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Heterosis in relation to genetic divergence in minicore collections of Chickpea (*Cicer arietinum* L.)

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Abstract

Genetic analysis in chickpea using twelve lines belonging to high, medium and low diversity groups from different inter and intra cluster and four testers having high *per se* productivity was carried out to study heterosis in relation to genetic diversity for yield and yield attributes. Significant variation for all the characters was noticed except number of primary branches per plant among parents. Parents versus hybrid interaction effect was highly significant for all the characters. The hybrids ICC 6279 x ICC 13124, ICC 15697 x ICC 13124, ICC 6877 x ICC 7315 and ICC 6877 x ICC 10755 exhibited negative significant mid parent heterosis for earliness. Twenty seven hybrids showed positive significant mid parent heterosis for number of pods per plant and the magnitude of heterosis values was high with the highest value of 119.61 per cent. Nearly 85-90 per cent hybrids showed significant positive mid parent heterosis for seed weight. The degree of heterosis for seed yield varied considerably Out of 48 hybrids, 19 exhibited significant positive mid parent heterosis, whereas three exhibited significant positive heterosis over mid parent. The top three potential hybrids over mid parent were ICC 6877 x ICC 2072, ICC 2507 x ICC 2072 and ICC 6877 x ICC 7315. Study of relationship between divergence of the parents and heterosis in the hybrids revealed that the parents separated by D^2 values of high to medium magnitude generally showed higher heterosis for different characters. This indicate the role of both heterosis and genetic diversity of parents in realizing higher yield in chickpea.

Key words : *Cicer arietinum*, minicore, hybrids, heterosis, genetic divergence

Introduction

Chickpea (*Cicer arietinum* L.) is a strictly self pollinated crop. The natural out crossing is extremely low ranging from 0-1.88 per cent [1]. Therefore, the approaches of varietal improvement being followed in self pollinated crops applies to chickpea as well. Variability is the pre requisite for any crop improvement. The extent of variability available in chickpea is relatively very low. Variability is generated by various ways. Among them, hybridization which results in newer combination of genes is usually preferred by the breeders [2]. Within the cultivated species of chickpea, *desi* and *kabuli* are two distinct groups of cultivars. The essential pre requisites for hybridization is that the parents compliment each other for most of the yield components so that on hybridization such combinations can generate the desired segregants accumulating the favourable alleles increasing expression of these yield traits. Exploitation of hybrid vigour is considered to be one of the outstanding achievements in plant breeding. Though it has played an important role in allogamous crops, heterosis has been used only in few autogamous crops. Commercial exploitation of heterosis in autogamous crop like chickpea is not feasible due to the absence of stable male sterility coupled with low recovery of crossed seed per crosses manually attempted. Neverthyless, information on nature and magnitude of heterosis is useful while selecting a cross for further evaluation and selection.

It is often suggested that the extent of diversity between the parents involved in hybridization programme assume greater importance in developing potential breeding populations. Though it was suggested that the extent of diversity should be high for realizing high heterosis and potential cross combination, Arunachalam *et al*. [3] based on their experimentation in groundnut reported that the level of diversity between

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parents should be medium. To verify such concept minicore will provide an excellent opportunity to identify parents with varying levels of diversity. Selection of parent is very crucial step in breeding programmes for generating potential breeding populations with high variability. This will ensure success of the breeding programme by employing proper and meticulous selection scheme in such population. Selection of parent can be done in different ways. It is suggested that parental diversity is important to generate productive breeding population. The present study aims at generating information on the usefulness of heterosis in relation to genetic divergence for genetic enhancement of chickpea.

Materials and methods

The experimental material for this study was constituted by a set of lines and testers selected based on diversity analysis of the data of *rabi* 2005-06. Twelve genotypes selected as lines which are having high *per se* and to some extent higher seed weight and four genotypes selected as testers having high *per se* productivity belong to high, medium and low diversity groups from different inter and intra clusters. These genotypes belong to both desi and kabuli and are short to medium maturity groups. Each of these tweleve lines were crossed to four testers used as male in a line x tester mating design to produce 48 F_1 hybrids. The experimental material consisting of 48 F_1 hybrids and 16 (12 lines+ 4 testers) parents was grown in a Randomized Block design with two replications at the Genetics and Plant Breeding garden, College of Agriculture, Dharwad during *rabi* 2007-08. Each entry was represented by a single two meter long row with a spacing of 60 cm between rows and 10 cm between plants within a row. Recommended production and protection practices were followed to ensure good crop growth. Both parents and F_1's were randomized completely among themselves but grown in a continuous block. Five plants in every entry were selected randomly for recording observations on days to 50 per cent flowering (DFF), plant height (PLHT), primary branches per plant (PB), secondary branches per plant (SB), tertiary branches per plant (TB), pods per plant (PPP), 100-seed weight (SDWT) and yield per plant (YPP). The analysis of variance was carried out and the magnitude of heterosis was estimated in relation to mid parental values. They were thus, calculated as percentage increase or decrease of F_1's over the mid-parent (MP) using the methods of Turner [4] and Hayes *et al.* [5]. Critical difference (CD) calculated from their appropriate standard error of difference was used to test the significance of F_1 mean over MP value.

Results and discussion

The analysis of variance revealed significant differences for all the characters indicating presence of adequate genetic variation among the genotypes. Further partitioning of mean squares due to parents were significant for all the characters except number of primary branches per plant in both female and male parents. The interaction between female and male was highly significant for all the characters except for number of primary branches per plant. Mean squares due to parents Vs hybrid component were also highly significant for all the characters which depicted presence of heterosis for all the characters. The source and special features of the parents used in this study are given in Table 1. It is generally believed that genetically divergent parents tend to give rise to heterotic hybrids on crossing. In the present study, relationship between genetic distance of the parents, as assessed by D^2 analysis and mid parent heterosis for seed yield and its components. Minicore comprising of 203 accessions was evaluated during 2004-05 to 2005-06 at Dharwad. Evaluation was done for productivity and seven other productivity related quantitative traits. The data was subjected to diversity analysis following Mahalnobis D^2 technique. With 203 accessions all possible (203x202/2 D^2 values) pair wise D^2 values were obtained. Taking the minimum D^2 value and maximum D^2 value , the mean D^2 value was computed. This provided the base for classifying the F_1's either as highly diverse or as low depending upon the D^2 value being more than or less than the mean, respectively. Further taking productivity of popular check cultivar A-1 and it's seed size as the criteria parents were chosen in such a way that pair wise they would represent high, medium and low diversity. The F_1's so generated were evaluated and heterosis were all computed. These exercise thus provided an opportunity to relate diversity status and heterosis Sixteen parents from five distinct geographical regions, India, Iran, Syria, Nepal and Turkey were distributed in different clusters indicating diversity in the parental genotypes selected for this study. In the present study seven genotypes originating from the same geographical region (India) have shown considerable genetic diversity among themselves by occupying different clusters. Also, six genotypes from Iran got clubbed in the same clusters with these from India, Turkey, Nepal and Syria clearly shows that geographic isolation may not be the only factor

Table 1. The sources and characteristic features of the parents of chickpea used in the study

S.No.	Parents	Source/ country	Special features
1	ICC 2969	Iran	High yield, high yellow seed, *desi* variety
2	ICC 9137	Iran	High yield, white seed, *Kabuli* variety
3	ICC 6279	India	Brown seeded, High yield, *desi* cultivar
4	ICC 15697	Syria	Bold seeded, *Kabuli* variety
5	ICC 506	India	High yield, light yellow seeded, *desi* cultivar
6	ICC 5878	India	High yield, Black seeded, *desi* cultivar
7	ICC 11944	Nepal	High yield, brown seeded, *desi* cultivar
8	ICC 1180	India variety	Bold black seeded, *desi*
9	ICC 6877	Iran	High yield, cream seeded
10	ICC 3776	Iran	High yield, black seeded, *desi* variety
11	ICC 1431	India	High yield, brown seeded, *desi* variety
12	ICC 2507	Iran	High yield, black seeded, *desi* variety
13	ICC 13124	India	High yield, bold seeded, reddish brown, *desi* cultivar
14	ICC 7315	Iran	High yield, bold seeded, white seeded, *Kabuli* variety
15	ICC 2072	India	High yield, black seeded, *desi* variety
16	ICC 10755	Turkey	High yield, white seeded, *desi* variety

responsible for genetic diversity. Lack of correspondence between geographical and genetic divergence in chickpea is known [3, 9-12].

The superiority of the hybrids in crosses was estimated over mid parent (MP) for all the eight characters studied. *Per se* performance and heterosis of top three potential hybrids in respect of eight quantitative characters studied are presented in Table 2. Per cent heterosis in respect of seed yield of heterotic hybrids with different parental diversity are given in Table 3-4.In the present study, days to 50 per cent flowering was recorded to get a measure of earliness. Only limited number of hybrids showed heterosis in the desirable

Table 2. *Per se* performance and heterosis of top three potential hybrids in respect of eight quantitative characters in chickpea

S.No.	Characters	Potential hybrids	Mean	MP(%)
1	DFF	ICC 6279 x ICC 13124	37.50	-3.23
		ICC 6877 x ICC 7315	39.50	-25.47
		ICC 6877 x ICC 10755	39.50	-22.55
2	PLHT (cm)	ICC 6877 x ICC 10755	67.30	20.77
		ICC 6877 x ICC 13124	67.10	38.55
		ICC 9137 x ICC 7315	66.15	20.38
3	PB	ICC 15697 x ICC 7315	9.15	150.68
		ICC 1180 x ICC 2072	8.95	167.16
		ICC 6877 x ICC 10755	8.80	121.38
4	SB	ICC 1180 x ICC 2072	18.95	67.70
		ICC 11944 x ICC 2072	18.90	83.05
		ICC 9137 x ICC 13124	18.80	51.00
5	TB	ICC 2969 x ICC 7315	37.10	123.83
		ICC 2969 x ICC 2072	30.35	106.81
		ICC 15697 x ICC 7315	28.55	78.72
6	PPP	ICC 5878 x ICC 7315	195.40	106.77
		ICC 11944 x ICC 13124	187.85	94.61
		ICC 11944 x ICC 7315	173.55	119.61
7	SDWT (g)	ICC 15697 x ICC 7315	38.40	29.84
		ICC 2507 x ICC 2072	37.00	124.58
		ICC 15697 x ICC 2072	36.90	78.48
8	YPP (g)	ICC 6877 x ICC 2072	64.40	136.76
		ICC 2507 x ICC 2072	61.00	83.05
		ICC 6877 x ICC 7315	60.55	90.86

negative direction over standard check. The hybrids ICC 6279 x ICC 13124, ICC 15697 x ICC 13124, ICC 6877 x ICC 7315 and ICC 6877 x ICC 10755 exhibited negative significant mid parent heterosis. This suggests that more number of hybrids were early . Wherever the hybrids exhibited highly desirable heterosis, one of their parent was also early in flowering and falls in the same geographic region. Therefore trait under consideration may be inferred to have additive gene action. Similar results were reported in chickpea [1]. Plant height is an important growth parameter from productivity point of view. The highest plant height was recorded for the hybrid ICC 2507 x ICC 2072 followed by ICC 6877 x ICC 2072 and ICC 6877 x ICC 13124 which also showed the high significant positive mid parent heterosis. There are reports as indicated in literature [6-10] that the importance dominant gene action for plant height. Primary, secondary and tertiary branches were the other important growth parameters expected to contribute to productivity. A fairly high number of hybrids (28 out of 48) exhibited heterosis in significant positive direction over mid parent thus confirming dominant gene action.

Table 3. Per cent heterosis in respect of seed yield of heterotic hybrids with different parental diversity in chickpea

S.No.	Hybrids	*Per se* performance			D^2 value	Per cent heterosis over
		Female	Male	F_1		MP
High diversity groups						
1	ICC 6877 x ICC 2072	57.05	39.88	54.65	695.04	136.76
2	ICC 6877 x ICC 7315	57.05	36.38	64.40	695.04	115.16
3	ICC 6877 x ICC 10755	57.05	38.17	60.55	695.04	90.86
4	ICC 5878 x ICC 7315	45.93	39.88	37.00	868.60	46.25
5	ICC 5878 x ICC 13124	45.93	40.60	50.30	868.60	57.68
6	ICC 5878 x ICC 10755	45.93	38.17	57.95	868.60	83.24
7	ICC 506 x ICC 7315	37.81	39.88	47.30	566.99	72.47
8	ICC 506 x ICC 13124	37.81	40.60	43.20	566.99	26.97
9	ICC 2507 x ICC 7315	50.28	39.88	47.25	968.70	49.88
10	ICC 2507 x ICC 2072	50.28	36.38	61.00	968.70	83.05
Medium diversity groups						
1	ICC 3776 x ICC 7315	45.10	39.88	57.10	488.90	99.83
2	ICC 3776 x ICC 10755	45.10	38.17	55.85	488.90	60.03
3	ICC 15697 x ICC 7315	40.39	39.88	52.90	292.28	110.55
4	ICC 15697 x ICC 2072	40.39	36.38	42.55	292.28	58.03
5	ICC11944 x ICC 13124	38.85	40.60	57.65	232.80	69.43
6	ICC 11944 x ICC 7315	38.85	39.88	39.95	232.80	45.67
Low diversity groups						
1	ICC 1431 x ICC 13124	31.94	40.60	35.15	10.62	12.84
2	ICC 1431 x ICC 7315	31.94	39.88	36.30	10.62	47.88
3	ICC 1431 x ICC 2072	31.94	36.38	32.25	10.62	22.39
4	ICC 2969 x ICC 2072	28.03	36.38	29.80	3.16	3.38

MP = Mid parent

This suggests the role of over dominance resulting in heterosis. Involvement of dominant gene action is supported by reports of earlier workers [13, 14]. In all these hybrids, heterosis was mainly due to over dominance as evident by the mean value of the F_1's as compared to their parental values. Positive heterosis for this trait was also reported [14, 15]. Number of tertiary branches among the parents ranged from 17.10 (ICC 2507) to 30.70 (ICC 2969). The number of tertiary branches among the hybrids ranged from 15.45 to 37.10. Out of 48 hybrids, 31 and 6 hybrids showed significant positive and negative deviation over MP, respectively suggesting that the heterosis was in both the directions. Based on the F_1 *per se* compared to their respective parental value, over dominance appeared to play major role for this trait in more than 50 per cent hybrids. Similar results were also reported by many workers [8, 15-18].

High pod number per plant is important trait to gain high productivity. The parental range for number of pods per plant was 80.99 (ICC 9137) to 162.55 (ICC 5878). Twenty seven hybrids showed positive significant mid parent heterosis for number of pods per plant and magnitude of heterosis values was high with the highest value of 119.61 per cent. Positive heterosis for pods per plant has been reported by several workers [13, 19-20]. Seed weight is one of the component character directly influencing the seed yield. In the present study, higher mean value was observed for hybrids compared to the means of parents nearly 85-90 per cent of hybrids were significant in either of direction over MP thus showing role of non-additivity and wide range of heterosis. Mid parent heterosis for seed weight was reported by earlier workers [21, 22].

Seed yield per plant is the ultimate and most important trait. In the present investigation, the degree of heterosis for seed yield varied considerably. Out of 48 hybrids, nineteen hybrids exhibited significant positive mid parent heterosis. The difference between mean value of parents and hybrids was significantly high. However, the highest mean value which was shown by ICC 6877 x ICC 2072 (64.4 g/plant) is much higher than their parents. The top three potential hybrids over MP were ICC 6877 x ICC 2072, ICC 2507 x ICC 2072 and ICC 6877 x ICC 7315.The direction and magnitude of the heterosis observed in the present investigation shows that there is a possibility of developing hybrid varieties in chickpea to increase it's productivity, although the highly self pollinating nature of the breeding system of chickpea and the non availability of male sterile lines are major limitations in the development of hybrids. However, high performing heterotic cross combinations involving parents in which at least one was a good general combiner has produced superior F6 progenies in chickpea [21]. and thus could be advantageously used in breeding programme for isolating productive pure lines. As the *per se* performance is the realized value and the heterotic response is an estimate, the former should also be given preference when making selection in cross combination [22]. In the present study three heterotic crosses showed significant heterosis over MP in the desirable direction for number of pods per plant. seed weight and seed yield per plant. The number of hybrids with high as well as low heterosis occurring in the high, medium and low diversity groups have been listed (Table 4). It may be seen from the table that there were as many as six highly heterotic crosses under high diversity class while their was none with low heterosis. In medium diversity group there were five hybrids showing high heterosis while two hybrids were with low heterosis. In low diversity group no hybrid was their with high heterosis while there was only one hybrid with low heterosis. This indicates that the probability of getting heterotic hybrids is high with high diversity. The mean performance of heterotic hybrid as well as the extent of mid parent heterosis are slightly better with the hybrids in high diversity group. This indicate the role of heterosis in relation to genetic diversity in realizing higher yield. These findings are similar to the observations made in chickpea [11, 13, 18-20, 23-25]. Hence, direct selection for higher values

Table 4. Heterosis index of heterotic hybrids in chickpea

S.No.	Hybrids	Heterosis index									
		DFF	PLHT	PB	SB	TB	PPP	SDWT	YPP	Total	Class score
	High diversity groups										
1	ICC 6877 x ICC 2072	0.01	0.006	0.02	0.0004	-0.01	0.14	0.11	1.37	1.65	High
2	ICC 6877 x ICC 7315	0.01	-0.004	0.12	0.007	-0.002	0.15	0.01	1.15	1.44	High
3	ICC 6877 x ICC 10755	0.01	0.03	0.15	0.01	0.17	0.15	0.02	0.91	1.45	High
4	ICC 5878 x ICC 7315	0.006	-0.002	0.15	0.01	0.16	0.35	-0.06	0.46	1.07	High
5	ICC 5878 x ICC 13124	0.003	0.000	0.02	0.002	0.002	0.07	-0.08	0.58	0.60	High
6	ICC 5878 x ICC 10755	-0.005	-0.000	0.15	0.006	0.05	0.02	-0.02	0.83	1.04	High
7	ICC 506 x ICC 7315	-0.002	0.01	0.03	-0.001	0.06	0.17	0.02	0.72	1.07	High
8	ICC 506 x ICC 13124	-0.005	-0.00	0.15	0.006	0.05	0.02	-0.02	0.83	1.04	High
9	ICC 2507 x ICC 7315	0.01	-0.002	0.01	0.003	0.04	0.09	-0.008	0.50	0.64	High
10	ICC 2507 x ICC 2072	0.01	0.02	0.09	0.002	-0.02	0.06	0.31	0.83	1.30	High
	Medium diversity groups										
1	ICC 3776 x ICC 7315	-0.003	0.008	0.18	0.01	0.20	0.17	0.08	1.11	1.75	High
2	ICC 3776 x ICC 10755	-0.01	0.02	0.11	0.008	0.16	0.02	0.19	0.58	1.08	High
3	ICC 15697 x ICC 7315	0.008	0.006	0.02	0.01	0.09	0.13	-0.06	0.99	1.19	High
4	ICC 15697 x ICC 2072	0.01	-0.03	0.02	-0.009	0.14	0.08	-0.04	0.60	0.77	High
5	ICC 11944 x ICC 13124	0.006	0.01	0.004	-0.004	0.06	0.17	-0.09	0.69	0.84	High
6	ICC 11944 x ICC 7315	0.001	0.005	0.0	-0.004	0.0	0.22	-0.06	0.46	0.62	High
	Low diversity groups										
1	ICC 1431 x ICC 13124	0.005	0.02	0.10	-0.001	-0.01	0.10	-0.05	0.13	0.29	Low
2	ICC 1431 x ICC 7315	0.009	0.007	0.14	0.006	0.03	0.14	-0.08	0.48	0.73	High
3	ICC 1431 x ICC 2072	0.004	0.002	0.04	0.003	0.03	0.03	0.04	0.22	0.37	Low
4	ICC 2969 x ICC 2072	0.000	0.006	0.186	0.006	0.27	0.06	0.06	0.034	0.62	High

of seed yield can be made in the advanced generations of the heterotic crosses involving such parents, as a large portion of the total variation is a result of additive gene effects.

Considering F_2 performance of these hybrids, three of the six highly heterotic F_1's in high diversity group and high mean (ICC 6877 x ICC 7315, ICC 6877 x ICC 2072 and ICC 6877 x ICC 10755) followed by high coefficient of variation and range. The mean F_2 values of these hybrids range from 25.6 to 37 g, from 32.2 to 39.0 per cent coefficient of variation and the higher value of range from 41.2 to 43 g per plant. While in case of medium diversity group, three hybrids (ICC 15697 x ICC 7315, ICC 3776 x CC 7315 and ICC 3776 x ICC 10755) showed relatively high mean values and higher coefficient of variation with reasonably high range of expression but these figures were lower than those of the hybrids in high diversity group. These facts indicate that parents with high diversity have a better chance of showing high heterosis and better F_2 performance.

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