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Studies on Heterosis and its Extent for Horticultural Traits in Long Melon (*Cucumis melo* var. *flexuosus* (L.) Naudin)

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ABSTRACT

A study was conducted to assess the extent of heterosis for various horticultural traits in long melon at College of Horticulture, Kolar, Karnataka, India. In the present study, 18 cross combinations of long melon were developed by crossing six female lines with three male lines in L×T mating design. The F_1 combinations were evaluated along with nine parental lines to study heterosis for earliness, growth, yield and yield attributing traits. The F_1 LM3×Arka Sheetal took minimum number of days for 50% female flower anthesis and exhibited maximum negative heterobeltiosis (-3.75%) for this trait. Six out of eighteen cross combinations showed significant negative heterosis over the better parent for the days to first harvest with the cross LM3 × JK Special showing highet value (-5.18%). High values of heterosis coupled with favourable *per se* values for male to female flower ratio were observed in LM11×Punjab Long melon-1 (-12.99%) and LM10×Arka Sheetal (-22.08%). The extent of heterosis over better parent was found as high as 59.44 % for fruit yield per vine in the cross LM 3×ArkaSheetal. This cross along with LM 9×Punjab Long melon-1, LM 15×Arka Sheetal and LM 3×J K Special were found to be the best crosses for yield and contributing traits exhibiting highest heterobeltiosis coupled with high *per se* values, and may be explored further for the development of promising genotypes. The highest yielding F_1 combinations in present study involved at least one poor to average yielding parent, suggesting that simple dominance components might have lead to expression of heterosis.

KEYWORDS: Long melon, snake melon, *Cucumis melo*, L×T, heterosis

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1. INTRODUCTION

Vegetables play a vital role in ensuring good human health. Nature has blessed us with a large variety of vegetable crops, of which quite a big number was domesticated by our ancestors. But with the passing times, only a limited number of vegetables seized our focus and they grabbed the place on our platter as well as in crop improvement and research programmes. As a result, many vegetables remained as un-exploited or under-utilized crops, despite of their nutritional importance (Akhalkatsi et al., 2017; Davari et al., 2013). The narrowing of diversity in crop species contributing to the world's food supplies has been considered a potential threat to food security (Khoury et al., 2014). Of late, this fact was realized and slowly the neglected crops have started getting attention.

Long melon, also known as snake melon or Armenian cucumber (*Cucumis melo* var. *flexuosus* (L.) Naudin) is one such under-exploited crop, belonging to vast Cucurbitaceae family, with diploid chromosome number of 24 and closely related to musk melon. India is considered as secondary center and Tropical Africa as primary center of origin for melons with existence of several cultivated and wild botanical varieties possessing good health building compounds (Manchali et al., 2021). Snake melon immature fruits are a significant source of minerals and several vitamins and accumulate moderate amounts of carotenoids, mainly the provitamin A, β carotene and lutein, within green plastids (Ilahy et al., 2019). Long melon is popular in North India with local name as *kakri*, especially in Uttar Pradesh and Punjab. The immature fruits are relished in Mediterranean regions for their crisp texture and refreshing, slightly acidic and non-sweet flavour since antiquity. It resembles cucumber with elongated slender fruits, the length varying from a few inches to about 3ft. Fruits are pale to dark green in colour, smooth or ridged, with soft downy hair covering the skin when tender, and are used mainly as salad or in pickles.Significant morphological diversity for fruit characters and yield traits as well as molecular diversity has been reported in earlier studies (Yousif et al., 2011; Solmaz et al., 2016; Ali-shtayeh et al., 2017; Sood et al., 2020; Muhanad et al., 2020; Abu Zaitoun et al., 2018; Dastranji et al., 2017; Merheb et al., 2020). Fruits are reported to have diuretic, anthelmintic and cooling effects (Nadkarni, 2002). Immature fruits are significant sources of several minerals and vitamins, while fruits and seeds as well as leaves are used in traditional medicine system (Ilahy et al., 2019; Ibrahim, 2017). The crop is highly cross pollinated and usually monoecious in nature. So far, only a little effort has been made for genetic improvement in this crop. Pandey et al. (2010) showed that hybridization can increase the number of fruits and quality components in snake melon. Identification and selection of parental lines and crosses with good combining abilities for desired traits is important to initiate a varietal development programme in any crop. Heterosis is superiority of the offspring over the parental lines. Hybridization between diverse parents leads to higher heterosis, and also used to combine the traits from different parental genotypes to develop progenies with combination of desirable traits from different backgrounds. This research was taken up to create variability in long melon through L×T mating design and to study the extent of heterosis present in order to formulate further breeding strategy to develop early and high yielding promising genotypes.

2. MATERIALS AND METHODS

The study was conducted in the experimental farm of College of Horticulture, Kolar sub-campus, University of Horticultural Sciences, Bagalkote, Karnataka, India. This campus is located at longitude of $78^0$10'33.24"E and latitude of $13^0$8'0.46"N. Six genetically diverse parental lines of long melon *viz*., LM 3, LM 4, LM 9, LM 10, LM 11, LM 15 and three testers *viz*., Arka Sheetal, Punjab Long melon-1and J K Special were crossed in L×T mating design proposed by Kempthorne (1957) during *kharif*, 2017 to obtain 18 F_1 hybrids. These F_1 hybrids along with their parents were evaluated in a randomized complete block design with 10 plants each in two replications during *Rabi*, 2017-18 between November 2017 to March 2018. Planting was done on beds with black polythene mulch cover and drip irrigation facility at a spacing of 1.5m between the rows and 0.8m between the plants within a row. The plants were trained on trellies. Cultural practices as recommended for cucumber as per the package of practices of horticultural crops of University of Horticultural Sciences, Bagalkot were followed for raising the crop (Anonymous, 2014). Fourteen horticultural traits were recorded on five randomly selected plants, treatment and replication wise. Mean values were used for analysis of variance as per Panse and Sukhatme (1967), and heterosis was calculated as the percentage increase or decrease of F_1 performance over the better parent values, which may specifically be referred to as heterobeltiosis.

3. RESULTS AND DISCUSSION

The analysis of variance indicated high magnitude of genetic variation among genotypes for all the traits under study. Significant heterosis of varying magnitude was observed in most of the crosses for different characters. Significant variation among long melon genotypes has also been reported in earlier studies (Khurana et al., 1995 and Yadav et al., 2005).

Earliness is a major criterion for any crop improvement programme as it benefits the grower to reap good profit by catching the high early market price and negative heterosis is desirable for earliness related traits. During the study, earliness in F_1 crosses was observed in form of various traits like early germination, early flowering, node and days taken to first female flower anthesis and days taken to first fruit harvest as compared to parental lines involved.

For days to 50 per cent seed germination, the hybrids LM 15×Arka Sheetal (-21.42%), LM 3×J K Special (-7.69 %) and LM 3×Arka Sheetal (-7.14 %) were found to be heterotic compared to better parent. Desirable heterobeltiosis for days to first male flower appearance was observed in LM 11×J K Special (-5.17%). The hybrids LM 3×Arka Sheetal (-46.33 %) and LM 3×J K Special (-43.33 %) exhibited the highest heterobeltiosis in negative direction for node to first female flower appearance.

Per se values for days taken to first female flower anthesis varied from 36 (LM 15×Arka Sheetal) to 41.70 (LM4×Arka Sheetal) in F_1s and from 37.40 (LM4) to 42.50 (Punjab Long Melon-1) among parents. Three F_1s showed significantly negative heterobeltiosis for this trait, viz., LM 15×Arka Sheetal (-4.76%), LM3×JK Special (-3.19%) and LM 3×Arka Sheetal (-3.17%). Significant negative heterobeltiosis was registered in the cross LM 3×Arka Sheetal (-3.75%) for days to 50% female flower appearance. The reason for significant negative heterosis may be due to the presence of dominant loci in different directions leading to cancellation of effects (Pandey et al., 2005) (Table 1).

Table 1: Per se performance of parents and crosses for earliness, yield and related traits in long melon

	NFF*	DFF*	DPF*	MFFR	DFFH	VL	NNV	NBV	NFV	FD	FL	AFW	FYV	PFS
Lines														
LM 3	6.00	39.23	40.00	13.49	46.30	155.00	19.30	5.20	21.50	2.77	28.00	83.50	1.78	45.68
LM 4	6.20	37.40	41.00	17.04	47.00	144.15	13.10	4.90	26.85	2.74	30.46	87.39	2.42	59.32
LM 9	7.40	38.95	44.00	9.89	45.90	164.40	18.20	5.30	21.70	2.91	28.83	94.40	1.89	43.93
LM 10	6.95	40.05	42.00	15.63	49.15	81.23	17.20	6.50	24.50	2.62	29.50	79.08	2.33	56.70
LM 11	6.45	38.75	43.00	13.16	47.50	110.65	16.60	6.30	25.60	2.41	48.50	81.49	2.30	53.00
LM 15	5.60	39.30	40.00	16.60	45.90	162.95	20.60	6.40	28.35	2.37	28.82	89.24	2.90	61.40
Testers														
Arka Sheetal	6.63	37.80	41.00	14.99	44.20	145.00	19.10	6.10	23.60	3.07	20.48	79.99	1.51	57.29
Punjab Long melon-1	6.80	39.40	42.00	12.92	45.50	186.97	19.00	6.90	27.25	3.11	28.57	84.50	2.28	66.03
J K Special	6.19	42.50	44.00	16.63	48.75	163.00	20.10	5.30	26.80	3.02	32.10	90.68	2.50	57.17
Hybrids														
LM 3×Arka Sheetal	3.22	36.60	38.50	14.61	42.50	168.64	18.60	6.20	28.80	2.80	26.81	101.54	2.83	60.13
LM 3× Punjab Long melon-1	5.75	39.05	41.90	20.52	46.80	185.22	16.20	5.40	25.25	2.77	29.77	92.06	2.25	56.88
LM 3×J K Special	3.40	38.20	40.50	17.04	43.90	184.20	19.25	5.20	31.05	2.64	27.22	98.44	3.00	62.73
LM 4×Arka Sheetal	5.40	41.70	45.70	19.35	48.40	241.50	23.00	5.80	28.80	2.58	27.33	95.83	2.77	61.53
LM 4× Punjab Long melon-1	3.60	38.00	41.30	14.45	43.40	262.35	24.95	7.35	27.95	3.15	29.31	106.69	2.91	59.55
LM 4×J K Special	5.80	40.35	43.00	16.32	47.70	240.50	23.50	7.30	25.05	2.41	30.08	96.38	2.40	57.74
LM 9×Arka Sheetal	5.75	39.60	44.60	14.43	43.75	207.00	22.00	5.30	22.60	2.63	31.24	107.68	2.36	44.01

Table 1: Continue...

	NFF*	DFF*	DPF*	MFFR	DFFH	VL	NNV	NBV	NFV	FD	FL	AFW	FYV	PFS
LM 9× Punjab Long melon-1	5.60	39.20	43.50	14.95	46.10	186.00	17.00	5.20	26.50	2.82	32.93	94.02	2.31	56.02
LM 9×J K Special	5.52	40.50	43.50	19.00	47.80	201.25	22.00	5.60	25.15	2.94	27.49	95.83	2.36	56.99
LM 10×Arka Sheetal	6.95	37.00	41.50	11.68	43.45	215.36	21.20	5.50	15.90	2.50	28.41	96.60	1.40	37.25
LM 10× Punjab Long melon-1	6.00	39.25	42.50	13.76	45.70	207.72	20.50	5.10	21.85	2.77	27.27	96.06	2.20	49.54
LM 10×J K Special	5.60	39.70	42.50	16.66	46.40	210.90	22.10	5.50	17.85	2.80	30.63	94.33	1.79	40.43
LM 11×Arka Sheetal	5.95	37.25	42.50	17.11	44.80	172.20	23.25	6.25	20.55	1.89	27.30	92.78	2.05	47.29
LM 11×Punjab Long melon-1	6.65	40.60	42.50	10.99	46.75	213.18	20.50	5.10	16.90	2.60	30.01	87.40	1.16	41.76
LM 11×J K Special	5.15	39.60	42.50	11.45	46.30	207.00	19.60	5.70	21.60	2.60	43.49	85.43	1.56	52.53
LM 15×Arka Sheetal	3.87	36.00	40.50	18.19	42.40	229.50	21.80	6.45	30.35	3.11	31.54	115.36	3.29	58.61
LM 15×Punjab Long melon-1	5.95	39.40	41.50	18.78	45.10	202.70	18.30	5.40	25.35	2.54	30.70	94.05	2.26	55.61
LM 15×J K Special	6.11	39.30	42.50	17.65	46.95	157.91	18.50	5.10	21.05	3.07	30.97	95.26	1.98	48.27
SEm+	0.32	0.87	0.89	0.71	0.84	1.78	0.59	0.19	0.99	0.17	1.45	4.59	0.18	2.72
CD (p=0.05)	0.94	2.53	2.58	2.06	2.45	5.18	1.70	0.55	2.87	0.50	4.22	13.33	0.53	7.92
CD (p=0.01)	1.27	3.42	3.49	2.79	3.32	7.01	2.30	0.75	3.88	0.68	5.70	18.02	0.71	10.71

NFF*: Node of first female flower appearance; DFF*: Days to first female flower anthesis; DPF*: Days to 50 per cent female flower anthesis; MFFR: Male to female flower ratio; DFFH: Days to first fruit harvest; VL: Vine length (cm); NNV: No. of nodes vine^{-1}; NBV: No. of branches vine^{-1}; NFV: No. of fruits vine^{-1}; FD: Fruit diameter (cm); FL: Fruit length (cm); AFW: Average fruit weight (g); FYV: Fruit yield vine^{-1} (kg); PFS: Per cent fruit setting

Days taken to first fruit harvest in parental genotypes ranged from 44.20 (Arka Sheetal) to 49.15 (LM10), while in F_1s it ranged from 42.40 (LM 15×Arka Sheetal) to 48.40. Six F_1 crosses out of 18 showed significant negative heterobeltiosis for this trait viz., LM3×JK Special (-5.18%), LM 10×JK Special (-4.82%), LM4×Punjab Long Melon1(-4.16%), LM15×Arka Sheetal (-4.07%), LM3×Arka Sheetal (-3.84%) all statistically at par for heterotic values followed by LM11×JK Special (-2.52%).

Heterosis for growth parameters are an indication of heterosis for yield as the growth and yield parameters are strongly associated (Munshi and Verma, 1997). The highest *per se* values coupled with high heterosis for three growth characteristics i.e. vine length, number of nodes per vine and number of branches per vine were seen in the crosses LM4 ×Punjab Longmelon-1 and LM4×JK Special (Table 2).

Long melon, being monoecious crop ratio of male and female flowers is an important yield attributing trait as lower ratio has been reported to be associated with higher fruit set and subsequently higher yield. The least *per se* values for this trait were observed in LM11×Punjab Longmelon-1 (10.99) and LM 10×Arka Sheetal (11.68), with heterobeltiosis of -12.99% and -22.08 %, respectively. High yield is always the prime objective of any crop breeding programme, which

Table 2: Estimates of heterosis for earliness, yield and related traits in long melon

Cross	NFFFA	DFFFA	DPFFA	MFFR	DFFH	VL	NNV	NBV	NFV	FD	FL	AFW
LM 3×Arka Sheetal	-46.33**	-3.17*	-3.75**	8.30**	-3.84**	8.80**	-3.63	1.64**	22.03**	-8.79	-4.25*	21.60**
LM 3× Punjab Long melon-1	-4.16**	-0.45	4.75**	58.82**	2.85*	-0.94	-16.06	-21.74	-7.34	-10.79	4.20	8.94*
LM 3×J K Special	-43.33**	-3.19**	1.87	26.31**	-5.18**	13.01**	-4.23	-1.89	15.86**	-12.42	-15.22	8.56*
LM 4×Arka Sheetal	-12.90**	11.49**	11.46**	29.08**	9.50**	66.55**	20.42**	-4.92	7.26**	-16.12	-10.28	9.66*
LM 4× Punjab Long melon-1	-41.93**	1.60	0.73	11.84**	-4.16**	40.32**	31.32**	6.52**	2.57	1.45**	-3.78	22.09**
LM 4×J K Special	-6.30**	7.88	4.87**	-1.86	1.48	47.55**	16.92**	37.74**	-6.70	-20.20	-6.29	6.29
LM 9×Arka Sheetal	-13.27**	4.76**	8.78**	45.90**	-1.01	25.91**	15.18**	-13.11	-4.24	-14.50	8.36**	14.07**
LM 9× Punjab Long melon-1	-17.64**	0.64	3.57**	51.16**	1.31	-0.52	-10.53	-24.64	-2.75	-9.02	14.22**	-0.40
LM 9×J K Special	-10.82**	3.97**	-1.13	92.11**	4.13**	22.41**	9.45**	5.66**	-6.16	-2.65	-14.36	1.51
LM 10×Arka Sheetal	4.82**	-2.11	1.21	-22.08**	-1.69	48.52**	10.99**	-15.38	-35.10	-18.73	-3.69	20.76**
LM 10× Punjab Long melon-1	-11.76**	-0.38	1.19	6.50**	0.43	11.10**	7.89**	-26.09	-19.82	-10.79	-7.56	13.67**
LM 10×J K Special	-9.53**	-0.87	1.19	6.58**	-4.82**	29.39**	9.95**	-15.38	-33.40	-7.28	-4.58	4.03
LM 11×Arka Sheetal	-7.75**	-1.45	3.65**	30.01**	1.35	18.76**	21.73**	-0.79	-19.73	-38.27	-43.71	13.86**
LM 11× Punjab Long melon-1	3.10**	4.77**	1.19	-14.93**	2.74*	14.02**	7.89**	-26.09	-37.98	-16.43	-38.12	3.43
LM 11×J K Special	-16.80**	2.19	-1.16	-12.99**	-2.52*	26.99**	-2.49	-9.52	-19.40	-14.07	-10.33	-5.80
LM 15×Arka Sheetal	-30.89**	-4.76**	1.25	21.34**	-4.07**	40.84**	5.83**	0.78	7.05**	1.30**	9.44**	29.27**
LM 15× Punjab Long melon-1	6.25**	0.25	3.75**	45.35**	-0.87	8.41**	-11.17	-21.74	-10.58	-18.20	6.52**	5.40
LM 15×J K Special	9.10**	0.00	6.25	6.32**	2.28*	-3.12	-10.19	-20.31	-25.75	1.66**	-3.52	5.05
SEm±	0.39	1.06	1.10	0.86	1.03	2.18	0.71	0.23	1.20	0.21	1.45	3.50
CD (p=0.05)	0.83	2.24	2.34	1.83	2.18	4.60	1.51	0.49	2.55	0.44	4.22	7.39
CD (p=0.01)	1.14	3.08	3.21	2.51	2.99	6.33	2.07	0.67	3.50	0.61	5.29	10.16

Table 2: Continue...

Cross	FYV	PFS	NFV	FD	FL	AFW	FYV	PFS
LM 3×Arka Sheetal	59.44**	4.94	22.03**	-8.79	-4.25*	21.60**	59.44**	4.94
LM 3×Punjab Long melon-1	2.98**	-13.86	-7.34	-10.79	4.20	8.94*	2.98**	-13.86
LM 3×J K Special	19.80**	9.73*	15.86**	-12.42	-15.22	8.56*	19.80**	9.73*
LM 4×Arka Sheetal	16.88**	7.40	7.26**	-16.12	-10.28	9.66*	16.88**	7.40
LM 4×Punjab Long melon-1	22.78**	-9.81	2.57	1.45**	-3.78	22.09**	22.78**	-9.81
LM 4×J K Special	-3.80	1.00	-6.70	-20.20	-6.29	6.29	-3.80	1.00
LM 9×Arka Sheetal	25.46**	-23.18	-4.24	-14.50	8.36**	14.07**	25.46**	-23.18
LM 9×Punjab Long melon-1	5.73**	-15.15	-2.75	-9.02	14.22**	-0.40	5.73**	-15.15
LM 9×J K Special	-5.80	-0.31	-6.16	-2.65	-14.36	1.51	-5.80	-0.31
LM 10×Arka Sheetal	-39.78	-34.98	-35.10	-18.73	-3.69	20.76**	-39.78	-34.98
LM 10×Punjab Long melon-1	-5.59	-24.97	-19.82	-10.79	-7.56	13.67**	-5.59	-24.97
LM 10×J K Special	-28.40	-29.28	-33.40	-7.28	-4.58	4.03	-28.40	-29.28
LM 11×Arka Sheetal	-11.06	-17.46	-19.73	-38.27	-43.71	13.86**	-11.06	-17.46
LM 11×Punjab Long melon-1	-49.67	-36.74	-37.98	-16.43	-38.12	3.43	-49.67	-36.74
LM 11×J K Special	-37.40	-8.11	-19.40	-14.07	-10.33	-5.80	-37.40	-8.11
LM 15×Arka Sheetal	13.64**	2.30	7.05**	1.30**	9.44**	29.27**	13.64**	2.30
LM 15×Punjab Long melon-1	-21.76	-15.77	-10.58	-18.20	6.52**	5.40	-21.76	-15.77
LM 15×J K Special	-31.61	-15.56	-25.75	1.66**	-3.52	5.05	-31.61	-15.56
SEm±	0.22	3.33	1.20	0.21	1.45	3.50	0.22	3.33
CD (p=0.05)	0.46	7.04	2.55	0.44	4.22	7.39	0.46	7.04
CD (p=0.01)	0.64	9.67	3.50	0.61	5.29	10.16	0.64	9.67

NFFFA: Node of first female flower appearance; DFFFA: Days to first female flower anthesis; DPFFA: Days to 50 per cent female flower anthesis; MFFR: Male to female flower ratio; DFFH: Days to first fruit harvest; VL: Vine length (cm); NNV: No. of nodes vine^{-1}; NBV: No. of branches vine^{-1}; NFV: No. of fruits vine^{-1}; FD: Fruit diameter (cm); FL: Fruit length (cm); AFW: Average fruit weight (g); FYV: Fruit yield vine^{-1} (kg); PFS:Per cent fruit setting

is a cumulative result of contributing traits like number of fruits per plant, fruit length, fruit diameter, average fruit weight and per cent fruit set. Eight crosses out of 18 hybrids studied showed significant heterobeltiosis for fruit yield per vine. The cross LM 3×Arka Sheetal depicted highest heterobeltiosis (59.44%) followed by LM 9×Arka Sheetal (25.46 %) and LM 4×Punjab Long melon-1(22.78%). Such crosses are likely to give better transgressive segregation and could be used for further crop improvement. Highest heterobeltiosis for *per cent* fruit set was observed in the cross LM 3×J K Special (9.73%). Out of 18 crosses, 10 crosses showed the positive and significant heterobeltiosis for average fruit weight, highest being in LM 15×Arka Sheetal (29.27%), LM 4×Punjab Long melon-1(22.09%) and LM3×Arka Sheetal (21.60%). For number of fruits per vine, highest heterosis over better parent was observed in LM 3×Arka Sheetal (22.03%) and LM 3×J K Special (15.86%). Superiority of F_1s over the parents for earliness with respect to anthesis and fruit harvest, and yield characters has been reported earlier in *Cucumis melo* var. *flexuosus* (Pande et al., 2010), *Cucumis sativus* (Singh and Tiwari, 2018) and *Cucumis melo* (Napolitano et al., 2020 and Saha et al., 2022).

A careful perusal of results revealed that the combinations of LM 15×Arka Sheetal, LM 3×J K Special, LM 3×Arka Sheetal, LM 4×Punjab Long melon-1 combined high positive heterobeltiosis for number of fruits per vine, fruit diameter, fruit length, average fruit weight and higher *per cent* fruit setting. Grafius (1959) opined that heterosis in yield is reflected through heterosis in individual yield components or alternatively due to multiplicative effects of partial dominance of component characters which substantiated the present findings. The highest yielding F_1 combinations in the present study involved at least one poor to average yielding parent, which suggests that even simple dominance in respect of yield components may lead to expression of heterosis (Williams and Gilbert, 1960).

4. CONCLUSION

The extent of heterosis varied for different traits depending on the genetic diversity between parents of different cross combinations. LM 15×Arka Sheetal, LM 3×Arka Sheetal, LM 3×J K Special, LM 4×Punjab Long melon-1, LM 4×Arka Sheetal were good for earliness and growth parameters. LM 15×Arka Sheetal, LM 3×Arka Sheetal and LM 9×Arka Sheetal exhibited maximum significant heterobeltiosis for yield and attributing traits. These promising parents and crosses may be exploited for further amelioration of yield and yield components.

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