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Studies on heterosis in pumpkin (*Cucurbita moschata* Duch. ex Poir)

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ABSTRACT

An investigation was carried out to assess the extent of heterosis for fruit, yield and quality parameters in pumpkin *(Cucurbita moschata* Duch. ex Poir). The trial was conducted at Department of Vegetable Crops, Horticulture College and Research Institute, Tamil Nadu Agricultural University, Coimbatore, during 2009-2010. Hybrids developed by line x tester mating design, with twelve lines and three testers along with commercial check MPH 1 in pumpkin, were evaluated for fruit weight, fruit number per vine, fruit equatorial diameter, fruit polar diameter, flesh thickness, seed number per fruit, seed weight per fruit, fruit yield per vine and quality parameters, viz., total carbohydrate content, total carotenoid and crude fibre content in the fruit. Among the hybrids, Kasi Harit x Avinashi Local showed positive and significant heterosis for fruit number per vine, flesh thickness, seed weight per fruit, total carotenoid content and fruit yield per vine. Vadhala Gundu Local x CO 2 was the next best, as, the hybrid possessed desirable traits, viz., high fruit number per vine, flesh thickness, total carotenoid content and fruit yield per vine.

Key words: Heterosis, pumpkin, relative heterosis, heterobeltiosis, standard heterosis

INTRODUCTION

Pumpkin (*Cucurbita moschata Duch. ex Poir.*) is commonly grown as a vegetable and its large sized seeds contain appreciable quantities of protein and oil and may serve as a good substitute for edible oil, similar to the oil of summer squash (*Cucurbita pepo).* Though a wide range of variability is encountered in this crop, very little attention has been paid to exploiting it in breeding programmes. A thorough knowledge of genetic behaviour of any character is important for formulating appropriate breeding techniques in a crop. The monoecious character, conspicuous and solitary flowers, large seed number per fruit and wide variability for yield, size and shape of the fruit make this crop ideal for commercial breeding. During the last two decades, several workers have utilized heterosis breeding as a tool for yield improvement in pumpkin (Sirohi and Ghorui, 1993). However, the genetic potential of this crop can be further exploitated to almost perfection. Hence, the present investigation was undertaken to determine the magnitude of heterosis for fruit, yield and quality parameters in pumpkin.

MATERIAL AND METHODS

The experimental material comprised twelve lines of pumpkin, viz., Pusa Vishwas (L_1), Punjab Samrat (L_2), Narendra Abhushan (L_3), Narendra Uphar (L_4), Ambili (L_5), Virudhachalam Local (L_6), Chakor (L_7), Ashoka Farm Aids (L_8), Vadhalagundu Local (L_9), Karamadai Local (L_{10}), Karwar Local (L_{11}) and Kasi Harit (L_{12}). These were crossed with three testers viz., Arka Suryamukhi (T_1), Avinashi Local (T_2) and CO 2 (T_3), and, their resultant thirty six hybrids obtained through line x tester mating design were raised in Randomized Block Design (RBD) during the year 2009-2010 at Department of Vegetable Crops, Horticulture College and Research Institute, Coimbatore. Observations were recorded on single-plant basis in five randomly selected plants from each replication for different parameters, viz., fruit weight, fruit number per vine, fruit equatorial diameter, fruit polar diameter, flesh thickness, seed number per fruit, seed weight per fruit, fruit yield per vine and quality parameters such as total carbohydrate, total carotenoid and crude fibre content in the fruit. Data were analyzed as per Kempthrone (1957). Performance of F_1 hybrids in terms of percentage increase or decrease over the mid-parent (relative heterosis), better parent (heterobeltiosis) and the commercial check (standard heterosis) over MPH 1 was calculated for expressing the extent of heterosis (Heyes *et al*, 1955).

RESULTS AND DISCUSSION

Performance of 36 F_1 hybrids in the experiment is presented in Table 1. Among all the hybrids, Kasi Harit x

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Table 1. *Per se* performance of F_1 hybrids of pumpkin for fruit, yield and quality parameters

Hybrid	Fruit weight (kg)	Fruit number per vine	Fruit equatorial diameter (cm)	Fruit polar diameter (cm)	Flesh thickness (cm)	Seed number per fruit	Seed weight per fruit(g)	Fruit yield per vine (kg)	Total carotenoid content (mg per 100g)	Total carbohydrate content (g per 100g)	Crude fibre content (per cent)
Pusa Vishwas x Arka Suryamukhi	3.60	2.62	17.00	20.07	2.43	201.62	15.62	9.33	0.53	0.98	1.26
Pusa Vishwas x Avinashi Local	4.45	1.37	17.57	22.81	2.08	229.87	17.25	5.83	1.03	0.88	0.64
Pusa Vishwas x CO 2	4.16	1.25	21.88	19.68	2.62	230.12	16.37	5.29	0.76	0.77	1.02
Punjab Samrat x Arka Suryamukhi	3.57	3.62	25.59	16.88	2.72	152.75	13.87	10.10	1.03	0.92	0.85
Punjab Samrat x Avinashi Local	3.76	4.25	19.08	16.68	2.98	273.37	19.62	13.44	1.73	1.31	0.89
Punjab Samrat x CO 2	3.06	3.37	16.58	14.41	1.91	339.12	19.00	6.43	1.08	0.71	0.79
Narendra Abhushan x Arka Suryamukhi	2.57	2.50	19.37	14.40	2.22	277.25	20.75	6.42	1.17	0.98	0.98
Narendra Abhushan x Avinashi Local	2.78	1.62	20.12	11.47	2.65	298.62	28.62	4.49	1.25	1.02	0.88
Narendra Abhushan x CO 2	4.11	2.87	21.87	15.90	3.05	331.87	26.75	11.02	1.20	0.90	1.17
Narendra Uphar x Arka Suryamukhi	3.27	1.37	19.76	11.75	2.18	268.62	22.75	4.70	1.11	0.82	0.99
Narendra Uphar x Avinashi Local	3.71	2.50	17.30	13.15	2.66	191.25	16.62	9.26	2.11	1.37	0.68
Narendra Uphar x CO 2	4.08	3.37	18.06	9.66	2.10	219	15.75	13.74	1.14	0.96	1.19
Ambili x Arka Suryamukhi	4.74	2.25	18.28	16.76	3.07	227.5	17.12	10.61	1.13	0.84	1.00
Ambili x Avinashi Local	3.76	2.00	15.55	14.03	2.57	234.62	14.87	7.54	1.52	1.17	1.03
Ambili x CO 2	4.07	2.37	21.91	11.45	2.67	203.87	19.00	10.01	0.51	0.44	0.79
Virudhachalam Local x Arka Suryamukhi	4.51	1.37	19.51	20.31	3.08	389.75	34.75	6.92	1.44	0.95	1.01
Virudhachalam Local x Avinashi Local	4.59	1.12	23.47	20.66	3.01	309.37	40.50	6.16	1.66	1.30	0.95
Virudhachalam Local x CO 2	4.09	1.62	22.73	19.28	2.98	244.12	33.12	6.74	1.19	0.85	0.89
Chakor x Arka Suryamukhi	3.60	3.37	21.61	13.83	3.40	425.75	21.18	10.24	1.15	1.01	1.04
Chakor x Avinashi Local	4.41	3.12	24.00	15.87	2.92	220.12	23.12	12.18	1.98	1.27	0.87
Chakor x CO 2	4.18	4.37	21.88	15.87	2.83	270.75	26.62	14.00	1.55	1.15	0.93
Ashoka Farm Aids x Arka Suryamukhi	4.35	2.87	21.96	15.53	3.42	273.5	18.00	8.70	1.36	0.91	0.72
Ashoka Farm Aids x Avinashi Local	3.35	3.50	21.27	14.58	3.52	283.62	22.12	10.30	1.79	1.40	1.30
Ashoka Farm Aids x CO 2	3.73	2.87	18.5	14.25	2.53	290.62	19.12	6.92	1.03	0.89	0.96
Vadhalagundu Local x Arka Suryamukhi	2.50	4.25	20.68	11.40	1.71	235.87	18.75	8.35	1.47	1.22	0.87
Vadhalagundu Local x Avinashi Local	2.58	3.87	17.02	11.58	1.73	160.5	18.12	6.23	2.08	1.78	0.82
Vadhalagundu Local x CO 2	1.94	8.50	14.33	10.77	3.22	250.12	21.00	17.51	2.56	5.10	0.64
Karamadai Local x Arka Suryamukhi	3.32	4.25	18.50	13.72	2.80	234.75	16.87	9.46	1.95	1.53	0.75
Karamadai Local x Avinashi Local	2.39	5.50	20.68	13.6	2.48	209.25	19.62	10.03	2.93	2.11	0.92

Table 1. ***Contd.***

Hybrid	Fruit weight (kg)	Fruit number per vine	Fruit equatorial diameter (cm)	Fruit polar diameter (cm)	Flesh thickness (cm)	Seed number per fruit	Seed weight per fruit(g)	Fruit yield per vine (kg)	Total carotenoid content (mg per 100g)	Total carbohydrate content (g per 100g)	Crude fibre content (per cent)
Karamadai Local x CO 2	3.02	3.87	17.43	12.82	3.00	211.62	21.87	9.21	1.65	1.30	1.31
Karwar Local x Arka Suryamukhi	3.66	2.62	18.76	13.77	1.93	197.12	20.25	6.67	1.83	1.60	1.25
Karwar Local x Avinashi Local	2.66	2.87	19.91	14.56	2.50	246.87	20.87	8.77	3.05	3.24	0.93
Karwar Local x CO 2	3.21	2.87	16.38	15.23	2.47	234.87	24.12	5.65	3.13	2.80	0.86
Kasi Harit x Arka Suryamukhi	2.09	3.12	17.48	11.82	2.46	125.5	15.37	6.00	2.54	2.16	1.17
Kasi Harit x Avinashi Local	2.22	7.37	16.99	13.42	3.55	306	29.37	18.01	3.07	3.57	0.77
Kasi Harit x CO 2	2.40	4.12	16.57	11.40	2.28	174.5	21.62	8.25	2.88	2.68	1.05
MPH-1	3.01	5.37	13.47	18.06	2.38	262.50	27.12	9.17	1.80	3.25	1.32
SEd	0.16	0.38	0.63	0.35	0.24	16.55	0.62	0.21	0.04	0.06	0.04

Avinashi Local was the best, since, it exhibited superior mean performance for fruit number per vine, flesh thickness, seed weight per fruit, total carbohydrate content, total carotenoid content and fruit yield per vine, followed by Vadhalagundu Local x CO 2 which showed good mean performance for fruit number per vine, seed weight per fruit, flesh thickness, total carbohydrate content, total carotenoid content and fruit yield per vine.

Traits showing significant differences were subjected to analysis for heterosis, heterobeltiosis and standard heterosis. Data on heterosis for fruit, yield and quality parameters in pumpkin are presented in Table 2.

Fruit weight

Fruit weight is a primary trait to be considered in any hybrid development programme, as, it contributes directly towards yield in a genotype. Heterosis over mid-parent for this trait varied from –27.65% (Karwar Local x Avinashi Local) to 56.70% (Ashoka Farm Aids x Arka Suryamukhi) among the 36 pumpkin hybrids under study. Relative heterosis was found to be significant and positive in 15 hybrids for this trait. Heterobeltiosis was significant and positive for eight hybrids and non-significant for only one hybrid. Estimates for heterobeltiosis were found to range from -41.94% (Vadhalagundu Local x CO 2) to 46.38% (Chakor x Avinashi Local). The highest value for standard heterosis was recorded in Ambili x Arka Suryamukhi (57.49%) and was the least in Vadhalagundu Local x CO 2 (-35.28%), and, non-significant in six hybrids. Standard heterosis for this trait was positive and significant in 21 hybrids. Nine hybrids registered significant negative standard heterosis for this trait. In all, five cross-combinations recorded significant and positive heterosis for all the three kinds of heterosis, viz., relative heterosis, heterobeltiosis and standard heterosis. As for fruit size, small to medium sized fruits are preferred. Among the 36 hybrids, the hybrid Ambili x Arka Suryamukhi showed positive and significant heterosis over the standard parent, followed by the hybrid Ashoka Farm Aids x Arka Suryamukhi which recorded the highest positive and significant heterosis of all the three kinds. The *per se* and *gca* values of parents Ambili, Virudhachalam Local and Avinashi Local, and *sca* values of hybrids, also confirmed their superiority. Vidhya *et al* (2002) too reported similar results in pumpkin.

Fruit number per vine

Of the various yield components, fruit number per vine is a direct contributor to yield, and, its heterotic vigour contributes towards higher yield (Yadav *et al*, 1989). Relative heterosis calculated for fruit number per vine in the 36 hybrids studied ranged from -60.78% (Pusa Vishwas x CO 2) to 82.14% (Kasi Harit x Avinashi Local,) and heterobeltiosis values was –73.68% (Pusa Vishwas x CO 2) to 70.00% (Kasi Harit x Avinashi Local), while standard heterosis for this character ranged from -79.07% (Virudhachalam Local x Avinashi Local) to 37.21% (Vadhalagundu Local x CO 2). Among these 36 hybrids, 10 hybrids expressed significantly positive relative heterosis, seven hybrids showed significantly positive heterosis values over the better parent, and just two hybrids expressed significant positive standard heterosis for this trait. The hybrid Vadhalagundu Local x CO 2, followed by Kasi Harit

Table 2. Heterosis in F_1 hybrids with reference to fruit, yield and quality parameters in pumpkin

Hybrid	Fruit weight			Fruit number per vine			Fruit equatorial diameter			Fruit polar diameter		
	d_i	d_{ii}	d_{iii}	d_i	d_{ii}	d_{iii}	d_i	d_{ii}	d_{iii}	d_i	d_{ii}	d_{iii}
Pusa Vishwas x Arka Suryamukhi	-0.16	-31.81**	19.76**	61.54**	61.54*	-51.16**	1.08	-7.92*	-3.75	25.57**	-10.83**	11.14**
Pusa Vishwas x Avinashi Local	7.19*	-15.81**	47.86**	-43.59**	-57.69**	-74.42**	-3.70	-4.81	-0.50	23.94**	1.33	26.30**
Pusa Vishwas x CO 2	-3.56	-21.18**	38.44**	-60.78**	-73.68**	-76.74**	5.90*	-4.32	23.92**	11.66**	-12.55**	9.00**
Punjab Samrat x Arka Suryamukhi	22.62**	-8.19	18.60**	31.82*	-6.45	-32.56**	51.76**	37.95**	44.88**	24.98**	-3.84	-6.51**
Punjab Samrat x Avinashi Local	8.92*	-3.28	24.95**	19.30*	9.68	-20.93**	4.34	2.90	8.07*	4.75*	-4.98*	-7.61**
Punjab Samrat x CO 2	-15.30**	-21.11**	1.91	-21.74**	-28.95**	-37.21**	-19.92**	-27.49**	-6.09	-4.91*	-17.94**	-20.21**
Narendra Abhushan x Arka Suryamukhi	-16.40**	-39.05**	-14.49*	25.00	5.26	-53.49**	6.38*	-8.82**	9.70**	16.42**	-5.73*	-20.28**
Narendra Abhushan x Avinashi Local	-23.11**	-34.08**	-7.51	-42.22**	-50.00**	-69.77**	2.45	-5.29	13.94**	-22.40**	-24.88**	-36.47**
Narendra Abhushan x CO 2	8.49*	-2.66	36.57**	-19.30*	-39.47**	-46.51**	-0.85	-4.37	23.85**	13.47**	4.09	-11.97**
Narendra Uphar x Arka Suryamukhi	23.85**	-2.35	8.76	-52.17**	-66.67**	-74.42**	22.04**	14.81**	11.89**	21.53**	18.99**	-34.95**
Narendra Uphar x Avinashi Local	16.52**	10.70*	23.29**	-32.20**	-39.39**	-53.49**	-1.84	-4.09	-2.05	8.79**	-8.04**	-27.20**
Narendra Uphar x CO 2	21.80**	21.75**	35.70**	-23.94**	-28.95**	-37.21**	-9.88**	-21.04**	2.26	-14.59**	-24.22**	-46.51**
Ambili x Arka Suryamukhi	35.14**	-6.71*	57.49**	0.00	-21.74	-58.14**	1.95	-11.65**	3.54	44.89**	22.58**	-7.20**
Ambili x Avinashi Local	-7.13*	-25.99**	24.95**	-34.69**	-38.46**	-62.79**	-19.72**	-24.88**	-11.96**	0.36	-1.84	-22.28**
Ambili x CO 2	-3.44	-19.84**	35.33**	-37.70 **	-50.00**	-55.81**	0.57	-4.21	24.06**	-13.34**	-16.27**	-36.61**
Virudhachalam Local x Arka Suryamukhi	2.92	-34.00**	50.06**	0.00	-15.38	-74.42**	12.38**	-0.19	10.47**	41.43**	5.45**	12.46**
Virudhachalam Local x Avinashi Local	-6.87*	-32.90**	52.55**	-48.57**	-65.38**	-79.07**	24.91**	20.08**	32.91**	23.13**	7.27**	14.39**
Virudhachalam Local x CO 2	-19.75**	-40.20**	35.95**	-44.68**	-65.79**	-69.77**	7.19**	-0.60	28.73**	20.50**	0.13	6.78**
Chakor x Arka Suryamukhi	50.82**	26.82**	19.55**	42.11**	8.00	-37.21**	20.95 **	5.11	22.36**	8.42**	-13.85**	-23.39**
Chakor x Avinashi Local	50.87**	46.38**	46.74**	-1.96	-3.85	-41.86**	24.35 **	16.72**	35.88**	4.57*	-1.17	-12.11**
Chakor x CO 2	35.19**	24.77**	39.06**	11.11	-7.89	-18.60*	0.78	-4.32	23.92**	10.20**	-1.17	-12.11**
Ashoka Farm Aids x Arka Suryamukhi	56.70**	20.17**	44.67**	-2.13	-32.35**	-46.51**	23.69**	7.99*	24.35**	15.09**	-11.40**	-13.98**
Ashoka Farm Aids x Avinashi Local	0.85	-7.59	11.25*	-6.67	-17.65	-34.88**	10.88**	4.61	20.45**	-8.36**	-16.82**	-19.24**
Ashoka Farm Aids x CO 2	6.93	2.97	23.95**	-36.11**	-39.47**	-46.51**	-14.38**	-19.13**	4.74	-5.90**	-18.75**	-21.11**
Vadhalagundu Local x Arka Suryamukhi	28.86**	28.08**	-16.69**	51.11**	6.25	-20.93**	39.66**	36.33**	17.13**	9.75**	0.77	-36.89**
Vadhalagundu Local x Avinashi Local	3.72	-14.49*	-14.28*	6.90	-3.13	-27.91**	4.81	-5.61	-3.61	-9.54**	-18.99**	-35.86**
Vadhalagundu Local x CO 2	-26.67**	-41.94**	-35.28**	68.57**	55.26**	37.21**	-23.17**	-37.32**	-18.83**	-10.44**	-15.49**	-40.35**
Karamadai Local x Arka Suryamukhi	53.45**	38.61**	10.42	70.00**	25.93*	-20.93**	21.01**	20.13**	4.74	19.48**	1.57	-24.01**
Karamadai Local x Avinashi Local	-11.63*	-20.70**	-20.51**	66.04**	62.96**	2.33	4.30	-3.33	-1.27	-2.20	-4.90	-24.71**

Table 2. Contd.

Hybrid	Fruit weight			Fruit number per vine			Fruit equatorial diameter			Fruit polar diameter		
	d_i	d_{ii}	d_{iii}	d_i	d_{ii}	d_{iii}	d_i	d_{ii}	d_{iii}	d_i	d_{ii}	d_{iii}
Karamadai Local x CO 2	5.13	-9.87	0.46	-4.62	-18.42*	-27.91**	-1.96	-17.98 **	6.23	-2.33	-5.09	-29.00**
Karwar Local x Arka Suryamukhi	16.71**	-15.63**	21.63**	55.56**	50.00*	-51.16**	14.23**	1.14	12.74**	-1.52	-25.59**	-23.74 **
Karwar Local x Avinashi Local	-27.65**	-38.67**	-11.58*	15.00	-11.54	-46.51**	-13.12**	-16.76**	-7.22*	-11.24**	-21.34**	-19.38**
Karwar Local x CO 2	-16.53**	-26.00**	6.68	-11.54	-39.47**	-46.51**	-17.83**	-23.55**	-0.99	-2.52	-17.69**	-15.64**
Kasi Harit x Arka Suryamukhi	-2.33	-11.00	-30.47**	16.28	-16.67	-41.86**	10.08**	8.24*	-3.79	2.33	-13.37**	-34.53**
Kasi Harit x Avinashi Local	-17.34**	-26.46**	-26.28**	82.14**	70.00**	18.60*	-1.74	-8.11*	-6.16	-3.94	-6.12*	-25.67**
Kasi Harit x CO 2	-15.83**	-28.42**	-20.22**	-2.94	-13.16	-23.26**	-30.14**	-41.09**	-23.71**	-13.64**	-16.48**	-36.89**
SEd	0.14	0.16	0.16	0.33	0.38	0.40	0.42	0.64	0.58	0.25	0.36	0.35

d_i - Relative heterosis; d_{ii} - Heterobeltiosis; d_{iii}- Standard heterosis; * Significant at *P* = 5 per cent level, ** Significant at 1 per cent level

Hybrid	Flesh thickness			Seed number per fruit			Seed weight per fruit			Fruit yield per vine		
	d_i	d_{ii}	d_{iii}	d_i	d_{ii}	d_{iii}	d_i	d_{ii}	d_{iii}	d_i	d_{ii}	d_{iii}
Pusa Vishwas x Arka Suryamukhi	-1.52	-20.73	2.09	27.71**	18.17	-23.19**	14.16**	1.63	-42.40**	97.70**	60.24**	1.81
Pusa Vishwas x Avinashi Local	-31.56**	-32.11**	-12.57	-6.17	-33.35**	-12.43	-26.01**	-44.80**	-36.41**	-14.47**	-25.32**	-36.42**
Pusa Vishwas x CO 2	-15.48*	-16.16*	9.74	-0.81	-27.83**	-12.33	-27.82**	-45.42**	-39.63**	-26.39**	-38.17**	-42.23**
Punjab Samrat x Arka Suryamukhi	17.20	-1.80	14.14	-41.53**	-56.59**	-41.81**	-20.14**	-39.01**	-48.85**	62.85**	14.97**	10.14**
Punjab Samrat x Avinashi Local	3.02	-1.24	25.13*	-21.53**	-22.31**	4.14	-27.31**	-37.20**	-27.65**	62.09**	53.06**	46.63**
Punjab Samrat x CO 2	-35.04**	-38.68**	-19.74*	1.12	-3.62	29.19**	-27.96**	-36.67**	-29.95**	-25.86**	-26.78**	-29.85**
Narendra Abhushan x Arka Suryamukhi	-18.16*	-37.54**	-6.81	5.52	-21.87**	5.62	22.51**	-5.14	-23.50**	-1.77	-32.11**	-29.89**
Narendra Abhushan x Avinashi Local	-19.54**	-25.61**	10.99	-14.65**	-15.85**	13.76	7.76**	-8.40**	5.53*	-47.96**	-52.53**	-50.98**
Narendra Abhushan x CO 2	-8.79	-14.39*	27.75**	-1.48	-6.48	26.43**	3.13	-10.83**	-1.38	22.22**	16.39**	20.20**
Narendra Uphar x Arka Suryamukhi	4.17	-5.91	-8.38	60.25**	57.44**	2.33	52.30**	27.27**	-16.13**	-18.49**	-40.64**	-48.69**
Narendra Uphar x Avinashi Local	-0.47	-11.98	11.52	-24.98**	-44.58**	-27.19**	-32.32**	-46.80**	-38.71**	17.78**	16.89**	1.04
Narendra Uphar x CO 2	-22.94**	-32.80**	-12.04	-9.41	-31.32**	-16.57*	-34.20**	-47.50**	-41.94**	66.70**	60.46**	49.92**
Ambili x Arka Suryamukhi	31.55**	9.82	28.80**	32.41**	31.50**	-13.33	5.79	-15.95**	-36.87**	44.14**	-4.45*	15.77**
Ambili x Avinashi Local	-11.67	-14.96	7.75	-9.39	-31.97**	-10.62	-42.37**	-52.40**	-45.16**	-20.22**	-32.08**	-17.71**
Ambili x CO 2	-9.70	-14.40	12.04	-17.10**	-36.06**	-22.33**	-24.57**	-36.67**	-29.95**	1.80	-9.85**	9.23**
Virudhachalam Local x Arka Suryamukhi	19.90*	-5.73	29.32**	63.59**	27.42**	48.48**	84.72**	35.61 **	28.11**	24.10**	-8.19**	-24.47**
Virudhachalam Local x Avinashi Local	-4.37	-8.02	26.18**	-4.92	-10.29*	17.86*	42.42**	29.60 **	49.31**	-19.74**	-21.09**	-32.82**
Virudhachalam Local x CO 2	-6.64	-8.78	25.13*	-21.85**	-23.44**	-7.00	19.10**	10.42 **	22.12**	-16.32**	-21.32**	-26.49**

Table 2. Contd.

Hybrid	Flesh thickness			Seed number per fruit			Seed weight per fruit			Fruit yield per vine		
	d_i	d_{ii}	d_{iii}	d_i	d_{ii}	d_{iii}	d_i	d_{ii}	d_{iii}	d_i	d_{ii}	d_{iii}
Chakor x Arka Suryamukhi	31.72**	3.42	42.41**	81.56**	42.69**	62.19**	-0.29	-30.53 **	-21.89**	70.36**	21.87**	11.67**
Chakor x Avinashi Local	-7.33	-11.03	22.51*	-31.56**	-36.17**	-16.14*	-25.10**	-26.00**	-14.75**	50.35**	45.02**	32.88**
Chakor x CO 2	-11.50	-13.69	18.85	-12.27*	-15.09**	3.14	-11.98**	-12.70**	-1.84	65.09**	63.50**	52.75**
Ashoka Farm Aids x Arka Suryamukhi	45.36**	20.70*	43.46**	-2.56	-30.01**	4.19	-0.35	-25.39**	-33.64**	32.62**	-8.45**	-5.07**
Ashoka Farm Aids x Avinashi Local	20.26**	16.53*	47.64**	-22.89**	-27.42**	8.05	-20.09**	-29.20**	-18.43**	19.03**	8.37**	12.38**
Ashoka Farm Aids x CO 2	-14.88*	-18.80*	6.28	-18.09**	-25.62**	10.71	-29.33**	-36.25**	-29.49**	-23.37**	-27.16**	-24.47**
Vadhalagundu Local x Arka Suryamukhi	-30.81**	-44.31**	-28.27**	11.36	-6.77	-10.14	12.36**	-12.28**	-30.88**	21.68**	-17.40**	-8.87**
Vadhalagundu Local x Avinashi Local	-43.03**	-43.50**	-27.23**	-46.31**	-53.46**	-38.86**	-31.12**	-42.00**	-33.18**	-30.45**	-38.39**	-32.03**
Vadhalagundu Local x CO 2	4.03	3.20	35.08**	-12.52*	-21.56**	-4.71	-18.25**	-30.00**	-22.58**	87.48**	73.12**	90.99**
Karamadai Local x Arka Suryamukhi	32.15**	18.52	17.28	21.47**	8.74	-10.57	4.25	-17.18**	-37.79**	56.41**	11.59**	3.16**
Karamadai Local x Avinashi Local	-7.66	-17.77*	4.19	-25.37**	-39.33**	-20.29**	-23.97**	-37.20**	-27.65**	23.30**	18.42**	9.47**
Karamadai Local x CO 2	9.34	-4.00	25.65*	-20.85**	-33.63**	-19.38**	-13.15**	-27.08**	-19.35**	8.17**	7.60**	0.53
Karwar Local x Arka Suryamukhi	-15.76	-28.90**	-18.85	-19.17**	-37.84**	-24.90**	15.30**	-12.43**	-25.35**	29.34**	-0.41	-27.21**
Karwar Local x Avinashi Local	-13.04	-17.36*	4.71	-25.42**	-28.42**	-5.95	-23.22**	-33.20**	-23.04**	20.93**	12.38**	-4.33**
Karwar Local x CO 2	-15.38*	-20.80*	3.66	-26.14**	-26.34**	-10.52	-9.18**	-19.58**	-11.06**	-25.97**	-34.02**	-38.36**
Kasi Harit x Arka Suryamukhi	-8.16	-29.39**	3.14	-46.47**	-57.92**	-52.19**	-12.77**	-33.87**	-43.32**	-12.75**	-40.80**	-34.54**
Kasi Harit x Avinashi Local	9.02	1.79	48.69**	-4.84	-11.27*	16.57*	7.80**	-6.00**	8.29**	100.75**	77.65**	96.44**
Kasi Harit x CO 2	-30.81**	-34.41**	-4.19	-43.45**	-45.28**	-33.52**	-18.78**	-27.92**	-20.28**	-11.77**	-18.61**	-10.01**
SEd	0.21	0.24	0.22	14.46	16.70	18.14	0.54	0.62	0.65	0.18	0.21	0.10

d_i - Relative heterosis ; d_{ii} - Heterobeltiosis ;d_{iii}- Standard heterosis; * Significant at *P* = 5 per cent level, ** Significant at 1 per cent level

Hybrid	Total carotenoid content			Total carbohydrate content			Crude fibre content		
	d_i	d_{ii}	d_{iii}	d_i	d_{ii}	d_{iii}	d_i	d_{ii}	d_{iii}
Pusa Vishwas x Arka Suryamukhi	26.45 **	-1.01	-69.89 **	-41.76 **	-49.52 **	-70.56 **	22.33 **	-8.70 **	-4.55
Pusa Vishwas x Avinashi Local	-50.56 **	-70.67 **	-72.96 **	-44.35 **	-64.92 **	-42.50 **	-39.91 **	-53.62 **	-51.52 **
Pusa Vishwas x CO 2	-39.25 **	-61.01 **	-76.34 **	-50.73 **	-67.17 **	-57.78 **	-14.41 **	-25.72 **	-22.35 **
Punjab Samrat x Arka Suryamukhi	-5.64	-7.07	-71.74 **	-25.09 **	-39.41 **	-42.78 **	42.26 **	25.00 **	-35.61 **
Punjab Samrat x Avinashi Local	-33.84 **	-56.33 **	-59.75 **	-25.59 **	-41.36 **	-3.89	40.71 **	18.67 **	-32.58 **
Punjab Samrat x CO 2	-51.62 **	-64.05 **	-78.19 **	-46.20 **	-53.35 **	-40.00 **	3.27	-22.17 **	-40.15 **
Narendra Abhushan x Arka Suryamukhi	12.64	-1.01	-69.89 **	-18.83 **	-36.31 **	-34.72 **	23.27 **	7.69	-25.76 **
Narendra Abhushan x Avinashi Local	-45.60 **	-66.00 **	-68.66 **	-47.86 **	-57.63 **	-30.56 **	6.02	-3.30	-33.33 **

Table 2. Contd.

Hybrid	Total carotenoid content			Total carbohydrate content			Crude fibre content		
	d_i	d_{ii}	d_{iii}	d_i	d_{ii}	d_{iii}	d_i	d_{ii}	d_{iii}
Narendra Abhushan x CO 2	-33.94 **	-54.43 **	-72.35 **	-42.31 **	-48.16 **	-33.33 **	21.56 **	15.27 **	-11.36 **
Narendra Uphar x Arka Suryamukhi	6.84	-17.17 *	-74.81 **	-21.20 **	-37.36 **	-38.06 **	34.69 **	25.32 **	-25.00 **
Narendra Uphar x Avinashi Local	-22.71 **	-54.33 **	-57.91 **	-10.57 **	-28.31 **	17.50 **	-11.69 *	-13.92 *	-48.48 **
Narendra Uphar x CO 2	-23.81 **	-51.39 **	-70.51 **	-44.32 **	-50.76 **	-36.67 **	31.86 **	17.24 **	-9.85 **
Ambili x Arka Suryamukhi	26.79 **	-15.15 *	-74.19 **	27.17 **	8.10	-36.94 **	16.28 **	-3.85	-24.24 **
Ambili x Avinashi Local	-29.84 **	-61.00 **	-64.06 **	-17.50 **	-48.47 **	-15.56 **	15.08 **	-0.96	-21.97 **
Ambili x CO 2	-61.90 **	-77.72 **	-86.48 **	-66.56 **	-77.97 **	-71.67 **	-23.11 **	-24.04 **	-40.15 **
Virudhachalam Local x Arka Suryamukhi	-5.24	-6.40	-70.81 **	-5.26 *	-27.64 **	-20.00 **	4.12	-19.84 **	-23.48 **
Virudhachalam Local x Avinashi Local	-35.24 **	-56.67 **	-60.06 **	-32.79 **	-43.73 **	-7.78 **	-4.98	-24.21 **	-27.65 **
Virudhachalam Local x CO 2	-43.14 **	-56.96 **	-73.89 **	-44.72 **	-48.60 **	-33.89 **	-21.76 **	-29.37 **	-32.58 **
Chakor x Arka Suryamukhi	15.76 *	2.02	-68.97 **	5.02	0.88	-36.11 **	34.63 **	20.23 **	-21.21 **
Chakor x Avinashi Local	-32.36 **	-57.67 **	-60.98 **	-2.93	-32.71 **	10.28 **	7.74	0.58	-34.09 **
Chakor x CO 2	-15.75 **	-41.77 **	-64.67 **	-10.27 **	-33.05 **	-13.89 **	-0.53	-7.88	-29.17 **
Ashoka Farm Aids x Arka Suryamukhi	9.64	-8.08	-72.04 **	-2.33	-21.61 **	-24.44 **	-21.53 **	-37.66 **	-45.45 **
Ashoka Farm Aids x Avinashi Local	-23.71 **	-53.33 **	-56.99 **	-23.59 **	-39.32 **	-0.56	36.48 **	12.55 **	-1.52
Ashoka Farm Aids x CO 2	-32.70 **	-54.94 **	-72.66 **	-48.89 **	-55.29 **	-42.50 **	-11.52 **	-16.88 **	-27.27 **
Vadhalagundu Local x Arka Suryamukhi	-24.69 **	-45.78 **	-62.52 **	-23.04 **	-46.93 **	-18.33 **	8.41	-5.95	-34.09 **
Vadhalagundu Local x Avinashi Local	-32.19 **	-40.67 **	-45.31 **	-27.27 **	-29.49 **	15.56 **	-1.49	-10.81 *	-37.50 **
Vadhalagundu Local x CO 2	141.42 **	126.67 **	56.68 **	0.69	-7.58 **	42.22 **	-34.02 **	-36.95 **	-51.52 **
Karamadai Local x Arka Suryamukhi	48.91 **	43.66 **	-53.00 **	31.21 **	1.30	8.61 **	-16.20 **	-32.43 **	-43.18 **
Karamadai Local x Avinashi Local	3.81	-29.67 **	-35.18 **	20.08 **	-0.68	62.78 **	-1.08	-17.12 **	-30.30 **
Karamadai Local x CO 2	-14.14 **	-33.92 **	-59.91 **	-22.26 **	-28.73 **	-8.33 **	23.29 **	18.02 **	-0.76
Karwar Local x Arka Suryamukhi	64.10 **	61.62 **	-50.84 **	55.74 **	40.77 **	1.67	71.23 **	60.26 **	-5.30
Karwar Local x Avinashi Local	63.64 **	8.00 **	-0.46	43.53 **	3.39 *	69.44 **	21.57 **	19.23 **	-29.55 **
Karwar Local x CO2	90.80 **	41.77 **	-13.98 **	73.44 **	35.42 **	74.17 **	-4.18	-15.27 **	-34.85 **
Kasi Harit x Arka Suryamukhi	42.34 **	5.62	-33.64 **	50.15 **	8.76 **	41.39 **	16.42 **	-12.03 **	-11.36 **
Kasi Harit x Avinashi Local	41.72 **	19.17 **	9.83 **	16.07 **	4.07 **	70.56 **	-25.96 **	-42.11 **	-41.67 **
Kasi Harit x CO2	33.33 **	31.05 **	-17.67 **	23.74 **	23.08 **	60.00 **	-10.45 **	-21.05 **	-20.45 **
SEd	0.05	0.06	0.07	0.03	0.04	0.04	0.03	0.04	0.04

d_i - Relative heterosis ; d_{ii} - Heterobeltiosis ;d_{iii}- Standard heterosis; * Significant at *P* = 5 per cent level, ** Significant at 1 per cent level

x Avinashi Local, exhibited a high positive and significant standard heterosis as also the other two types of heterosis. Positive standard heterotic values for fruit number per vine have been reported by Singh *et al* (2000) too in bitter gourd.

Fruit equatorial diameter

Relative heterosis of fruit equatorial diameter of 36 pumpkin hybrids ranged from –30.14% (Kasi Harit x CO 2) to 51.76% (Punjab Samrat x Arka Suryamukhi), fifteen hybrids recorded significant and positive relative heterosis, and eight hybrids exhibited negatively significant values for relative heterosis for this trait. Heterobeltiosis for this trait ranged from –41.09% (Kasi Harit x CO 2) to 37.95% (Punjab Samrat x Arka Suryamukhi), eight hybrids recorded positively significant values, while thirteen hybrids recorded negatively significant values for heterobeltiosis. Standard heterosis for this trait was positive and significant in eighteen hybrids. The highest value for standard heterosis was recorded in Punjab Samrat x Arka Suryamukhi (44.88%), while it was the least in Kasi Harit x CO 2 (-23.71%). The hybrids Kasi Harit x CO 2 and Punjab Samrat x Arka Suryamukhi expressed the lowest and the highest values, respectively, for relative heterosis, heterobeltiosis and standard heterosis for this trait. In all, 18 hybrids recorded positive significant standard heterosis for this trait. These results are supported by Nisha (1999) in pumpkin, where, the hybrid P_5x P_4 showed significant heterosis for this trait.

Fruit polar diameter

The heterosis percentage over mid-parent for fruit polar diameter varied from –22.40% (Narendra Abhushan x Avinashi Local) to 44.89% (Ambili x Arka Suryamukhi). The observations were positive and significant for 19 hybrids. However, negative and significant heterosis for fruit polar diameter was observed in 10 hybrids. Heterobeltiosis for fruit polar diameter was recorded in the range of –25.59% (Karwar Local x Arka Suryamukhi) to 22.58% (Ambili x Arka Suryamukhi). Four hybrids showed significant and positive heterobeltiosis, while, 20 hybrids showed significant and negative heterobeltiosis. Standard heterosis values for this trait ranged from -46.51% (Pusa Vishwas x CO 2) to 26.30% (Pusa Vishwas x Avinashi Local). Standard heterosis for this trait was positive and significant for six hybrids only. Thirty hybrids registered negative significant standard heterosis for this trait. Highest values of relative heterosis and heterobeltiosis were noted in the hybrid Ambili x Arka Suryamukhi. This is in line with earlier findings of Nisha (1999) in pumpkin.

Flesh thickness

Flesh thickness in pumpkin fruits is an important trait to be considered in crop improvement. Relative heterosis calculated for flesh thickness in the 36 hybrids was observed to range from -43.03% (Vadhalagundu Local x Avinashi Local) to 45.36% (Ashoka Farm Aids x Arka Suryamukhi). Only six hybrids recorded positive and significant relative heterosis for this trait. Estimates for heterobeltiosis varied from –44.31% (Vadhalagundu Local x Arka Suryamukhi) to 20.70% (Ashoka Farm Aids x Arka Suryamukhi). Significant positive heterobeltiosis was recorded in two hybrids for flesh thickness. Standard heterosis for this character ranged from -28.27% (Vadhalagundu Local x Arka Suryamukhi) to 48.69% (Kasi Harit x Avinashi Local). Out of the 36 hybrids, 13 expressed significant positive standard heterosis for this trait. Six hybrids recorded positive heterosis for all the three kinds, irrespective of the level of significance. Similar reports are also available from Vidya *et al* (2002) in pumpkin.

Seed number per fruit

In the development of hybrids in pumpkin, higher numbers of seeds per fruit is a preferable trait if the aim is to reduce F_1 hybrid seed production cost. Estimates for relative heterosis for this trait ranged from –46.47% (Kasi Harit x Arka Suryamukhi) to 81.56% (Chakor x Arka Suryamukhi). Among the 36 hybrids under study, six recorded significant positive relative heterosis, while nineteen hybrids expressed negative and significant relative heterosis for this trait. Estimates for heterobeltiosis ranged from –57.92% (Kasi Harit x Arka Suryamukhi) to 57.44% (Narendra Uphar x Arka Suryamukhi) for seed number per fruit. Of the 36 hybrids, only four recorded significant and positive heterobeltiosis, whereas, 27 recorded significant but negative values. Standard heterosis for this trait ranged from -52.19% (Kasi Harit x Arka Suryamukhi) to 62.19% (Chakor x Arka Suryamukhi). Of the 36 hybrids, six recorded significant positive, and 12 showed significant negative values for standard heterosis for seed number per fruit. The lowest values for relative heterosis, heterobeltiosis and standard heterosis were expressed by the hybrid Kasi Harit x Arka Suryamukhi, while, the highest relative and standard heterosis values were expressed by Chakor x Arka Suryamukhi for seed number per fruit. The hybrids Virudhachalam Local x Arka Suryamukhi and Chakor x Arka Suryamukhi recorded positive heterosis for all the three kinds for seed number per fruit. These results are supported by Varghese and Rajan (1993) in snake gourd.

Seed weight per fruit

Though seed is an essential organ for fruit shape development, fewer seeds with lower weight is a trait preferable when used as a vegetable. However, in hybrid vegetable seed production, higher seed weight is preferred. Estimates for relative heterosis for this trait ranged from -42.37% (Ambili x Avinashi Local) to 84.72% (Virudhachalam Local x Arka Suryamukhi). Among the 36 hybrids under study, 10 recorded significant positive relative heterosis, while, 21 hybrids recorded significant negative relative heterosis. Here too, the estimates for heterobeltiosis ranged from –52.40% (Ambili x Avinashi Local) to 35.61% (Virudhachalam Local x Arka Suryamukhi) for seed weight. Of the 36 hybrids, only four hybrids recorded significant and positive heterobeltiosis, whereas, 30 hybrids recorded significant and negative values. Standard heterosis for this trait ranged from -48.85% (Vadhalagundu Local x CO 2 and Punjab Samrat x Arka Suryamukhi) to 49.31% (Virudhachalam Local x Avinashi Local). Out of the 36 hybrids, only five hybrids recorded significant positive and 29 showed significant negative values for standard heterosis for seed weight per fruit. Least values for relative heterosis and heterobeltiosis were expressed by the hybrid Ambili x Avinashi Local, while, the highest relative and standard heterosis for seed weight per fruit was observed in Virudhachalam Local x Arka Suryamukhi. Three hybrid combinations recorded positive and significant heterosis, of all the three kinds, for this trait. These results are supported by Doijode and Sulladmath (1982) too in pumpkin.

Total carotenoids content

Among 36 cross-combinations, 11 crosses expressed positive significant relative heterosis, seven hybrids expressed positive and significant heterobeltiosis, and only two recorded positive and significant values for standard heterosis. For this trait, the lowest and the highest heterosis per cent ranged from –61.90 (Ambili x CO2) to 141.42 (Vadhalagundu Local x CO 2). Maximum and minimum values for heterobeltiosis were recorded in Vadhlagundu Local x CO 2 (126.67%) and Ambili x CO 2 (-77.72%) respectively. Standard heterosis values for this trait ranged from -86.48% (Ambili x CO 2) to 56.68 (Vadhlagundu Local x CO 2). Similar results were obtained by Srinivasan (2003) too for this trait in pumpkin.

Total carbohydrate content

Heterosis percentage estimated over the mid-parent for total carbohydrate content in 36 pumpkin hybrids varied from -66.56% (Ambili x CO 2) to 73.44% (Karwar Local x CO 2). Just nine hybrids recorded significant and positive relative heterosis for this trait. Highest and lowest values for heterobeltiosis were recorded in the hybrids Karwar Local x Arka Suryamukhi (40.77%) and Ambili x CO 2 (-77.97%), respectively. Only six hybrids showed significant and positive heterobeltiosis, while, 25 hybrids showed significant and negative heterobeltiosis. Standard heterosis was positive and significant in 11 hybrids, ranging from -71.67% (Ambili x CO 2) to 74.17% (Karwar Local x CO 2). In all, 22 hybrids expressed negative significant standard heterosis for this trait, while, only 11 hybrids expressed positive standard heterosis. All the three types of heterosis were found to be lowest for carbohydrate content in the hybrid Ambili x CO 2. The hybrid Karwar Local x CO 2 expressed highest relative heterosis and standard heterosis values for total carbohydrate content in the fruit. Further, only five hybrids were found to be positive and significant for all the three kinds of heterosis for this trait. Similar results for these characters were obtained by Srinivasan (2003) in pumpkin.

Crude fibre content

Among the 36 pumpkin hybrids, relative heterosis for total crude fibre content ranged from –39.91% (Pusa Vishwas x Avinashi Local) to 71.23% (Karwar Local x Arka Suryamukhi), and, fifteen hybrids recorded significant positive relative heterosis, while 11 hybrids exhibited negative significant values. The highest and the lowest values for heterobeltiosis in this trait were recorded by the hybrid Karwar Local x Arka Suryamukhi (60.26%) and Pusa Vishwas x Avinashi Local (-53.62%), respectively. Ten hybrids showed significant positive heterobeltiosis, while, 18 hybrids showed significant negative heterobeltiosis for this trait. Standard heterosis values for this trait ranged from -51.52% (Pusa Vishwas x Avinashi Local) to -0.76% (Karamadai Local x CO 2). All the hybrids recorded negative values for standard heterosis for crude fibre content. Also, relative heterosis and heterobeltiosis were found to be the highest and the lowest for crude fibre content in the hybrids Karwar Local x Arka Suryamukhi and Pusa Vishwas x Avinashi Local, respectively. Similar results for these characters were obtained by Shivanand Hegde (2009) in ridge gourd.

Fruit yield per vine

Expression of yield is a prime trait to be considered in any hybridization programme. Among the 36 pumpkin hybrids in their study, heterosis percentage estimated over the mid-parent varied from -47.96% (Narendra Abhushan x Avinashi Local) to 100.75% (Kasi Harit x Avinashi Local).

Twenty hybrids recorded significant and positive relative heterosis. The highest and the lowest values for heterobeltiosis were recorded in Kasi Harit x Avinashi Local (77.65%) and Narendra Abhushan x Avinashi Local (-52.53%). In all, 16 hybrids showed significant and positive heterobeltiosis for yield per vine. Standard heterosis values for this trait ranged from -50.98% (Narendra Abhushan x Avinashi Local) to 96.44% (Kasi Harit x Avinashi Local). Only 14 hybrids recorded positive significant values for standard heterosis. All the three types of heterosis were found to be the highest and the lowest for fruit yield per vine in the hybrids Kasi Harit x Avinashi Local and Narendra Abhushan x Avinashi Local, respectively. The crosses Kasi Harit x Avinashi Local and Vadhalagundu Local x CO 2 recorded positive and significant values for all the three kinds of heterosis. Excellence for hybrid combination was also supported by *per se* performance. A positive and significant heterosis for yield per vine was reported by Kushwaha and Hari Har Ram (2002) and Singh and Rajesh Kumar (2002) in bottle gourd.

Speedy improvement can be achieved by assessing heterosis coupled and knowledge on gene action controlling yield and yield attributes. In the present study, a predominance of non-additive gene action in inheritance was noticed in important traits viz., fruit number per vine, fruit weight, fruit equatorial diameter, fruit polar diameter, flesh thickness, seed number per fruit, seed weight per fruit, total carbohydrate content, total carotenoid and crude fibre content in the fruit, and fruit yield per vine.

Results from the present study suggest that hybrid combinations, Kasi Harit x Avinashi Local and Vadhalagundu Local x CO 2, were the best based on *per se* performance and heterotic values for fruit number per vine, flesh thickness and quality traits, namely total carotenoids content, total carbohydrate content and yield per vine. Hence, these hybrids can be effectively utilized for development of F_1 hybrids in pumpkin. These hybrids need to be validated in different locations for yield stability.

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