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Comparative analysis of genetic diversity and its relation to heterosis in early and mid-maturity Indian cauliflower (*Brassica oleracea* var. *botrytis* L.)

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ABSTRACT

An experiment involving self-incompatible line based 80 F_1 hybrids in early and 54 F_1 hybrids in mid-maturity groups derived from line × tester design were studied with an aim of relating genetic divergence among the parents with the magnitude of heterosis in the F_1 generations and to identify suitable hybrids. The significant improvements in mean of the hybrids were observed over the parents for all the traits in both maturity groups. Mean performance of all growth and yield contributing traits of parents and hybrids were higher in mid-maturity group over early maturity. Based on cluster analysis in early maturity group six (cc-13, cc-14, 14-4-17, 351aa, Pusa Deepali and SL-7) out of eighteen inbred lines were least diverse. Line vv of cluster VI was found most diverse from the lines xx-2-6, cc-32E and cc-12 of cluster VII with inter-cluster distance of 3.88. However, in mid-maturity group the most diverse lines were ccm-8 (II) and Palam Uphar (VI) with inter-cluster distance of 5.48. The combination of heterosis and diversity analysis indicated the higher fre quency and magnitude of heterosis of hybrids derived from the parental divergence class DC_3 in early maturity and DC_2 in mid-maturity group suggesting moderate genetic diversity is most desirable to produce highly heterotic hybrids in Indian cauliflower. The correlation between genetic distance and the level of mid-parent heterosis was not reliable for all the quantitative traits in both early and mid-maturity group of the cauliflower. Identified hybrids 395aa x Pusa Deepali and cc-32E × 23000 in early maturity and cc-22 × Sarju Maghi and cc-22 × Palam Uphar of mid-maturity group having higher magnitude of heterosis for maximum number of desirable traits may be selected for further evaluation and commercialization.

Key words: Genetic divergence, self-incompatibility, line x tester, heterosis, Indian cauliflower.

INTRODUCTION

The tropical Indian cauliflowers developed mainly from Cornish and other European types, like Rosecoffs, Italians, Northerss. Natural crossing between different types followed by selection by the farmers and adoption resulted in the tropical indian cauliflower that is distinctly different. Besides being heat tolerant, the Indian cauliflowers have genes for resistance to diseases, like downy mildew, black rot, curd and inflorescence blight. The early maturing indian cauliflowers have very stable self-incompatibility, which is not thermo-sensitive unlike many temperate European types (Swarup and Chatterjee, 18). The primary objective of heterosis breeding in cauliflower is that F_1 hybrids are advantages especially in uniform maturity, high early and total yield, better curd quality with respect to compactness and colour, resistance to insect-pests, diseases and unfavorable weather conditions (Kucera *et al.*, 9). Two pollination control mechanisms, *viz*., self-incompatibility and male sterility (particularly CMS) are widely used for production of F_1 hybrid seeds. So far majority of the crucifer hybrid cultivar have been developed by using self-incompatibility system (Watanabe and Hinata, 20). The selection of best parents for hybridization has to be based upon the complete genetic information and esteemed prepotency of potential parents. Improvement in yield is normally attained through exploitation of the genetically diverse parents in breeding programmes. Genetic diversity between populations/ genotypes indicates the differences in gene frequencies. For identifying such diverse parents for crossing, multivariate analysis using Mahalanobis's D^2 statistic has been used in several crops. This is a valuable tool to study genetic divergence at inter-varietal and sub-species level in classifying the crop plants. The objectives of this study were to relating genetic divergence among the parents with the frequency and magnitude of heterosis in the F_1 generations, correlation between genetic divergence and mid-parent heterosis and to identify suitable hybrids in early and mid-maturity group of Indian cauliflower.

MATERIALS AND METHODS

The experimental materials were comprised of self-incompatible lines and hybrids derived from the ten lines and eight testers (80 F_1) in early and

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nine lines and six testers (54 F_1) in mid-maturity group of indian cauliflower. The parental lines were maintained through bud pollination. The seedlings were raised in plug tray using soilless medium of cocopit, perlite and vermiculite (3:1:1). Seeds of early group was sown in June and mid-group in August. The one-month-old seedlings of parents and hybrids were planted in randomized block design with three replications at Main Experimental Farm, Division of Vegetable Science, ICAR-IARI, New Delhi. The spacing was kept as 45 cm × 45 cm and 60 × 45 cm for early and mid-maturity groups, respectively. The recommended packages of practices were followed in crop production. Observations were recorded on six randomly selected plants on eight growth and yield attributes such as days taken to 50% curd maturity, leaf size (cm^2), plant height (cm), marketable curd weight (kg), net curd weight (kg), curd compactness estimated as suggested by Pearson (14), gross plant weight (kg) and harvest index.

The hybrids were developed using line x tester mating design as suggested by Kempthorne (7). Genetic divergence was studied following Mahalonobis's D^2 (Mahalonobis, 10) distance technique. Tocher's method (Rao, 15) was used for grouping the genotypes. Arunachalam's (1) method was used to classify the parental divergence into four divergence classes (DC_1, DC_2, $DC_3$and DC_4). The procedure used was as the mean (m) and standard deviation (sd) of parental distance were computed. The minimum (x) and maximum (y) values of parental divergence of 80 F_1 and 54 F_1 combinations of early and mid-maturity group, respectively were derived. Using mean (m), standard deviation (sd), minimum (x) and maximum (y) values, parental divergence was classified into four divergence classes. Heterosis was calculated based on the formula as mid-parent heterosis (%) = [(F_1-mid parent)/ mid parent]/ 100 and standard parent heterosis (%) = [(F_1-standard check)/standard check]/100. Significance was tested through F test at 5 and 1%, probability. Pusa Kartik Sankar and Pusa Sharad were selected as a standard check in early and mid-maturity group, respectively. Heterosis in relation to divergence between parents over mid-parent value of hybrids for growth and yield parameters associated with each divergence class were obtained and for each heterotic hybrid the divergence class to which corresponding D^2 values of their parents in both groups was established. Spearman's correlation coefficient was computed to establish the relationship between genetic diversity of parental lines with mid-parent heterosis of F_1 hybrids for all the characters. The mean data were analyzed using SAS software.

RESULTS AND DISCUSSION

Mean data for eight quantitative traits of the parents was subject to diversity analysis, which portioned evaluated 18 genotypes of early maturity into eleven groups and 15 genotypes of mid-maturity into seven groups (Table 1). The result revealed that in early maturity, cluster group I and VII comprised of six and three genotypes, respectively, while others were mono-genotypic. Similarly in mid-maturity, cluster I was comprised of nine lines and rest were mono-genotypic.

Table 1. Grouping of the Indian cauliflower genotypes based on D^2 values.

Early maturity			Mid-maturity		
Cluster	No. of genotype(s)	Genotype(s)	Cluster	No. of genotype(s)	Genotype(s)
I	6	cc-13, cc-14, 14-4-17, 351aa, Pusa Deepali, Sl-7	I	9	cc-35E, 754, Pusa Paushja, cc-32L, HR-12-4, Sarju Maghi, Pusa Sharad, HR-6-5-1-2, cc-35L
II	1	23000	II	1	ccm-8
III	1	cc-15	III	1	Sl-1-2
IV	1	Pusa Meghna	IV	1	Pusa Shukti
V	1	41-5	V	1	cc-5
VI	1	vv	VI	1	Palam Uphar
VII	3	xx-2-6, cc-32E and cc-12	VII	1	cc-22
VIII	1	Sl-71			
IX	1	18-19			
X	1	395aa			
XI	1	98-10			

Canonical variety analysis was done to compute the intra-cluster Mahalonobis's value. Clusterwise intra- and inter-cluster distance (D^2) values is presented in Table 2. In early maturity group, the maximum (1.17) and minimum (1.01) intra-cluster value was recorded in group VII and I, respectively. The highest inter-cluster distance (3.88) was found between group VI and VII and lowest (0.7) was in between group IV and II. Similarly in mid-maturity group, the maximum (1.26) intra-cluster value was recorded in group I. The highest inter-cluster distance (5.48) was found between group VI and II and lowest (0.67) was in between group II and III. Low intra-cluster distance value and high inter-cluster distance value between the group suggested close relationship between the genotypes of same cluster and wide diversity between two clusters, respectively. The frequencies of maximum numbers of heterotic crosses over mid-parent were under the divergence class DC_3 in early maturity and DC_2 of mid-maturity group.

Data on correlation between genetic distances and heterosis over mid-parent for the traits are shown in Table 3. The correlation between genetic distance and the level of mid-parent heterosis was not reliable for all the quantitative traits in both early and mid-maturity groups. In early maturity negative and insignificant correlation was recorded between genetic distance and all the parameters except for leaf size. However in mid maturity group, the negative and insignificant correlation was observed for days to curd maturity and harvest index, while the other traits showed positive and insignificant correlation with genetic distance indicating that prediction of heterosis for complex traits based on genetic diversity estimates is difficult.

Table 2. Average intra- (bold) and inter-cluster D^2 values, divergence classes values and frequency of heterotic crosses in different divergence classes (DC) of Indian cauliflower.

Cluster	I	II	III	IV	V	VI	VII	VIII	IX	X	DC_1	: > 2.29
Early maturity												
I	**1.01**										DC_2	: 1.74-2.28
II	1.69	0.00									DC_3	: 1.20-1.73
III	1.34	1.51	0.00								DC_4	: < 1.19
IV	1.34	0.7	1.83	0.00							Mean	: 1.749
V	1.65	0.74	1.02	1.32	0.00						Standard deviation	: 0.544
VI	1.72	3.27	1.52	2.73	2.32	0.00					Maximum value	: 3.72
VII	2.24	1.57	1.7	2.24	1.4	3.88	**1.17**				Minimum value	: 0.70
VIII	1.34	1.22	1.77	1.31	1.74	3.72	1.74	0.00			Frequency of mid-parent crosses	
IX	1.93	1.73	1.49	1.53	2.4	2.43	3.04	1.66	0.00		DC_1	: 5
X	1.6	1.56	1.25	1.65	1.3	1.6	2.14	2.09	1.99	0.00	DC_2	: 21
XI	1.72	1.44	1.46	2.21	1.6	2.23	2.07	2.33	3.3	1.72	DC_3	: 44
											DC_4	: 10
Mid-maturity												
Group	I	II	III	IV	V	VI	VII				DC_1	: > 3.209
I	**1.26**										DC_2	: 2.195-3.208
II	2.17										DC_3	: 1.180-2.194
III	1.99	0.67									DC_4	: < 1.17
IV	2.63	5.22	4.44								Mean	: 2.195
V	2.26	1.89	1.74	3.13							Standard deviation	: 1.013
VI	2.53	5.48	4.39	1.14	2.6						Maximum value	: 5.48
VII	2.83	3.89	3.02	4.93	3.4	4.09	0.00				Minimum value	: 0.67
											Frequency of mid-parent crosses	
											DC_1	: 4
											DC_2	: 30
											DC_3	: 19
											DC_4	: 1

Table 3. Spearman's rank correlation coefficient between D^2 value and mid-parent heterosis for different traits.

Parameter	Genetic distance	
	Early maturity	Mid-maturity
Genetic distance	1.0	1.0
Days to 50% curd maturity	-0.16	0.13
Leaf size (cm^2)	0.01	0.16
Plant height (cm)	-0.03	0.06
Marketable curd weight (kg)	-0.14	0.03
Net curd weight (kg)	-0.11	0.00
Curd compactness	-0.17	0.10
Gross plant weight (kg)	-0.01	0.20
Harvest index	-0.06	-0.22
$p \leq 0.05$		

To estimate the level of heterosis line × tester mating design was used to produce hybrids. The mean, range, top three heterotic crosses with their heterosis (%), cluster distance value and divergence classes of early and mid-maturity group for eight important traits are presented in Tables 4 and 5. The significant improvement in mean of the hybrids was observed over the parents for all the traits in both maturity groups. The mean performance of all growth and yield contributing traits of parents and hybrids were higher in mid-maturity group over early maturity. The degree of heterosis showed variation from traits to traits.

For getting early crop, heterosis in negative direction was considered desirable for days to curd maturity. In early group cauliflower for days to curd maturity the range of percent heterosis was -12.01-16.48 and -13.81-14.92 over mid parent and standard check, respectively. Hybrids cc-32E × Pusa Meghna and cc-32E × 98-10 of divergence class DC_3 and DC_2 were best over mid-parent as well as standard check. Similarly in mid-maturity group, for days to curd maturity the range of percent heterosis was -17.45-11.27 and -19.07-7.91 over mid-parent and standard check, respectively. However, hybrids cc-35L × 6-5-1-2 and cc-35E × HR-12-4 of divergence class DC_2 were superior over mid-parent and standard check with percent heterosis of -13.64 and -12.95, respectively over mid-parent.

Leaf size is one of the most important growth and yield contributing trait in cauliflower, which is positively correlated with curd yield (Sheemar *et al.*, 17). Significant improvement was observed in mean values (874.24 and 928.33 cm^2) in early and (1384.60 and 1585.16 cm^2) in mid-maturity group parents and hybrids, respectively. Hybrids, cc32E × 23000 and 395aa × Pusa Deepali of divergence class DC_4 and DC_3 in early group were identified as best over mid-parent and also over standard check with heterosis of 94.89 and 86.50% over mid-parent. Likewise in mid-maturity group, hybrid ccm-8 × Pusa Paushja (82.44%) and ccm-8 × 6-5-1-2 (81.62%) of divergence class DC_1 and DC_2, respectively were superior over mid-parent. However, hybrid cc-35L × Pusa Shukti and cc-32E × Palam Uphar were superior over standard check.

For plant height, the mean performance of parents and hybrids, were 51.55 and 54.02 cm in early group, 64.44 and 70.65 cm in mid maturity group, respectively. In early group the range of heterosis was -23.84-40.52% over mid-parent and -2.94-65.44% over standard check. However, it was -12.44-34.44% and -18.75-18.75% over mid-parent and standard check, respectively. Hybrids of early group, 351aa × Sl-71 and 351aa × 18-19 of divergence class DC_4 and DC_3, respectively were superior over mid-parent, while cc-32E × 23000 (65.44%) and 395aa × Pusa Deepali (62.50%) were superior over standard check. Similarly in mid-maturity group, hybrids cc-32E × Sl-1-2 (34.44%) and cc-32L × Pusa Sharad (27.98%) of divergence class DC_3 and DC_2 were superior over mid-parent. However, over standard check, the hybrids cc-32L × Pusa Sharad (18.75%) and cc-32L × Palam Uphar (16.35%) were superior for plant height.

The gross plant weight ranged from 0.96-1.75 kg in parents and 0.88-2.57 kg in hybrids of early maturity group, while it was 1.55-3.44 kg in parents and 1.79-3.88 kg in mid-maturity cauliflower. In early maturity group, heterosis ranged from -38.75-144.03% over mid-parents and -19.02-198.52% over standard check. However, it was -17.10-102.72% over mid-parent and -13.26-87.86% over standard check. Hybrids, cc-32E × 23000 (144.03%) and 395aa × Pusa Deepali (84.87%) of divergence class DC_3 and DC_2 respectively were highly heterotic in early maturity group over mid-parent. These hybrids were also superior over standard check. Likewise in mid-maturity group, crosses cc-5 × SL-1-2 (102.72%) and cc-22 × 754 (89.51%) of divergence class DC_3 and DC_2 were highly heterotic over mid parent, while hybrids 35L × Pusa Shukti and cc-5 × Pusa Shukti were superior over standard check.

From growers point of view marketable curd weight is one of the most economically important traits. In early group cauliflower percentage heterosis for marketable curd weight ranged-25.99-68.10 and -12.08-122.64 over mid parent and standard check, respectively. Hybrids 351aa × Sl-71 and 395aa × Pusa Deepali of divergence class DC_3 were best over mid-

Table 4. Comparative performance of parents and hybrids of early and mid-maturity cauliflower genotypes.

	Days to 50% curd maturity		Leaf size (cm^2)		Plant height (cm)		Gross plant weight (kg)	
	Early maturity	Mid-maturity	Early maturity	Mid-maturity	Early maturity	Mid-maturity	Early maturity	Mid-maturity
Mean value and range								
Parents	59.70 (53.33-67.33)	68.57 (59.33-77.00)	874.24 (583.33-1206)	1348.60 (828-1906)	51.55 (38.0-66.67)	64.44 (54.69-71.33)	1.33 (0.96-1.75)	45.82 (1.55-3.44)
F_1s	62.68 (-52.00-69.33)	66.80 (58.33-66.80)	928.33 (660-1946.0)	1585.16 (888-2014.67)	54.02 (44.0-75.0)	70.65 (56.33-82.33)	1.32 (0.88-2.57)	2.82 (1.79-3.88)
Range of heterosis (%) over								
Mid parent	-10.09-16.48	-17.45-11.27	-35.46-94.89	-31.38-82.38	-23.86-40.52	-12.44-34.44	-38.75-144.03	-17.10-102.72
Standard checks	-13.81-14.92	-19.07-7.91	-20.60-146.80	-48.97-15.79	-2.94-65.44	-18.75-18.75	-19.02-198.52	-13.26-87.86
Top three F_1 hybrids with heterosis (%)over mid parent, D^2 value and divergence class								
1	cc-32 × 18-19 (-11.61/1.34)^{III}	cc-35L × 6-5-1-2 (-13.64/2.83)^{II}	cc-32E × 23000 (94.89/1.01)^{IV}	ccm-8 × PP (82.44/4.09)^{I}	351aa × SI-7 (40.52/1.01)^{IV}	cc-32L × SI-1-2 (34.44/1.99)^{III}	cc-32E × 23000 (144.03/1.7)^{III}	cc-5 × SI-1-2 (102.72/1.74)^{III}
2	cc-32E × PM (-11.11/1.60)^{III}	cc35E × HR-12-4 (-12.95/3.02)^{II}	395aa × PD (86.50/1.60)^{III}	ccm-8 × 6-5-1.2 (81.62/3.02)^{II}	351aa × 18-19 (30.68/1.72)^{III}	cc-32L × PS (27.98/2.63)^{II}	395aa × PD (84.87/1.6)^{III}	cc-22 × 754 (89.51/2.83)^{II}
3	cc-32E × 98-10 (-8.06/2.09)^{II}	cc-35E × P. Shukti (12.85/1.26)^{III}	xx-2-6 × SI-71 (77.63/1.26)^{III}	ccm-8 × P. Shukti (63.29/2.83)^{II}	351aa × SI-71 (28.84/1.65)^{III}	cc-32L × 754 (27.11/1.26)^{III}	cc-32E × PD (62.10/2.24)^{II}	ccm-8 × PS (76.51/2.17)^{III}
Top three F_1 hybrids with heterosis (%) over standard check								
1	cc-32E × PM (-13.81)	cc-35L × HR-12-4 (-19.07)	cc-32E × 23000 (146.8)	cc-35L × P. Shukti (15.79)	cc-32E × 23000 (65.44)	cc-32L × PS (18.75)	cc-32E × 23000 (198.53)	cc-35L × P. Shukti (87.86)
2	cc-32E × 98-10 (-11.05)	cc-5 × HR-12-4 (-18.61)	395aa × PD (113.3)	cc-32E × PU (11.03)	395aa × PD (62.50)	cc-32L × PU (16.35)	395aa × PD (137.03)	cc-5 × P. Shukti (86.74)
3	cc-32E × 23000 (-9.94)	cc-35L × 6-5-1-2 (-18.61)	cc-32E × SI-71 (77.00)	cc-35L × PP (10.96)	cc-32 E × SI-71 (45.59)	cc-22 × 754 (14.42)	cc-32E × PD (104.06)	ccm-8 × PU (85.44)

NS = Non significant, PS = Pusa Sharad, PU = Palam Uphar, SM = Sarju Maghi. PM = Pusa Meghna, PD = Pusa Deepali, PP = Pusa Paushja, P. Shukti = Pusa Shukti

Table 5 Comparative performance of parents and hybrids of Indian cauliflower.

	Marketable curd weight (kg)		Net curd weight (kg)		Curd compactness		Harvest Index (%)	
	Early maturity	Mid-maturity	Early maturity	Mid-maturity	Early maturity	Mid-maturity	Early maturity	Mid-maturity
Mean value and range								
Parents	0.65 (0.48-0.95)	0.98 (0.83-1.12)	0.47 (0.30-0.70)	0.76 (0.67- 0.92)	42.58 (25.15-58.51)	39.59 (26.05-57.66)	49.83 (39.33-63.28)	45.82 (32.39-60.46)
F_1s	0.67 (0.46-1.18)	1.18 (0.88-1.68)	0.49 (0.35-0.72)	0.90 (0.68-1.25)	53.35 (28.35-82.68)	42.339 (25.49-61.3)	52.58 (30.91-65.15)	42.60 (30.26-63.53)
Range of heterosis (%) over								
Mid parent	-25.99-68.10	-6.74-76.15	-31.52-52.50	-8.24-76.47	-31.73-143.89	-29.02-116.00	-8.42-53.87	-32.92-32.15
Standard checks	-12.08-122.64	-13.17-66.63	-17.97-69.50	-18.75-56.35	-65.71-0.00	-30.07-68.25	-36.29-45.01	-39.59-29.86
Top three F_1 hybrids with heterosis (%) over mid parent, D^2 value and divergence class								
1	351aa × Sl-71 (68.10/1.34)^{III}	cc-22 × SM (76.15/2.83)^{II}	cc-14 × Sl-7 (52.50/1.01)^{IV}	cc-22 × PU (76.47/4.09)^{I}	cc-14 × Sl-7 (143.89/1.01)^{IV}	cc-22 × SM (116.0/2.83)^{II}	395aa × Sl-7 (53.87/1.6)^{III}	cc-22 × SM (32.15/2.83)^{II}
2	395aa × PD (55.43/1.60)^{III}	cc-22 × Sl-1-2 (73.58/3.02)^{II}	395aa × PD (51.69/1.60)^{III}	cc-22 × Sl-1-2 (68.29/3.02)^{II}	14-4-17 × 98-10 (113.99/1.72)^{III}	cc-22 × Sl-1-2 (63.45/3.02)^{II}	cc-32E × 23000 (45.49/1.57)^{III}	cc-22 × PP (26.52/2.83)^{II}
3	395aa × Sl-71 (47.04/2.09)^{II}	cc-35L × PP (63.43/1.26)^{III}	395aa × Sl-71 (41.34/2.09)^{II}	cc-22 × SM (68.29/2.09)^{II}	cc-14 × 41-5 (103.00/1.65)^{III}	cc-22 × PS (63.41/2.83)^{II}	14-4-17 × PM (37.46/1.34)^{III}	cc-22 × PU (17.74/4.09)^{I}
Top three F_1 hybrids with heterosis (%) over standard check								
1	351aa × SL-71 (122.64)	cc-35L × PP (66.63)	cc-32E × SL-7 (69.50)	cc-22 × PU (56.25)	NS	cc-22 × SM (68.25)	cc-15 × PM (45.01)	cc-22 × Sl-1-2 (29.86)
2	cc-32E × 23000 (89.25)	cc-22 × PU (54.46)	cc-32E × 23000 (67.85)	cc-22 × SM (43.75)	NS	cc-5 × SM (54.74)	395aa × PM (34.27)	cc-35E × P. Shukti (10.29)
3	395aa × PD (80.38)	cc-22 × SL-1-2 (51.78)	cc-32E × PD (60.05)	cc-22 × SL-1-2 (43.75)	NS	cc-22 × 754 (54.60)	xx-2-6 × PD (31.66)	cc-22 × 6-5-1-2 (9.75)

NS = Non significant, PS = Pusa Sharad, PU = Palam Uphar, SM = Sarju Maghi. PM = Pusa Meghna, PD = Pusa Deepali, PP = Pusa Paushja, P. Shukti = Pusa Shukti parent. However, hybrids 351aa × Sl-71 (122.64%), cc-32E × 23000 and 395aa × Pusa Deepali (80.38%) were top three heterotic hybrids. Similarly in mid-maturity group, the range of percentage heterosis was -31.52-52.50 and -17.97-69.50 over mid-parent and standard check, respectively. However, hybrids cc-22 × Sarju Maghi (76.15%) and cc-22 × Sl-1-2 (73.58%) of divergence class DC_2 were superior over mid-parent, while hybrids cc-35L × Pusa Paushja and cc-22 × Palam Uphar were superior over standard check with heterosis of 66.63 and 54.46%, respectively.

Net curd weight is also one of the most important traits form the consumers and processing industries point of view. In early group, percentage heterosis for net curd weight ranged -31.52-52.50 and -17.97-69.50 over mid parent and standard check, respectively. Hybrids cc-14 × Sl-7 and 395aa × Pusa Deepali of divergence DC_4 and DC_3 were identified as best with heterosis of 52.50 and 51.69% over mid-parent, respectively. Likewise in mid-maturity group, hybrid cc-22 × Palam Uphar (76.49%) of divergence class DC_1 and cc-22 × Sl-1-2 (68.29%) and cc-22 × Sarju Maghi (68.29%) of divergence DC_2 were superior over mid parent and these hybrids were also superior over standard check.

Curd compactness is one of the most important quality traits in cauliflower. In early maturity cauliflower, heterosis varied from -31.73-143.89% over mid parent and none of the hybrids were superior over standard check. Hybrids cc-14 × Sl-7 and 14-4-17 × 98-10 of divergence class DC_4 and DC_3 with heterosis of 143.89 and 113.99% respectively were superior over mid-parent. Similarly in mid-maturity group, hybrids cc-22 × Sarju Maghi (34.44%) and cc-22 × Sl-1-2 (27.98%) of divergence class DC_2 were superior over mid-parent. However, over standard check, hybrids cc-22 × Sarju Maghi (18.75%) and cc-5 × Sarju Maghi (16.35%) were superior for curd compactness.

Improvement in the harvest index is one of the most important tasks for the breeders to get higher yield per plant. In early maturity group both parents and hybrids were found superior over mid-maturity group. In early maturity group, heterosis for harvest index ranged from -8.42-53.87% over mid-parents and -36.29-45.01% over standard check. Hybrids, 395aa × Sl-7 (53.87%) and cc-32E × 23000 (45.49%) of divergence class DC_3 were highly heterotic in early maturity group over mid-parent. However, hybrids cc-22 × Sarju Maghi and 395aa × Pusa Meghna were superior over standard check. Likewise in mid-maturity group, hybrid cc-22 × Sarju Maghi (32.15%) and cc-22 × Pusa Paushja (26.52%) of divergence class DC_2 were highly heterotic over mid-parent, while hybrids cc-22 × Sl-1-2 and cc-35E × Pusa Shukti were superior over standard check.

The result of present investigation revealed that in early maturity group six (cc-13, cc-14, 14-4-17, 351aa, Pusa Deepali and SL-7) out of eighteen inbred lines were genetically most closer to each other than other lines. Genotype vv of cluster VI was found most diverse from the lines xx-2-6, cc-32E and cc-12 of cluster VII with inter-cluster distance of 3.88. However in mid-maturity group, the most diverse lines were ccm-8(II) and Palam Uphar (VI) with inter-cluster distance of 5.48. Hybrids derived from the parents of divergence classes DC_3 in early maturity and DC_2 in mid-maturity group showed significantly and positive heterosis for most of the traits over mid parents as compare to DC_1 and DC_4. In cauliflower, for getting higher and desired level of heterosis for maximum number of traits, the hybrids involving parents with moderate genetic divergence (DC_2 and DC_3 classes) should be ensured. The results are in agreement with Arunachalam *et al*. (1) on groundnut, Mahmud *et al*. (11) on *Brassica* and Dharwad *et al*. (5) on brinjal and also supported by Moll *et al.* (12) who reported that heterosis decreases beyond a certain level of genetic diversity wing to incompatible gene combinations when two highly divergent parents are crossed.

Inbred-hybrid correlation relative to the average percent better-parent heterosis for each trait reveals a negative trend suggesting that as the amount of heterosis for a trait increases, the ability to predict the hybrid phenotype based upon the parental phenotype decreases (Flint-Garcia *et al*., 6). The results of this study showed that genetic distance correlated insufficiently with heterosis and hybrid performance in both the maturity group. The similar findings based on quantitative traits also has been reported by Moll *et al*. (12) on maize, Biswas *et al.* (4) on potato, Kiran *et al*. (8) on okra and based on molecular analysis by Bansal *et al*. (2) on *Brassica juncea*, and Usatov *et al*. (19) on sun flower. However, negative and reduced correlations between genetic distances with the heterosis of most of the measured traits were observed, the majority of the progeny expressed appreciable levels of heterosis in the desired directions for these characters. Thus, heterosis probably also exists due to different allelic combinations at particular loci in each parent, which when brought together in hybrid combination, complement each other, resulting in heterosis expression (Bingham *et al*., 3). Riday *et al*. (16) indicated that such loci may not be directly related to observable morphological differences but could have an effect on the physiology of the plant. The identified hybrids 395aa × Pusa Deepali and cc-32E × 23000 with higher magnitude of heterosis in early maturity for desirable traits leaf size, plant height, gross plant weight, marketable and net curd weight, while hybrids cc-22 × Sarju Maghi and cc-22 × Palam Uphar for marketable and net curd weight, curd compactness as well as harvest index may be selected for the further testing, promotion for adoption and commercialization.

Results from this study indicate that, despite the lack of direct correlation between the genetic distance and the degree of heterosis, genetic diversity forms a very useful guide not only for investigating the relationships among the genotypes but also in the selection of parents for heterotic hybrid combinations. The identified hybrid with high level of heterosis may be utilized for further evaluation under multilocation and commercial production.

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