	36.3	29.9	37	11.85**	2.1
20	ICCV 95333 x Vihar	18.7	27.6	42.5	83.53**	53.86**	11.2	10.9	15.8	43.02**	41.38**	54.8	37.6	36.3	-21.47**	-33.78**	36.3	32.3	34.5	0.63	-4.93
21	KAK-2 x Vihar	18.3	27.6	40.4	75.96**	46.14**	8.5	10.9	19	95.29**	73.29**	44.1	37.6	45.6	11.66**	3.4	29.9	32.3	37.7	21.35**	16.99**
S Em±		0.7	0.7	0.7	0.15	0.17	0.4	0.4	0.4	0.09	0.11	1.3	1.3	1.3	0.3	0.36	1.2	1.2	1.2	0.26	30
CD P≤ 0.05		1.9	1.9	1.9	1.6	1.9	1.1	1.1	1.1	1	1.1	3.8	3.8	3.8	3.3	3.8	3.3	3.3	3.3	2.9	3.3
CD P≤ 0.01		2.5	2.5	2.5	2.1	2.5	1.5	1.5	1.5	1.3	1.5	5	5	5	4.3	5	4.4	4.4	4.4	3.8	4.4

* Significant at P≤ 0.05 level, ** Significant at P≤ 0.01 level