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Heterosis and combining ability in small fruited ash gourd (*Benincasa hispida*)

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ABSTRACT

An attempt was made to develop small fruited ash gourd [*Benincasa hispida* (Thunb) Cogn] hybrids by crossing 10 genetically diverse ash gourd genotypes in a diallel mating system. The 45 F_1 hybrids along with their parents were evaluated for assessing their heterosis and combining ability for 11 important economic traits. The parent P_2 (Elevenchery local) was the best general combiner for fruit yield and fruits/plant. The specific combining ability component of variance (∂^2s) was higher than general combining ability component of variance (∂^2g) for the all the 11 characters studied which indicated the predominance of non-additive gene action in the improvement of these characters. The hybrids, viz. $P_2 \times P_7$ (Elevenchery local × Chengamanad) which exhibited the highest heterosis over top parent (79.95 %) and highly significant sca effects for fruit yield, fruit length, flesh thickness, average fruit weight and days to first fruit harvest followed by $P_3 \times P_4$ (Malappuram × IC 392313) which recorded the highest heterosis over better parent (166.38%) and highly significant sca effects for fruit yield, fruits/plant, flesh thickness and fruit length were found promising. Both the hybrids were small fruited with average fruit weight (2.04 kg) and (1.65 kg) respectively.

Key words: Ash gourd, General combining ability, Heterosis, Specific combining ability

Ash gourd [*Benincasa hispida* (Thunb) Cogn] is the only species in the monotypic genus *Benincasa* belonging to the family Cucurbitaceae. It is commonly called as white gourd, wax gourd, winter melon or chinese preserving melon, mainly due to the powdery white wax coating on the surface of fruit. The ash gourd grown in South East Asia has a smooth wax texture and is mainly available during winter and hence the name winter melon. In northern India, mature fruits are used for preparing '*Petha*' (ash gourd candy). In South India, fruits are used for culinary purpose. In China, a canned beverage is prepared from the fruit. In *ayurveda* system of medicine, the juice from mature fruits are used in the treatment of prostate enlargement and for treating obesity. The current market demand is for small fruited varieties (1 ½ - 2 kg) to cater to the needs of nuclear families.

In spite of economic importance and availability of considerable genetic diversity in this vegetable crop, not much work has been carried out on genetic improvement of this crop. A rapid improvement in ash gourd could be brought about by exploiting the hybrid vigour. Hybrids offer opportunities for improvement in production, uniformity in size, earliness and resistance to biotic factors. Heterosis for fruit yield to the tune of 37.6% (Sureja *et al.* 2006) over better parent and 23.36% over top parent (Verma and Behera, 2007) had been reported in ash gourd. Heterosis is a function of specific cross combination. Analysis of combining ability helps to determine the feasibility of its utilization and to identify the best combination. The superior hybrid combinations identified could be utilized for commercial exploitation of heterosis. Considering the above facts, the present study was undertaken with 10 ash gourd genotypes of diverse origin along with their 45 F_1 hybrids developed through diallel mating excluding reciprocals to identify potential parental combinations to develop superior small fruited hybrids.

MATERIALS AND METHODS

Ten ash gourd inbred lines, viz. P_1 – Thannyam, P_2 – Elevenchery Local, P_3 – Malappuram, P_4 – IC 392313 (NBPGR, New Delhi), P_5 – IC 0566995 (NBPGR, New Delhi), P_6 – IC 0596989 (NBPGR, New Delhi), P_7 – Chengamanad, P_8 – KAU Local, P_9 – AP 12 (Local collection from Arunachal Pradesh), P_{10} – AP 10 (Local collection from Arunachal Pradesh) selected from a germplasm of 42 collections maintained at Agricultural Research Station, Mannuthy, were used for the study. The inbred lines were crossed in all possible combinations excluding the reciprocals during 2014-15. The 10 parents along with their 45 F_1 hybrids were evaluated in the vegetable experimental plot of Agricultural Research Station, Mannuthy, during 2015-16 in 3 replications with 10 plants/genotype/replication. The

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crop was grown in rows spaced 4.0 m apart with 1.0 m spacing between plants. All the recommended package of practices for raising a successful crop of ash gourd under irrigated conditions was followed (KAU 2016). Out of 10 plants, 5 plants were randomly selected and observations were recorded on 11 important quantitative traits, viz. days to first male flower opening, days to first female flower opening, node number of first male flower, node number of first female flower, days to first fruit harvest, fruit length (cm), fruit diameter (cm), yield/plant (kg), fruits/plant, flesh thickness (cm) and fruit/weight (g). The mean data obtained was analyzed using Statistical Package SPAR-developed by Indian Agricultural Statistics Research Institute, New Delhi.

RESULTS AND DISCUSSION

The range of heterosis (%) and 3 best F_1 hybrids in terms of performance and heterosis for important economic traits are presented in Table 1. Considerable heterosis was observed both in positive and negative direction. Heterosis in negative direction is desirable for days to first male and female flower opening, node number of first male and female flower and days to first harvest. Among 11 economic traits studied, the range of heterosis was maximum in a negative direction for days to first female flower opening followed by node number of first female flower. Days to first male flower opening, node number of first male flower and days to first fruit harvest recorded lower negative heterosis. Similar results had been reported by Sureja (2003) and Verma and Behera (2007). Among the yield related traits, maximum positive heterosis was recorded for fruit yield/plant followed by number of fruits/plant and fruit weight. The range of heterosis was low for fruit length and fruit diameter. Flesh thickness exhibited positive heterosis over mid parent and better parent. High heterosis for fruit yield, fruit number and fruit weight had been reported by Mohanty and Mishra (1999) and Jha *et al.* (2009) in pumpkin. Low heterosis for flesh thickness was reported by Abdein *et al.* (2017).

Combining ability analysis of 10 parents and 45 F_1 hybrids showed significant gca and sca effects for all the characters studied (Table 2). This revealed the important role of additive and non-additive gene effects in the improvement the characters studied. The sca component of variance (s^2s) was higher than gca component of variance (s^2g) for all the characters which indicated the preponderance of non-additive gene action in the expression of the characters observed. The predictability ratio observed was also less than 0.5 for all the traits which again confirmed the role of non-additive component of variance in the improvement of economic traits. The analysis of general combining ability revealed that among the 10 parental lines, the parent P_9 exhibited the highest negative gca effect in a favourable direction for days to first male flower opening followed by parent P_8 (Table 3).

The parent P_8 showed the highest negative gca effect for number of days to first female flower followed by P_9. Highest positive gca effect for fruit yield was observed in

Table 1 Range of heterosis, heterotic crosses, and best F1 hybrids of ash gourd for economic traits

Character	Range of heterosis (%) over			Three best F_1 hybrids with heterosis % over		
	Better parent	Mid parent	Top parent	Better parent	Mid parent	Top Parent
Days to first male flower opening	–15.66 to 52.11	–17.95 to 38.46	–7.25 to 56.52	$P_2 \times P_6$ (–15.66) $P_6 \times P_9$ (–11.11) $P_4 \times P_5$ (–8.00)	$P_6 \times P_9$ (–17.95) $P_5 \times P_8$ (–12.82) $P_5 \times P_9$ (–12.82) $P_7 \times P_{10}$ (–12.82) $P_6 \times P_8$ (–11.54)	$P_6 \times P_9$ (–7.25), $P_5 \times P_8$ (–1.45), $P_5 \times P_9$ (–1.45), $P_7 \times P_{10}$ (–1.45)
Days to first female flower opening	–46.63 to 61.90	–54.23 to 19.72	–38.10 to 61.9	$P_6 \times P_9$ (– 46.15) $P_4 \times P_8$ (– 40.91) $P_2 \times P_6$ (– 40.63)	$P_4 \times P_8$ (–54.23) $P_6 \times P_9$ (–50.70) $P_3 \times P_8$ (–36.62)	$P_4 \times P_8$ (–38.1) $P_6 \times P_9$ (–33.33) $P_3 \times P_8$ (–14.29)
Node number of first male flower	–15.19 to 34.72	–13.10 to 25.81	–6.94 to 34.72	$P_2 \times P_6$ (–15.19) $P_6 \times P_{10}$ (–10.53) $P_9 \times P_{10}$ (–9.46)	$P_2 \times P_6$ (–13.10) $P_9 \times P_{10}$ (–13.10) $P_4 \times P_5$ (–11.80) $P_5 \times P_9$ (–11.80) P1 × P_8 (–10.51) $P_3 \times P_8$ (–10.51) $P_5 \times P_8$ (–10.51)	$P_2 \times P_6$ (–6.94) $P_9 \times P_{10}$ (–6.94) $P_5 \times P_9$ (–5.56) $P_6 \times P_{10}$ (–5.56) $P_7 \times P_{10}$ (–5.56)
Node number of first female flower	–38.71 to 52.63	–39.29 to 14.29	–10.53 to 68.42	$P_7 \times P_{10}$ (–38.71) $P_6 \times P_{10}$ (–35.48) $P_4 \times P_8$ (–32.00)	$P_4 \times P_8$ (–39.29) $P_3 \times P_9$ (–35.71) P1 × P_8 (–32.14) $P_3 \times P_7$ (–32.14) $P_7 \times P_{10}$ (–32.14)	$P_4 \times P_8$ (–10.53) $P_3 \times P_9$ (–5.26),

Contd.

Table 1. (*Concluded*)

Character	Range of heterosis (%) over			Three best F_1 hybrids with heterosis % over		
	Better parent	Mid parent	Top parent	Better parent	Mid parent	Top Parent
Days to first fruit harvest	–17.05 to 20.56	–5.81 to 13.56	0.00 to 20.56	$P_2 \times P_6$ (–17.05) $P_3 \times P_6$ (–17.05) $P_4 \times P_6$ (–17.05)	$P_2 \times P_3$ (–5.81), $P_2 \times P_5$, $P_2 \times P_6$, $P_2 \times P_7$, $P_2 \times P_8$, $P_2 \times P_9$, $P_2 \times P_{10}$, $P_3 \times P_4$, P3 × P5 , $P_3 \times P_6$, P3 × P_7, $P_3 \times P_8$, P3 × P_9, $P_3 \times P_{10}$, $P_4 \times P_5$, $P_4 \times P_6$, $P_4 \times P_7$, $P_4 \times P_8$, $P_4 \times P_9$, $P_4 \times P_{10}$, $P_5 \times P_8$, $P_5 \times P_9$, $P_6 \times P_8$, $P_6 \times P_9$, $P_6 \times P_{10}$, $P_7 \times P_8$, $P_7 \times P_9$, $P_7 \times P_{10}$, $P_8 \times P_9$, $P_8 \times P_{10}$, $P_9 \times P_{10}$	
Fruit length (cm)	27.54 to –59.38	61.21 to –66.73	21.15 to –75.00	$P_3 \times P_5$ (27.54) $P_5 \times P_9$ (27.03) $P_2 \times P_8$ (21.15)	$P_2 \times P_8$ (61.21) $P_2 \times P_5$ (52.25) $P_2 \times P_9$ (9.62)	$P_2 \times P_5$ (14.42) $P_2 \times P_8$ (21.15) $P_2 \times P_9$ (9.62)
Fruit diameter (cm)	14.29 to –44.90	25.21 to –53.00	4.84 to – 64.52	$P_2 \times P_9$ (14.29) $P_2 \times P_6$ (11.32) $P_4 \times P_7$ (6.59)	$P_6 \times P_{10}$ (37.95) $P_2 \times P_6$ (25.21) $P_8 \times P_9$ (23.51)	$P_6 \times P_{10}$ (4.84)
Yield/plant (kg)	166.38 to –q86.74	245.28 to –92.55	79.94 to –96.12	$P_3 \times P_4$ (166.38) $P_3 \times P_6$ (145.64) $P_8 \times P_{10}$ (144.97)	$P_2 \times P_7$ (245.28) $P_3 \times P_4$ (191.51) P2 × P_5 (186.79)	$P_2 \times P_7$ (79.94) $P_3 \times P_4$ (51.92) $P_2 \times P_5$ (49.46)
Fruits/plant	160.98 to –62.32	182.71 to –41.59	75.36 to –62.32	$P_2 \times P_3$ (160.98) $P_2 \times P_5$ (140.48) $P_3 \times P_4$ (140.48) $P_9 \times P_{10}$ (114.81)	P1 × P_2 (182.71) P1 × P_9 (150.00) $P_2 \times P_3$ (150.00) $P_2 \times P_5$ (135.98) $P_3 \times P_4$ (135.98)	P1 × P_2 (75.36) P1 × P_9 (55.07) $P_2 \times P_3$ (55.07) $P_3 \times P_4$ (46.38)
Flesh Thickness (cm)	2.5 to 3.95	35.89 to –61.67	0.00 to –71.79	$P_1 \times P_8$ (3.95), $P_2 \times P_8$, P3 x P_8, $P_4 \times P_8$, P_5 x P_8, $P_7 \times P_8$ P_8 x P_9, and P_8 x P_{10} $P_1 \times P_{10}$ (3.90), $P_2 \times P_{10}$, P_3 x P10, $P_4 \times P_{10}$, P_5 x P10, $P_6 \times P_{10}$, P_7 x P10, and P_9 x P_{10} $P_1 \times P_5$ (3.10), $P_2 \times P_5$, P_3 x P5, $P_4 \times P_5$, P_5 x P_6, $P_5 \times P_7$, P_5 x P_9	$P_2 \times P_8$ (35.89) $P_2 \times P_9$ (35.89) $P_4 \times P_7$ (35.89) $P_2 \times P_4$ (30.66) $P_2 \times P_{10}$ (21.95)	
Fruit weight (g)	99.39 to –75.12	98.85 to –75.27	19.12 to –85.18	$P_3 \times P_6$ (99.39) $P_2 \times P_{10}$ (45.22) $P_4 \times P_7$ (42.30)	$P_2 \times P_{10}$ (98.85) $P_4 \times P_7$ (81.15) P_2 × P8 (65.38)	$P_2 \times P_{10}$ (19.12) $P_4 \times P_7$ (8.53) $P_2 \times P_8$ (–0.92)

Table 2 Analysis of variance for combining ability for economic traits in ash gourd

Character	Source of variation of gca			Source of variation of sca			Error		s^2_g	s^2_S	PR
	DF	MSS	F	DF	MSS	F	DF	MSS			
Days to first male flower opening	9	180.898**	374.006	45	16.603**	34.326	54	0.484	0.018	0.165	0.18
Days to first female flower opening	9	31.532**	52.126	45	8.536**	14.110	54	0.605	0.023	0.206	0.18
Node number of first male flower	9	85.424**	184.114	45	18.231**	39.254	54	0.464	0.017	0.158	0.17
Node number of first female flower	9	13.766**	23.886	45	7.214**	12.516	54	0.576	0.022	0.196	0.18
Days to first fruit harvest	9	184.637**	5077.519	45	26.237**	721.519	54	0.036	0.001	0.012	0.14
Fruit length (cm)	9	239.441**	841.310	45	19.658**	69.071	54	0.285	0.011	0.097	0.18
Fruit diameter (cm)	9	42.812**	202.351	45	3.118**	14.739	54	0.212	0.008	0.072	0.18
Yield/plant (kg)	9	69.692**	354.742	45	24.118**	122.767	54	0.196	0.007	0.067	0.17
Fruits/plant	9	11.931**	84.026	45	11.059**	77.888	54	0.142	0.005	0.048	0.17
Flesh thickness (cm)	9	3.104**	199.886	45	0.410**	26..390	54	0.016	0.001	0.005	0.28
Fruit weight (g)	9	2.65**	314.152	45	0.215**	25.479	54	0.008	0.001	0.004	0.33

*Significant at P=0.05 level, **Significant at P=0.01 level, Predictability ratio (PR) = $2\partial^2g / 2\partial^2g + \partial^2s$

parent P_2 followed by P_7 and P_8 respectively. The parent P_8 had the highest positive gca effects for fruit weight and flesh thickness, followed by parent P_{10}. The parent P_2 had the highest positive gca effect for fruit length followed by $P_{10.}$ Highest positive gca effects for fruit diameter were observed in parent P_7 followed by parent P_{10} and P_6. In most of the cases, *per se* performance of parents had a direct reflection on their respective gca effects and the results were in conformity with the findings of Jha *et al.* (2009) in pumpkin, Pandey *et al.* (2005) in ash gourd and Reddy *et al.* (2014) in cucumber. The estimates of sca effects are presented in Table 4. Out of 45 F_1 hybrids studied, significant sca in favourable direction was observed in 22 hybrids for days to first male flower opening, 17 hybrids for days to first female flower opening and node number of first female flower, fruit length and yield/plant, 16 hybrids for flesh thickness, 23 hybrids for days to first fruit harvest, 11 hybrids for fruit diameter, 19 hybrids for fruits/plant and 12 hybrids for fruit weight. The hybrids which showed highest significant desirable sca effects for the economic characters observed were $P_2 \times P_6$ and $P_4 \times P_5$ for days to first male flower opening, $P_6 \times P_9$ and $P_4 \times P_8$ for days to first female flower opening, $P_1 \times P_8$, $P_2 \times P_6$ and $P_6 \times P_{10}$ for node number of first male flower, $P_6 \times P_{10}$, $P_1 \times P_8$ and

P2x P7 (Elevenchery local x Chengamanad)

P3x P4 (Malappuram x IC 392313)

Fig 1 Promising F_1 hybrids of ash gourd

Table 3 Estimates of gca effects of ash gourd genotypes

Parent	DFMO	DFFO	NNMF	NNFF	DFFH	FL	FD	Y/P	F/P	FT	FW
P1	7.262**	2.461**	4.825**	1.389**	6.967**	–7.225**	–2.683**	–3.292**	1.32**	–0.814**	–0.748**
P2	0.072	0.627**	–0.3*	0.764**	0.55**	4.95**	–0.124	2.734**	0.858**	0.298**	0.249**
P3	–0.613**	–0.664**	–0.508**	–0.486**	–2.2**	–1.492**	–1.887**	–0.413**	0.321**	–0.352**	–0.166**
P4	–0.172	–0.248	–0.092	–0.319	–1.283**	1.863**	0.08	–0.189	–0.771**	0.24**	0.163**
P5	–0.197	–0.677**	0.2	–0.515**	0.55**	–0.508**	–0.149	–1.341**	–0.17*	–0.168**	–0.294**
P6	0.328*	0.615**	0.283	0.61**	1.467**	–1.413**	1.055**	–0.912**	–0.929**	0.073*	0.018
P7	–1.113**	–0.373*	–0.592**	–0.278	–0.367**	1.137**	0.559**	1.435**	0.154	0.032	0.187**
P8	–2.613**	–1.664**	–2.008**	–0.944**	–2.2**	1.875**	1.559**	1.326**	–0.438**	0.315**	0.321**
P9	–5.53**	–0.789**	–1.967**	–0.694**	–2.22**	0.404**	0.534**	–0.349**	0.083	0.073	–0.034
P10	–0.28	0.711**	0.158	0.472*	–1.283**	0.408**	1.055**	1.006**	–0.429**	0.303**	0.303**
SE (gi)	0.135	0.151	0.132	0.147	0.037	0.103	0.089	0.086	0.073	0.024	0.018
SE (gi-gj)	0.201	0.225	0.197	0.219	0.055	0.154	0.133	0.128	0.109	0.036	0.027
CD (P=0.05)	0.31	0.342	0.299	0.332	0.084	0.233	0.201	0.195	0.165	0.054	0.040
CD (P=0.01)	0.44	0.49	0.429	0.477	0.120	0.335	0.289	0.279	0.237	0.078	0.058

*,**Significant at P=0.05, P=0.01. DFMO, Days to first male flower opening, DFFO, Days to first female flower opening; NNMF, Node number of first male flower; NNFF, Node number of first female flower; DFFH, Days to first fruit harvest; FL, Fruit length; FD, Fruit diameter; Y/P, yield/plant; F/P, Fruits/plant; FT, Flesh thickness; FW, Fruit weight.

Table 4 Estimates of sca effects of ash gourd genotypes

Parent	DFMO	DFFO	NNMF	NNFF	DFFH	FL	FD	Y/P	F/P	FT	FW
$P_1 \times P_2$	1.505**	1.502**	–1.125*	–1.365**	0.083	0.152	0.344	0.487	4.336**	0.196**	–0.205**
$P_1 \times P_3$	8.546**	2.797**	6.083**	–1.115*	2.833**	–4.406**	–1.594**	–2.931**	–2.827**	–0.454**	0.073
$P_1 \times P_4$	0.105	–1.12*	1.667**	–0.282	1.917**	–2.51**	0.44	–1.82**	–1.985**	0.354**	–0.252**
$P^1 \times P_5$	–0.87*	–1.691**	1.375**	0.414	0.083	–2.389**	–2.081**	–1.103**	–2.436**	–0.437**	0.06
$P_1 \times P_6$	–0.895*	–1.485**	0.792	1.289**	–0.833**	1.165**	–1.285**	–0.122	–0.877**	–0.079**	–0.029
$P_1 \times P_7$	–0.954*	–0.495	–0.883*	0.177	1**	–1.785**	–0.039	–1.799**	0.185	–0.238**	–0.288**
$P_1 \times P_8$	–1.954**	–0.203	–6.417**	–3.657**	2.833**	–2.773**	0.361	0.045	1.272**	–0.321**	–0.337**
$P_1 \times P_9$	0.963*	0.422	0.042	2.093**	2.833**	4.448**	0.236	2.551**	3.711**	–0.029	–0.031
$P_1 \times P_{10}$	–2.787**	–2.078**	0.917*	0.427	1.917**	0.444	–0.285	0.326	2.773**	–0.508**	–0.224**
$P_2 \times P_3$	–1.12**	2.63**	0.208	2.51**	–1.75**	0.419	–0.552*	0.648*	3.934**	–0.167**	–0.442**
$P_2 \times P_4$	–2.562**	–1.286**	–1.708**	–0.157	8.333**	–4.935**	–0.119	–6.467**	–2.724**	0.492**	–0.535**
$P_2 \times P_5$	–1.037*	–1.357**	–1*	0.039	–4.5**	5.686**	0.611	6.771**	3.826**	–0.35**	–0.053

Contd.

Table 4. (*Continued*)

Parent	DFMO	DFFO	NNMF	NNFF	DFFH	FL	FD	Y/P	F/P	FT	FW
$P_2 \times P_6$	–4.062**	–4.149**	–4.583**	–1.086*	–5.417**	–6.16**	2.156**	3.962**	2.384**	–0.492**	–0.146**
$P_2 \times P_7$	0.88*	–1.161*	0.292	–1.198**	–3.583**	2.54**	0.902**	7.095**	2.201**	0.4**	0.306**
$P_2 \times P_8$	1.38*8	0.63	0.708	0.468	–1.75**	5.052**	0.652*	2.193**	–1.107**	0.567**	0.276**
$P_2 \times P_9$	0.796	0.255	0.167	0.218	–1.75**	3.523**	1.927**	4.346**	–3.428**	0.808**	0.112*
$P_2 \times P_{10}$	–1.454**	–1.745**	–2.958**	–0.948*	–2.667**	0.769*	–0.594	–0.716**	–3.016**	0.179**	0.729**
$P_3 \times P_4$	2.48**	2.505**	1*	2.593**	0.083	3.756**	0.394	9.016**	4.963**	0.392**	0.354**
$P_3 \times P_5$	–1.495*	–0.566	–1.792**	2.789**	–1.75**	4.377**	0.723*	2.113**	2.063**	0.3**	0.111*
$P_3 \times P_6$	–1.52**	–1.357**	–2.875**	–2.336**	–2.667**	2.781**	–1.981**	1.609**	–0.628**	0.058*	0.489**
$P_3 \times P_7$	–2.079**	–1.87**	–1.5**	–2.448**	–0.833**	–0.769*	0.915**	–2.283**	–0.511*	–0.3**	–0.235**
$P_3 \times P_8$	0.421	–1.078*	–1.083**	0.218	1**	–0.756*	1.415**	–0.094	0.331	–0.133**	–0.119*
$P_3 \times P_9$	–0.662	–0.953	–0.625	–2.532**	1**	–5.335**	–1.31**	1.711**	–0.491*	–0.422**	0.291**
$P_3 \times P_{10}$	–0.412	–0.953	2.75**	0.802	0.083	1.211**	–0.027	–3.329**	–1.979**	0.279**	–0.156**
$P_4 \times P_5$	–3.937**	–0.482	–4.208**	–0.378	–2.667**	–5.977**	–0.798**	0.478	–0.645**	–0.292**	0.607**
$P_4 \times P_6$	1.338**	1.726**	1.708**	1.997**	–3.583**	1.927**	0.202	–0.986**	–0.387	–0.033	0
$P_4 \times P_7$	–2.02**	0.214	–1.917**	0.385	–1.75**	4.877**	1.448**	3.607**	0.031	0.908**	0.701**
$P_4 \times P_8$	–1.02*	–3.995**	–0.5	–2.948**	0.083	0.39	–1.302**	0.156	0.623**	–0.525**	–0.013
$P_4 \times P_9$	–0.104	–1.87**	–0.042	–1.198**	0.083	–0.139	–0.027	1.647**	1.701**	0.067**	–0.198**
$P_4 \times P_{10}$	7.646**	–0.87	7.833**	–0.865	–0.833**	0.106	–0.798**	–3.913**	–1.887**	–0.263**	–0.175**
$P_5 \times P_6$	5.563**	2.005**	5.417**	1.343**	5.583**	–1.952**	–0.819**	0.026	1.013**	–0.125**	–0.158**
$P_5 \times P_7$	5.505**	–0.357	5.292**	–0.419	7.417**	–4.002**	0.073	–5.261**	–2.97**	–0.583**	–0.547**
$P_5 \times P_8$	–1.995**	0.934*	–1.792**	0.247	–1.75**	4.011**	0.829**	–0.227	–0.078	0.233**	0.039
$P_5 \times P_9$	–2.079**	0.559	–2.333**	–0.503	–1.75**	3.981**	–0.298	–0.281	1.501**	–0.075**	–0.045
$P_5 \times P_{10}$	2.171**	1.059*	2.042**	0.831	8.333**	–1.023**	–0.569*	0.114	–0.182	–0.104**	0.027
$P_6 \times P_7$	2.98**	1.351**	3.208**	0.456	6.5**	–0.848**	–0.077	–0.624*	0.289	0.075**	0.316**
$P_6 \times P_8$	–2.02**	–0.857	–0.375	–0.378	–2.667**	–1.335**	–0.277	2.524**	0.231	–0.008	0.297**
$P_6 \times P_9$	–4.604**	–5.232**	–0.417	–0.628	–2.667**	1.386**	0.648*	–0.8**	–0.591*	0.433**	0.062
$P_6 \times P_{10}$	–0.854*	1.268**	–4.542**	–3.794**	–3.583**	0.631*	2.477**	–0.945**	–0.979**	–0.196**	0.2**
$P_7 \times P_8$	0.421	–0.87	–0.5	0.01	–0.833**	–0.385	0.469	–2.038**	–0.002	–0.067**	–0.347**

Contd.

Table 4. (*Concluded*)

Parent	DFMO	DFFO	NNMF	NNFF	DFFH	FL	FD	Y/P	F/P	FT	FW
$P_7 \times P_9$	–0.162	1.755**	–0.542	–0.24	–0.833**	–1.664**	–1.256**	–4.262**	–3.024**	0.125**	–0.042
$P_7 \times P_{10}$	–3.412**	–3.245**	–3.667**	–3.407**	–1.75**	0.331	–2.527**	5.038**	1.788**	–0.554**	0.181**
$P_8 \times P_9$	2.338**	0.547	2.875**	1.427**	1.000**	–1.402**	0.794**	–0.013	0.568*	–0.608**	–0.316**
$P_8 \times P_{10}$	0.588	1.047*	1.25**	–0.74	0.083	–1.656**	–1.777**	5.232**	2.581**	–0.338**	0.072
$P_9 \times P_{10}$	–0.995*	0.172	–2.795**	–0.99*	0.083	–0.935**	0.248	4.368**	3.459**	0.354**	–0.273**
SE S_{ii}	0.406	0.454	0.398	0.443	0.111	0.311	0.269	0.259	0.220	0.024	0.054
SE S_{ii} - S_{jj}	0.568	0.635	0.556	0.62	0.156	0.436	0.376	0.362	0.308	0.102	0.075
SE $_{ij}$	0.453	0.507	0.444	0.494	0.124	0.347	0.300	0.289	0.245	0.081	0.06
SE_{ij} - S_{ik}	0.658	0.748	0.732	0.712	0.568	0.521	0.568	0.433	0.359	0.146	0.097
SE S_{ij} - S_{kl}	0.635	0.710	0.622	0.693	0.174	0.487	0.420	0.405	0.344	0.114	0.084

*, **Significant at P=0.05, P=0.01. DFMO, Days to first male flower opening; DFFO, Days to first female flower opening; NNMF, Node number of first male flower; NNFF, Node number of first female flower; DFFH, Days to first fruit harvest; FL, Fruit length; FD, Fruit diameter; Y/P, yield/plant; F/P, Fruits/plant; FT, Flesh Thickness; FW, Fruit weight.

$P_7 \times P_{10}$ for node number of first female flower, $P_2 \times P_7$, $P_4 \times P_6$ and $P_6 \times P_{10}$ for days to first fruit harvest , $P_2 \times P_5$, $P_2 \times P_8$, $P_4 \times P_7$ for fruit length, $P_6 \times P_{10}$, $P_2 \times P_6$ and $P_2 \times P_9$ for fruit diameter, $P_2 \times P_{10}$, $P_4 \times P_7$ and $P_4 \times P_5$ for fruit weight, $P_3 \times P_4$, $P_1 \times P_2$, and $P_2 \times P_5$ for fruits/ plant, $P_4 \times P_7$, $P_2 \times P_9$ and $P_2 \times P_8$ for flesh thickness and $P_3 \times P_4$, $P_2 \times P_7$ and $P_2 \times P_5$ for fruit yield. The two top performing hybrids for yield/plant had significantly higher sca effects for yield contributing characters. A comparison of gca effects of parents and sca effects of crosses revealed that highly significant gca effects of parents for a particular character were reflected in sca effects of their crosses for those characters. F_1 hybrids showing high heterosis for yield and its components traits like number of fruits, fruit length, fruit weight had at least one of their parental lines having high gca effects for yield and its component traits. This proved the strong tendency of transmitting higher gains of parents to offspring.

The results of present investigation revealed that heterosis breeding could be effectively utilized for exploiting the non-additive genetic variance for improvement of yield and its component characters in ash gourd. The cross combinations that showed highest sca effects and heterosis over top parent can be utilized for heterosis breeding. The F_1 hybrids, $P_2 \times P_7$ (Elevenchery × Chengamanad) which exhibited highest heterosis over top parent and second highest sca effects for fruit yield and highly significant sca effects for fruit length, fruit diameter, flesh thickness, average fruit weight (2.04 kg) and days to first harvest and the hybrid $P_3 \times P_4$ (Malappuram × IC 392313), which exhibited highest heterosis over better parent and highly significant sca effects for fruit yield, fruits/plant, flesh thickness and fruit length and average fruit weight (1.655 kg) can be utilized as promising small fruited F_1 hybrids of ash gourd.

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