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Heterosis for seedling characters in cardamom (*Elettaria cardamomum* Maton)

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Abstract

A study was conducted to assess the nature and extent of relative heterosis, heterobeltiosis and economic heterosis in cardamom (*Elettaria cardamomum*) hybrids under nursery conditions. Among the 54 cardamom hybrids evaluated for seedling characters, NKE-9 x NKE-34, NKE-19 x NKE-12, NKE-3 x RR-1 and NKE-34 x NKE-12 were the best for plant height, number of leaves per plant, leaf length and leaf breadth, respectively. No positive and significant economic heterosis was observed in the hybrids for number of leaves per plant. Nine hybrids exhibited significantly higher and positive heterobeltiosis and economic heterosis for all the characters studied except number of leaves per plant.

Key words : cardamom, *Elettaria cardamomum*, heterosis.

Cardamom (*Elettaria cardamomum* Maton) is a cross-pollinated crop generally propagated by seeds and suckers. Improvement of cardamom has been done mainly by clonal and open pollinated (OP) seedling selection and eight improved varieties of cardamom are available (Edison & Johny 1997). Three hybrid cardamom lines (MHC-10, MHC-13 and MHC-18) are under field evaluation (Madhusoodanan *et al.* 1998). However, efforts for evolving improved varieties are not adequate (Madhusoodanan *et al.* 1998) and published information on hybrid vigour in cardamom is scanty.

Since hybrid vigour is expressed to a greater extent during the initial stages of seedling growth (Singh 1997), selection based on high heterosis for vegetative characters would be highly beneficial. The present study was hence conducted to assess the nature and extent of heterobeltiosis and standard heterosis under nursery conditions in cardamom hybrids.

The experimental material consisted of 54 cardamom hybrids evolved from random crossing of diverse parents which were high yielding, cardamom mosaic resistant and/or rhizome rot tolerant types. The experiment was conducted at Cardamom Research Centre, Indian Institute of Spices Research, Appangala (Karnataka, India) during 1998 using hybrids grown in polybags under controlled nursery conditions adopting a completely randomised block design with two replications. The recommended cultural practices were followed. Observations were recorded on 10 randomly selected plants from each replication after 4 months of transplanting (transplanted at three leaved stage from primary nursery) to polybags. Data on plant height, number of leaves per plant, leaf length and leaf breadth were recorded and per cent heterosis of the crosses over the average of the parents (mid parent) ie, relative heterosis or average heterosis, over the better parent ie, heterobeltiosis, and over the best commercial variety in Kodagu District of Karnataka (CCS-1) ie, economic heterosis, or useful heterosis were computed as per the formulas of Allard (1960) and Singh (1997).

The analysis of variance indicated that the values were significant for all the characters. The data on the heterotic response for plant height, number of leaves, leaf length and leaf breadth are presented in Table 1. The heterosis for plant height ranged

Table 1. Heterosis for seedling characters in cardamom hybrids

Cross	Plant height			No. of leaves/plant			Leaf length			Leaf breadth		
	RH (%)	HB (%)	EH (%)	RH (%)	HB (%)	EH (%)	RH (%)	HB (%)	EH (%)	RH (%)	HB (%)	EH (%)
CCS-1 x RR-1	38.52	13.82	13.82	2.84	-2.69	-2.69	30.40*	10.08	10.08	16.61*	5.38	5.38
CCS-1 x NKE-3	-1.59	-3.34	-3.34	-9.20	-15.05**	-15.05**	-6.85	-12.75	-12.75	-12.39	-15.86*	-0.56*
CCS-1 x NKE-9	-28.47	-33.36*	-33.36*	-11.49*	-17.20**	-17.20	-22.79	-28.58*	-28.58*	-22.10**	-22.10**	-22.09**
CCS-1 x NKE-12	-40.73*	-46.81**	-46.81**	-25.88**	-32.26**	-32.26**	-35.70**	-40.42**	-40.42**	-26.96**	-28.61**	-28.61**
CCS-1 x NKE-19	29.96	8.62	8.62	16.36**	3.23	3.23	26.27	7.33	7.33	10.00	-3.40	-3.40
CCS-1 x NKE-27	14.11	-2.08	-2.08	0.11	-5.27	-5.27	10.36	-6.75	-6.75	25.94**	14.16*	14.16*
CCS-1 x NKE-34	20.70	-2.97	-2.97	-0.58	-7.53	-7.53	7.51	-7.00	-7.00	-2.72	-8.78	-8.78
RR-1 x CCS-1	-1.64	-19.69	-19.69	-13.64*	-18.28**	-18.28**	-11.94	-25.67*	-25.67*	-17.55*	-25.50**	-25.50**
RR-1 x NKE-3	-39.63	-50.04**	-51.82**	-30.85**	-31.75**	-39.09**	-30.98*	-38.48**	-46.17**	-21.64**	-26.39**	-32.44**
RR-1 x NKE-9	-22.24	-32.56	-41.83*	-14.63*	-15.66**	-24.73**	-22.97	-30.29*	-40.75**	-24.45**	-31.53**	-31.73**
RR-1 x NKE-12	8.43	-2.62	-22.59	-12.50	-15.66**	-24.73**	-17.62	-25.59	-36.50**	-9.00	-15.77*	-19.83**
RR-1 x NKE-19	-37.02	38.76	-58.92**	-31.61**	-36.15**	-43.01**	-38.46*	-38.98*	-57.33**	-28.26**	-30.53**	-43.91**
RR-1 x NKE-27	28.52	21.06	-13.29	9.64	-9.75	-19.36**	14.53	14.39	-21.17	6.64	6.27	-13.60*
RR-1 x NKE-34	44.31	41.37	-10.51	-1.84	-3.61	-13.98**	15.16	11.87	-18.33	10.10	6.01	-7.51
NKE-3 x CCS-1	58.47**	55.65**	55.65**	-3.45	-9.68	-9.68	25.00	17.08	17.08	37.76**	32.30**	32.30**
NKE-3 x RR-1	177.00**	129.40**	121.25**	0.10	8.43	-3.23	100.64**	78.86**	56.50**	61.97**	52.47**	39.94**
NKE-3 x NKE-9	80.49**	71.03**	64.93**	-2.47	-2.47	-15.05**	46.62**	44.38**	26.33*	16.27*	11.65	11.33
NKE-3 x NKE-12	102.62**	84.82**	78.23**	7.59	4.94	8.60	47.20**	45.24**	27.08*	41.52**	38.99**	32.30**
NKE-3 x NKE-19	67.94**	42.45**	37.37*	8.50	2.47	-10.75*	68.19**	51.05**	32.17**	28.38**	17.28**	7.65
NKE-3 x NKE-27	74.45**	52.00**	46.58**	1.22	-0.12	-10.75**	45.46**	29.81*	13.58	38.56**	30.86**	20.11**
NKE-3 x NKE-34	92.63**	56.97**	51.37**	5.71	5.06	-8.50	46.36**	34.05*	17.29	19.62**	16.51*	6.94
NKE-9 x CCS-1	116.40**	101.63**	101.63**	-5.75	-11.83*	-11.83*	41.40**	30.92*	30.92*	40.79**	40.79**	40.79**
NKE-9 x RR-1	122.24**	92.77**	66.27**	-6.10	-7.23	-17.20**	55.36**	40.59**	19.50	38.87**	25.85**	25.50**
NKE-9 x NKE-3	100.00**	89.52**	82.76**	4.94	4.94	-8.60	45.74**	43.52**	25.58*	41.72**	36.08**	35.69**
NKE-9 x NKE-12	127.90**	119.12**	89.00**	7.59	4.94	-8.60	68.98**	68.65**	43.92**	45.93**	42.61**	42.21**
NKE-9 x NKE-19	145.30**	118.09**	88.11**	13.73*	7.41	-6.45	73.55**	58.24**	34.50**	58.39**	39.49**	39.09**
NKE-9 x NKE-27	160.50**	138.50**	105.72**	-2.44	-3.73	-13.98**	81.71**	64.61**	39.92**	49.06**	35.51**	35.13**

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Table 1. (Continued)

Cross	Plant height			No. of leaves/plant			Leaf length			Leaf breadth		
	RH (%)	HB (%)	EH (%)	RH (%)	HB (%)	EH (%)	RH (%)	HB (%)	EH (%)	RH (%)	HB (%)	EH (%)
NKE-9 x NKE-34	202.00**	157.54**	122.14**	1.86	1.24	-11.83*	63.19**	51.67**	28.92*	34.85**	26.42**	26.06**
NKE-12 x CCS-1	10.76	-0.59	-0.59	-1.18	-11.83	-11.83	7.37	-0.50	-0.50	-1.74	-3.97	-3.97
NKE-12 x RR-1	-5.52	-15.14	-32.54*	-7.50	-10.84	-20.43**	-41.08	-13.38	-26.08*	-11.25	-17.89*	-21.81**
NKE-12 x NKE-3	-6.08	-14.33	-17.39	-5.06	-7.41	-19.36**	1.54	0.19	-12.33	-6.06	-7.74	-12.18
NKE-12 x NKE-19	39.41	28.60	2.23	11.41	7.79	-10.75**	28.33	16.80	-0.33	6.95	-8.24	-8.50
NKE-12 x NKE-27	1.57	-3.46	-23.25	1.25	-2.53	-12.90**	2.70	-7.13	-20.75	12.50	-18.75**	-22.66**
NKE-12 x NKE-34	38.24	21.96	-3.05	3.18	1.25	-12.90**	22.21	13.38	-3.25	3.11	-1.19	-5.95
NKE-19 x CCS-1	127.20**	89.90**	89.90**	15.15**	2.15	2.15	65.78**	40.90**	40.92**	48.71**	30.60**	30.60**
NKE-19 x RR-1	143.40**	136.66**	58.77**	22.58**	14.46*	2.15	97.48**	95.80**	36.92**	59.42**	54.39**	24.65**
NKE-19 x NKE-3	127.70**	93.14**	86.26**	28.10**	20.99**	5.38	66.49**	49.50**	30.83*	54.05**	40.74**	29.18**
NKE-19 x NKE-9	153.00**	124.89**	93.98**	21.57**	14.82*	0.00	88.28**	71.70**	45.92**	51.94**	33.81**	33.43**
NKE-19 x NKE-12	189.60**	167.10**	112.33**	27.52**	23.38**	2.15	97.21**	79.50**	53.17**	58.61**	42.56**	35.69**
NKE-19 x NKE-27	208.70**	199.07**	114.19**	22.42**	14.32**	2.15	110.08**	108.60**	45.83**	66.79**	60.98*	30.88**
NKE-19 x NKE-34	164.20**	151.94**	69.02**	18.42**	12.50*	-3.23	86.60**	82.80**	33.42**	60.42**	50.00**	30.88**
NKE-27 x CCS-1	2.94	-11.66	-11.66	-12.50*	-17.20**	-17.20**	15.09	-2.75	-2.75	21.88**	10.48	10.48
NKE-27 x RR-1	62.67*	53.22*	9.73	2.41	2.29	-8.60	48.31**	48.13**	2.08	41.26**	40.77**	14.45*
NKE-27 x NKE-3	49.43*	30.20	25.56	7.80	6.50	-4.84	48.77**	32.76*	16.17	7.52	1.54	-6.79
NKE-27 x NKE-9	119.70**	101.12**	73.48**	3.66	2.29	-8.60	78.68**	61.90**	37.58**	49.38**	35.78**	35.41**
NKE-27 x NKE-12	67.60**	58.97**	26.37	12.50*	8.30	-3.23	45.46**	31.54*	12.25	18.59*	10.12	4.82
NKE-27 x NKE-19	173.30**	164.83**	89.67*	12.11*	4.69	-6.45	88.12**	86.80**	30.58*	62.45**	56.79**	27.48**
NKE-27 x NKE-34	209.60**	186.20**	104.98**	16.56**	14.32	2.15	119.48**	113.50**	55.83**	74.50**	68.83*	47.31**
NKE-34 x CCS-1	39.28	11.96	11.96	2.89	-4.30	-4.30	21.10**	4.75	4.75	-0.60	-6.8	-6.80
NKE-34 x RR-1	133.60*	128.99**	44.95**	11.66*	9.64	-2.15	73.44**	68.50**	23.00	23.23**	18.83*	3.68
NKE-34 x NKE-3	92.72**	57.09**	51.49**	13.04*	12.35*	-2.15	59.36**	46.00**	27.75*	21.20**	18.21*	8.50
NKE-34 x NKE-9	88.79**	60.98**	38.86*	9.44	8.70	-5.32	59.49**	48.20**	26.00*	9.09	2.27	1.98
NKE-34 x NKE-12	194.50**	159.81**	106.54**	7.13	5.13	-9.57	90.32**	76.60**	50.67**	63.04**	56.25**	48.73**
NKE-34 x NKE-19	176.50**	163.68**	76.90**	22.37**	16.25**	0.00	108.04**	103.80**	48.75**	73.66**	26.95**	10.77

*, ** = Significant at P = 0.05 and P = 0.01, respectively

RH = Relative heterosis; HB = Heterobeltiosis; EH = Economic heterosis from -40.73 (CCS-1 x NKE-12) to 209.65% (NKE-27 x NKE-34) for relative heterosis, from -50.04 (RR-1 x NKE-3) to 199.07% (NKE-19 x NKE-27) for heterobeltiosis and from -58.92 (RR-1 x NKE-19) to 122.14% (NKE-9 x NKE-34) for economic heterosis. Significant positive values were observed in 32, 31 and 29 hybrids for relative heterosis, heterobeltiosis and economic heterosis, respectively.

Heterosis for number of leaves per plant ranged from -31.61 (RR-1 x NKE-19) to 28.10% (NKE-19 x NKE-3) for relative heterosis, from -36.15 (RR-1 x NKE-19) to 23.38% (NKE-19 x NKE-12) for heterobeltiosis and -43.01 (RR-1 x NKE-19) to 5.38% (NKE-19 x NKE-3) for economic heterosis. Eight hybrids exhibited significant positive relative heterosis and heterobeltiosis for number of leaves per plant. None of the hybrids showed significant positive values for economic heterosis. Only 7 crosses exhibited positive heterobeltiosis and 23 crosses exhibited a significant negative heterobeltiosis.

In the case of leaf length, the heterosis ranged from -41.08 (NKE-12 x RR-1) to 119.48% (NKE-27 x NKE-34) for relative heterosis, from -38.98 (RR-1 x NKE-19) to 113.47% (NKE-27 x NKE-34) for heterobeltiosis and -57.33 (RR-1 x NKE-19) to 56.50% (NKE-3 x RR-1) for economic heterosis. Relative heterosis for 33 hybrids, heterobeltiosis for 31 hybrids and economic heterosis for 24 hybrids were positive and significant.

Heterosis for leaf breadth ranged from -28.26 (RR-1 x NKE-19) to 74.50% (NKE-27 x NKE-34) for relative heterosis, from -31.53 (RR-1 x NKE-9) to 68.83% (NKE-27 x NKE-34) for heterobeltiosis and -43.91(RR-1 x NKE-19) to 48.73% (NKE-34 x NKE-12) for standard heterosis. The relative heterosis, heterobeltiosis and economic heterosis values were positive and significant in 33, 29 and 24 hybrids respectively. This indicates that the number of leaves were more or less the same in the hybrids as that of the parents but the seedling vigour was due to increased plant height, leaf length and leaf breadth.

The best hybrids identified among the 54 hybrids were NKE-9 x NKE-34 for plant height, NKE-19 x NKE-12 for number of leaves per plant, NKE-3 x RR-1 for leaf length and NKE-34 x NKE-12 for economic heterosis. However in practical plant breeding, the superiority of F_1 over midparent is of no use since it does not offer the hybrid any advantage over the better parent (Singh 1997). Hence the hybrids which exhibited higher positive and significant heterobeltiosis and economic hetorosis were identified as superior types in this trial. Nineteen hybrids namely, NKE-27 x NKE-19, NKE-27 x NKE-34, NKE-27 x NKE-34 , NKE-27 x NKE-9, NKE-19 x NKE-12, NKE-19 x CCS-1, NKE-19 x RR-1, NKE-19 x NKE-27, NKE-19 x NKE-34, NKE-19 x NKE-3, NKE-19 x NKE-9, NKE-34 x NKE-12, NKE-3 x NKE-12, NKE-3 x RR-1, NKE-9 x NKE-12, NKE-9 x CCS-1, NKE-9 x NKE-19, NKE-9 x NKE-3, NKE-9 x NKE-34 and NKE-9 x NKE-27 exhibited higher significant and positive heterobeltiosis and economic heterosis values for plant height, leaf length and leaf breadth. Significant positive heterobeltiosis for number of leaves was also observed in NKE-19 x NKE-12, NKE-19 x RR-1, NKE-19 x NKE-27, NKE-19 x NKE-34, NKE-19 x NKE-3, NKE-19 x NKE-9, NKE-34 x NKE-3 and NKE-34 x NKE-19 in addition to plant height, leaf length and leaf breadth.

Hybrid vigour of even small magnitude for individual components may have additive or syneristic effect on the end product (Sasikumar & Sardana 1990). Studies on physiological basis of heterosis revealed that the rate of growth in the seedling stage may be expected to be greater in the hybrids than in the inbreds due to larger embryo and endosperm of hybrid seeds. The superiority of the hybrids in the early seedling stages is due to a more efficient enzyme system which mobilizes stored food materials earlier than those of the inbreds (Singh 1997). Attempts to correlate hybrid vigour in the nursery with the field performance of a perennial crop like cardamom will be of great significance in the early identification of elite lines. Such studies have been attempted earlier in cardamom. Hence all the 54 hybrids were planted in the field for further evaluation of yield attributing characters namely, number of bearing tillers, number of panicles, number of capsules per plant, weight of capsules and number of seeds per capsule to obtain desirable heterotic recombinants.

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