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Development of F_1 Hybrids in Chilli (*Capsicum annuum* L.) for Dual Purpose (Green as well as Dry)

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A B S T R A C T

Fifteen hybrids of chilli (*Capsicum annuum* L.) were produced through the half diallel genetic design using improved chilli varieties *viz.*, CA 3, CA 5, CA 6, CA 8, CA 23 and CA 32. Hybrids and parents were evaluated for growth and yield traits using RBD in field conditions at College of Agriculture, Vellayani, Kerela Agricultural University, Thiruvananthapurum during 2014-2015. Analysis of variance for combining ability exhibited the significance for *gca* and *sca* effects for all the characters studied. This indicated that materials used for present investigation had adequate diversity for different characters. In the present study based on *per se* performance, standard heterosis and *sca* effects, the hybrids CA 23 x CA 32, CA 8 x CA 32, CA 8 x CA 23, CA 6 x CA 32, CA 6 x CA 23, CA 6 x CA 8, CA 5 x CA 32 and CA 5 x CA 23 were found superior in respect of seven characters *viz.*, days to first harvest, fruit length, fruit girth, fruit weight, seeds per fruit, green fruit yield per plant and dry fruit yield per plant. Among the hybrids CA 8 x CA 32 and CA 5 x CA 32 suitable for dual purpose (green as well as dry chilli) based on yield and quality. These cross combinations could be exploited in heterosis breeding programme.

Introduction

Among the five cultivated species of the genus Capsicum, *Capsicum annuum* L. is most widely cultivated for its pungent (hot pepper) and nonpungent (sweet pepper) fruits throughout the world. Chilli forms an indispensable adjunct in every home of tropical world as it provides a spicy taste, pungency and adds appealing colour to the food preparation. Its fruit contains a broad variety of antioxidant vitamins especially vitamin A and C, capsaicin, which determine the great variability of the fruit's smell, flavour, taste and consequently consumer preference. India is the largest producer of chillies in the world, an estimated cultivated area of about 0.792 million hectare and producing about 1.376 million tonnes of dry chilli pepper (FAO, 2013), but till the yield potential of chilli in India is low due to lack of high yielding, varieties/hybrids. Due to ever-increasing demand of vegetables in our country, the use of hybrids become popular to fulfill the recommended consumption level of 300g vegetables per capita per day. In the past two decades, in most of vegetable crops such as tomato, cabbage, okra, capsicum, gourds

and melons, the open pollinated varieties are being replaced with the hybrids ones. The introduction of hybrids in public and private sector has greatly boosted up the vegetable production in our country. However, it is estimated that presently only about 10 per cent of vegetable area is under hybrids, of which tomatoes cover 36 per cent, cabbage 30 per cent, brinjal 18 per cent, okra 7 per cent, melons and gourds 5 per cent each, cauliflower 2 per cent and chilli 1 per cent. With awareness of advantages for cultivation of F_1 hybrids, the area is bound to extend (Singh, 2004).

Heterosis breeding is an important genetic tool that can facilitate yield enhancement from 30-400% and helps to enrich many other desirable quantitative traits in crops Srivastava (2000). One of the methods to achieve quantum jump in yield and quality is heterosis breeding. Therefore, to meet this objective in a shorter time the heterosis breeding has been undertaken to develop and identify the suitable best performing hybrids.

Materials and Methods

Six genetically diverse parental lines *viz.*, CA 3, CA 5, CA 6, CA 8, CA 23 and CA 32 were crossed in diallel mating design excluding reciprocal to get 15 cross combinations. All the 15 hybrids along with six parents were raised in a randomized block design with three replications during 2014-15. The experiment was conducted at College of Agriculture, Vellayani, Kerala Agricultural University, Thiruvananthapurum.

The plot size for each treatment was 3.6m x 1.8m where in both row-to-row and plant-to-plant spacing was 45 x 45 cm. The crop was raised as per the KAU standard package of practices. Five plants were randomly selected per plot for recording data on plant height (cm), days to first harvesting, fruits per plant, fruit length (cm), fruit girth (cm), fruit weight (g), seeds per fruit, green fruit yield per plant (g), dry fruit yield per plant (g), driage percentage, capsaicin (%), oleoresin (%), ascorbic acid (mg/100g) and colour (ASTA units).

The magnitude of heterosis as the difference in F_1 performance over mid parent (MP), better parent (BP) and standard check (Arka Harita) in percentage was calculated for these characters. Estimation of heterosis was carried out following the methods suggested by Turner (1953) and Hayes *et al.*, (1995).

Results and Discussion

Analysis of variance for the experimental design

Analysis of variance revealed that, significant difference among the treatment for all the traits studied. Variance due to parents was significant for all characters except days to first harvest and driage. The parents vs. hybrids showed significant differences for all the characters for this study except driage in table 1. This indicated that materials used for present investigation had adequate diversity for different characters. The analysis of variance for combining ability for different characters is presented in table 2. The *gca* and *sca* were highly significant for all the characters indicating that both additive and non-additive variances were important in controlling the expression of the traits evaluated. However, the values of components of genetic variance revealed the preponderance of additive genetic variance for characters, *viz.*, fruit girth and fruit weight, while non-additive genetic variance was comparatively more important for plant height (cm), days to first harvesting, fruits per plant, fruit length, seeds per fruit, green fruit yield per plant and dry fruit yield per plant, driage percentage, capsaicin, oleoresin, ascorbic acid and colour.

Mean performance of parents and F_1 hybrids in relation to their heterosis and combing ability

Heterosis is the increase of size, yield and vigour through cross-breeding rather than interbreeding. Heterosis breeding is a potential method to achieve improvement in production and productivity of chilli that otherwise cannot be achieved through existing traditional methods. Creating hybrid variety is utilizing heterosis effect. Heterosis is the increasing of character value of F_1 hybrids compared to the average value of both parents.

The information concerning the effect of heterosis in crossing determines the choice of potential parental lines to obtain high productivity hybrids as well as having a good endurance. Better hybrids were generally identified based on their mean performance, *sca* effects and standard heterosis expression.

Plant height (cm)

Plant height is an important growth parameter from productivity and crop management point of view. On the basis of mean performance, the hybrids CA 23 x CA 32, CA 6 x CA 23, CA 5 x CA 32 and CA 6 x CA 8 were found to be superior. The female parent in hybrid CA 6 x CA 8 and male parent in hybrid CA 23 x CA 32 were good general combiners. High mean performance of crosses between poor and good general combiners can be attributed to interaction between genes. High *sca* effect was noticed for the crosses CA 6 x CA 23, CA 23 x CA 32, CA 6 x CA 8, CA 3 x CA 8 and CA 3 x CA 5. None of the hybrids exhibited positive standard heterosis but 15 hybrids exhibited negative standard heterosis for this character. The hybrids CA 23 x CA 32, CA 6 x CA 23 and CA 6 x CA 8 were superior based on mean performance and *sca* effect. Similar findings have also been reported by earlier workers Tembhurne and Rao (2012) and Patel *et al.*, (2014).

Days to first harvest

Early harvest which is profitable as the produce gets better price in the market. The hybrids CA 5 x CA 32 (good x good general combiner), CA 23 x CA 32 (poor x good general combiner) and CA 8 x CA 23 (good x poor general combiner) were superior based on mean performance, *sca* effect and standard heterosis. While CA 3 x CA 6, CA 3 x CA 8, CA 3 x CA 5, CA 5 x CA 8, CA 5 x CA 23, CA 6 x CA 8, CA 6 x CA 23, CA 6 x CA 32 and CA 8 x CA 32 had significant and negative standard heterosis as well as heterobeltiosis and average heterosis for the days to first harvest. The parents CA 5, CA 8 and CA 32 were good general combiners for this trait. CA 5 x CA 32 and CA 23 x CA 32 were projected as the best hybrids for early harvest. Early harvest was also reported by Kamble *et al.*, (2009) and Navhale *et al.*, (2014).

Fruits per plant

In chilli, number of fruits per plant is the most important primary component of total yield. In chilli, fruits per plant are the most important primary component of total yield. The mean value and *sca* effect were high for the hybrids CA 6 x CA 8, CA 8 x CA 32, CA 6 x CA 23 and CA 8 x CA 23. Of these cross CA 6 and CA 8 parents were good general combiners. None of the hybrids exhibited positive standard heterosis while 14 hybrids showed significant positive heterosis over mid parent and eight hybrids showed significant positive heterosis over better parent. The crosses CA 6 x CA 8 (147.33) and CA 8 x CA 32 (141.66) were projected as the best for number of fruits per plant. Similar findings have also been reported by Payakhapaab *et al.*, (2012) and Navhale *et al.*, (2014).

Fruit length (cm)

Fruit length is an important parameter in deciding consumer preference. The hybrids CA 3 x CA 32, CA 8 x CA 32, CA 3 x CA 6 and CA 6 x CA 32 differed from other hybrids in having high mean value and standard heterosis. Among the parents CA 3 and CA 32 were good general combiners. The hybrid CA 6 x CA 23 had high *sca* effect and significant standard heterosis. All hybrids exhibited positive significant standard heterosis. CA 3 x CA 32 and CA 8 x CA 32 were projected as the best hybrids for fruit length. Similar findings have also been reported by earlier workers, Payakhapaab *et al.,* (2012) and Navhale *et al.,* (2014).

Fruit girth (cm)

Average fruit girth directly contributes towards total yield and has a key role in acceptance of produce by the consumer. Best *per se* performance for fruit girth was exhibited by CA 3 x CA 5. The hybrids CA 3 x CA 5, CA 23 x CA 32, CA 8 x CA 23 and CA 5 x CA 23 were superior based on mean value and standard heterosis but *sca* effect were not satisfactory. The male and female parents in the hybrid CA 23 x CA 32 were good general combiners and the interaction of additive factors lead to hybrid vigour fixable by selection. Fourteen hybrids had significant positive standard heterosis while all of the hybrids were having negative heterobeltiosis. These results are in conformity with that of obtained by Tembhurne and Rao (2012) and Payakhapaab *et al.,* (2012).

Fruit weight (g)

Fruit weight is one of the component characters directly influencing the fruit yield. The hybrid CA 23 x CA 32 (good x good general combiner) was superior based on the mean performance, *sca* effect and standard heterosis. Other hybrids CA 5 x CA 23, CA 3 x CA 5 and CA 3 x CA 32 also had high mean performance and significant standard heterosis but *sca* effect were not satisfactory. Among the parents CA 3, CA 5, CA 6 and CA 8 were poor combiners. All 15 hybrids recorded significant positive heterosis over the check while most of the hybrids showed negative average heterosis and heterobeltiosis. Among the hybrids CA 23 x CA 32 was best for fruit weight. Similar findings have also been reported by Payakhapaab *et al.,* (2012) and Kumar *et al.,* (2014).

Seeds per fruit

Number of seeds per fruit should be less to make it more acceptable to the consumer. The hybrid CA 3 x CA 32 was superior based on the mean performance, *sca* effect and standard heterosis. Other hybrids CA 5 x CA 23, CA 6 x CA 32 and CA 23 x CA 32 also had high mean performance and significant standard heterosis. The female parent in hybrid CA 6 x CA 32 was good general combiner. Fifteen hybrids had significant standard heterosis while most of the hybrids were had negative heterobeltiosis and relative heterosis. Similar results were reported by Ganeshreddy *et al.,* (2008) and Navhale *et al.,* (2014).

Green fruit yield per plant (g)

High total fruit yield per plant is one of the most important breeding objectives in any crop improvement programme. The green fruit yield per plant of parents and F1hybrids varied from 311.20 to 590.02 g and 177.66 to 1048.21 g, respectively (Table 2). Among the parents, the maximum green fruit yield per plant was observed in CA 32 (590.02 g) fallowed by CA 3 (574.26 g) and CA 8 (520.07 g). The magnitudes of heterosis for green fruit yield were ranged from 14.90 to 162.68%, -69.06 to 123.13% and -73.24 to 57.90% over mid parent, better parent and standard check, respectively (Table 3).

Table.1 Analysis of variance for different characters in chilli

Source of variation	d.f	Plant height (cm)	Days to first harvest	Fruits per plant	Fruit length (cm)	Fruit girth (cm)	Fruit weight (g)	Seeds per fruit	Green fruit yield per plant (g)	Dry fruit yield per plant (g)	Driage (%)	Capsaicin (%)	Oleoresin (%)	Ascorbic acid (mg per100g)	Colour (ASTA units)
Replicates	2	10.39	1.52	74.58	1.58	0.10	0.069	218.11	850.40	14.481	5.29	0.000	0.17	10.85	127.99
Treatments	20	114.45 **	47.43 **	2775.72 **	10.42 **	4.69 **	12.68 **	579.78 **	149841.70 **	3157.76 **	10.20 **	0.008 **	49.27 **	1154.92 **	1336.57 **
Parents	5	113.93 **	4.08	1612.66 **	26.78 **	9.86 **	12.82 **	573.03 *	31181.25 **	1395.08 **	3.96	0.001 **	10.73 **	535.82 **	1112.76 **
Hybrids	14	103.75 **	59.28 **	2615.83 **	3.65 **	3.10 **	13.24 **	472.87 *	133129.40 **	2676.44 **	12.94 **	0.01 **	59.64 **	1421.95 **	1276.75 **
Parents Vs. Hybrids	1	266.90 **	98.25 **	10829.43 **	23.39 **	1.21 **	4.02 *	2110.17 **	977116.30 **	18709.63 **	2.90	0.01 **	96.84 **	512.01 **	3293.02 **
Error	40	9.42	1.73	52.07	0.96	0.10	0.90	199.61	1438.86	5.191	2.66	0.00	1.11	40.54	48.82

*Significant at 5 per cent level ** Significant at 1 per cent level

Table.2 Analysis of variance for combining ability of different characters in chilli

Character	GCA	SCA	` Error	$\sigma^2 gca$	$\sigma^2 sca$	$\sigma^2 gca per \sigma^2 sca$
Plant height (cm)	70.12 **	27.49 **	3.14	8.37	24.35	0.34
Days to first harvest	11.57 **	17.22 **	0.57	1.37	16.64	0.08
Fruits per plant	1422.12 **	759.61 **	17.35	175.59	742.25	0.23
Fruit length (cm)	7.83 **	2.02 **	0.32	0.93	1.69	0.55
Fruit girth (cm)	5.63 **	0.21 **	0.03	0.70	0.17	3.96
Fruit weight (g)	13.72 **	1.06 **	0.30	1.67	0.76	2.20
Seeds per fruit	270.91 **	167.37 *	66.55	25.54	100.82	0.25
Green fruit yield per plant (g)	28757.39 **	57010.50 **	479.62	3534.72	56530.88	0.06
Dry fruit yield per plant (g)	764.85 **	1148.50 **	1.73	95.39	1146.77	0.08
Driage (%)	4.01 **	3.19 **	0.88	0.39	2.30	0.16
Capsaicin (%)	0.004 **	0.002 **	0.00	0.00	0.002	0.23
Oleoresin (%)	21.19 **	14.83 **	0.37	2.60	14.46	0.18
Ascorbic acid (mgper100 g)	541.49 **	332.80 **	13.51	65.99	319.28	0.20
Colour (ASTA units)	521.31 **	420.26 **	16.27	63.13	403.98	0.15

*Significant at 5 per cent level, **Significant at 1 per cent level

Table.3 Parents and hybrid performance range and heterosis range for different characters in chilli

Characters	Range					Better parents (Based on per se performance)
	Performance		Heterosis (%)			
	Parents	Hybrids	MP	BP	SC	
Plant height (cm)	42.57 to 60.74	36.97 to 63.04	-17.84 to 28.72	-22.04 to 18.99	-48.87 to -12.81	CA 32 (60.74), CA 5 (50.26), CA 6 (50.15)
Days to first harvest	46.93 to 50.00	41.13 to 60.73	-14.72 to 25.31	-15.80 to 21.47	-21.10 to 16.50	CA 3 (46.93), CA 5 (47.93), CA 8 (48.20)
Fruits per plant	39.33 to 109.00	20.66 to 147.33	-67.71 to 70.54	-76.69 to 71.97	-88.89 to -20.79	CA 8 (109.00), CA 5 (91.00), CA 3 (88.66)
Fruit length (cm)	6.30 to 15.21	10.96 to 14.46	-3.33 to 54.83	-15.38 to 22.31	29.09 to 70.40	CA 3 (15.21), CA 32 (13.33), CA 8 (11.41)
Fruit girth (cm)	4.53 to 9.28	3.88 to 7.18	-23.98 to 4.57	-42.56 to -1.08	12.88 to 108.71	CA 23 (9.28), CA 3 (5.36), CA 32 (5.35)
Fruit weight (g)	6.76 to 11.21	6.34 to 14.43	-28.57 to 29.53	-42.30 to 28.75	78.87 to 309.36	CA 23 (11.21), CA 32 (11.07), CA 3 (10.99)
Seeds per fruit	83.66 to 120.00	99.66 to 147.33	-2.43 to 43.04	-14.90 to 43.04	42.11 to 111.48	CA 6 (124.00), CA 23 (116.33), CA 5 (109.00)
Green fruit yield per plant (g)	311.20 to 590.02	177.66 to 1048.21	14.90 to 162.68	-69.06 to 123.13	-73.24 to 57.90	CA 32 (590.02), CA 3 (574.26), CA 8 (520.07)
Dry fruit yield per plant (g)	39.47 to 100.48	20.01 to 139.89	-69.95 to 153.00	-78.65 to 96.71	-82.48 to 22.52	CA 32 (100.48), CA 3 (93.71), CA 4 (80.63)
Driage (%)	20.86 to 23.95	18.94 to 26.81	-14.15 to 19.05	-18.58 to 16.82	-23.78 to 7.90	CA 32 (23.95), CA 3 (23.26), CA 8 (23.11)
Capsaicin (%)	0.18 to 0.23	0.16 to 0.36	-19.35 to 54.61	-28.57 to 53.52	-41.86 to 26.74	CA 32 (0.23), CA 3 (0.23), CA 5 (0.23)
Oleoresin (%)	11.66 to 16.50	11.33 to 25.50	-15.48 to 76.88	-28.42 to 61.05	-19.05 to 82.14	CA 32 (16.50), CA 3 (15.00), CA 6 (15.00)
Ascorbic acid (mgper100g)	120.90 to 154.00	93.41 to 164.33	-31.30 to 18.36	-34.06 to 17.00	-25.27 to 31.47	CA 5 (154.00), CA 8 (154.00), CA 32 (141.66)
Colour (ASTA units)	114.34 to 157.89	117.18 to 197.96	-12.99 to 54.39	-24.40 to 39.31	-36.85 to 6.68	CA 8 (157.89), CA 32 (155.00), CA 6 (142.10)

Table.4 Heterosis (%) for days to first harvest, fruits per plant, green fruit yield per plant and dry fruit yield per plant in chilli

Crosses	Days to first harvest			Fruits per plant			Green fruit yield per plant (g)			Dry fruit yield per plant (g)		
	RH	HB	SH	RH	HB	SH	RH	HB	SH	RH	HB	SH
CA 3 x CA 5	-2.32	-3.21	-11.25 **	21.71 **	20.15 **	-41.22 **	47.25 **	35.80 **	17.48 **	35.44 **	18.52 **	-2.73
CA 3 x CA 6	-8.00 **	-10.59 **	-14.71 **	20.00 **	13.91	-45.70 **	35.23 **	20.05 **	3.85	26.10 **	10.90 **	-8.99 **
CA 3 x CA 8	-4.98 *	-6.22 **	-13.30 **	17.71 **	6.73	-37.46 **	14.90 **	9.48	-5.29	18.60 **	10.33 **	-9.46 **
CA 3 x CA 23	25.31 **	21.47 **	16.50 **	-67.71 **	-76.69 **	-88.89 **	59.87 **	-69.06 **	-73.24 **	-69.95 **	-78.65 **	-82.48 **
CA 3 x CA 32	-3.35	-5.07 *	-11.38 **	16.17 *	9.40	-47.85 **	27.83 **	26.12 **	12.10 *	12.53 **	8.74 **	-4.31 *
CA 5 x CA 6	-2.80	-4.69 *	-9.08 **	14.45 *	7.33	-47.49 **	20.13 **	15.22 *	-15.83 **	28.79 **	28.05 **	-20.25 **
CA 5 x CA 8	-7.64 **	-8.02 **	-14.96 **	19.33 **	9.48	-35.84 **	36.30 **	31.70 **	3.18	55.83 **	45.84 **	2.99
CA 5 x CA 23	-7.50 **	-9.53 **	-13.24 **	57.03 **	12.45	-44.98 **	116.39 **	77.62 **	29.76 **	145.57 **	91.74 **	18.04 **
CA 5 x CA 32	-14.72 **	-15.48 **	-21.10 **	38.19 **	28.57 **	-37.10 **	53.06 **	39.43 **	23.92 **	52.25 **	29.38 **	13.85 **
CA 6 x CA 8	-11.23 **	-12.60 **	-16.62 **	56.18 **	35.17 **	-20.79 **	56.24 **	45.01 **	13.60 **	69.33 **	59.33 **	12.52 **
CA 6 x CA 23	-6.68 **	-6.93 **	-10.74 **	130.25 **	71.97 **	-26.34 **	162.68 **	123.13 **	49.67 **	153.00 **	96.71 **	22.52 **
CA 6 x CA 32	-9.35 **	-10.32 **	-14.45 **	45.15 **	43.93 **	-38.35 **	75.97 **	54.39 **	37.22 **	39.47 **	19.09 **	4.80 **
CA 8 x CA 23	-9.98 **	-11.60 **	-15.22 **	73.48 **	18.04 **	-30.82 **	111.19 **	68.78 **	32.23 **	114.99 **	60.12 **	13.07 **
CA 8 x CA 32	-7.09 **	-7.53 **	-13.68 **	51.25 **	29.97 **	-23.84 **	65.30 **	55.50 **	38.21 **	54.29 **	39.05 **	22.36 **
CA 23 x CA 32	-14.66 **	-15.80 **	-19.25 **	70.54 **	28.09 **	-46.06 **	132.62 **	77.66 **	57.90 **	90.81 **	32.88 **	16.93 **

RH-Relative heterosis, HB-Heterobeltiosis, SH-Standard heterosis, *Significant at 5 per cent level, ** Significant at 1 per cent level

Table.5 General combining ability effects of parents in chilli

Characters	CA 3	CA 5	CA 6	CA 8	CA 23	CA 32
Plant height (cm)	-3.54 **	0.55	1.28 *	-0.79	-2.31 **	4.82 **
Days to first harvest	1.33 **	-0.76 **	-0.01	-0.93 **	1.59 **	-1.21 **
Fruits per plant	-11.30 **	1.94	5.61 **	19.90 **	-18.05 **	1.90
Fruit length (cm)	1.15 **	-0.18	-0.18	-0.20	-1.56 **	0.99 **
Fruit girth (cm)	-0.22 **	-0.42 **	-0.52 **	-0.54 **	1.64 **	0.06
Fruit weight (g)	0.22	-0.66 **	-0.92 **	-1.63 **	1.66 **	1.33 **
Seeds per fruit	-0.98	0.76	5.47 *	-10.73 **	0.80	4.68
Green fruit yield per plant (g)	-77.94 **	-14.28 *	0.70	13.91	-26.34 **	103.95 **
Dry fruit yield per plant (g)	-10.91 **	0.33	0.35	7.14 **	-10.76 **	13.84 **
Driage (%)	-0.42	-0.23	-0.33	0.24	-0.57	1.33 **
Capsaicin (%)	0.008 **	0.01 **	0.008 **	0.002	-0.04 **	0.009 **
Oleoresin (%)	0.34	-2.13 **	1.28 **	0.74 **	-1.90 **	1.66 **
Ascorbic acid (mgper100g)	-4.42 **	11.08 **	0.44	2.03	-13.22 **	4.08 **
Colour (ASTA units)	-10.15 **	5.08 **	8.08 **	4.07 **	-10.24 **	3.15 *

*Significant at 5 per cent level, **Significant at 1 per cent level

Table.6 Specific combining ability effects of hybrids in chilli

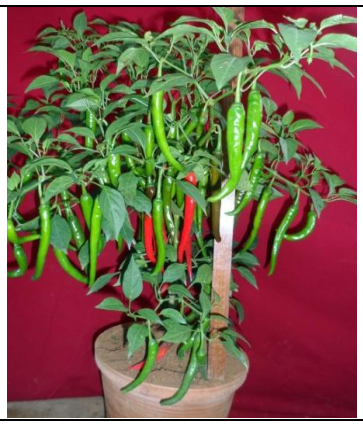
Characters	Plant height (cm)	Days to first harvest	Fruits per plant	Fruit length (cm)	Fruit girth (g)	Fruit weight (g)	Seeds per fruit	Green fruit yield per plant (g)	Dry fruit yield per plant (g)	Driage (%)	Capsaicin (%)	Oleoresin (%)	Ascorbic acid (mgper100g)	Colour (ASTA units)
CA 3 x CA 5	3.81 *	-0.88	16.96 **	-0.09	-0.17	-0.51	6.90	187.54 **	18.44 **	0.42	0.09 **	-2.50 **	23.14 **	-0.91
CA 3 x CA 6	-0.54	-3.43 **	4.96	0.30	-0.02	0.59	0.53	82.09 **	11.28 **	-0.69	0.02 **	5.74 **	25.46 **	0.79
CA 3 x CA 8	4.10 *	-1.78 *	6.00	-0.40	-0.78 **	-1.88 **	1.73	8.17	3.95 **	0.78	0.002	3.11 **	-15.48 **	14.08 **
CA 3 x CA 23	-9.99 **	11.22 **	-51.70 **	-0.95	0.32	0.005	-15.80 *	-402.59 **	-61.50 **	-2.88 **	-0.02 **	-2.23 **	-1.53	-12.74 **
CA 3 x CA 32	-0.76	-0.50	4.67	-0.01	-0.07	-0.01	27.98 **	33.59	3.13 *	-0.20	-0.05 **	-0.46	-40.77 **	21.70 **
CA 5 x CA 6	0.69	1.59 *	-11.61 **	-0.86	0.06	-0.49	-8.22	-112.18 **	-12.83 **	-0.85	0.04 **	-3.94 **	1.87	-4.17
CA 5 x CA 8	-0.78	-0.55	-4.24	0.48	0.12	0.56	8.98	0.74	6.91 **	-2.67 **	-0.03 **	-1.57 *	-14.30 **	-5.43
CA 5 x CA 23	2.66	-2.17 **	16.71 **	2.53 **	-0.28	0.99	13.78	217.48 **	42.01 **	1.57	-0.04 **	1.24 *	-11.88 **	50.49 **
CA 5 x CA 32	0.96	-3.47 **	11.42 **	-0.32	0.15	0.20	-5.09	48.44 *	12.62 **	2.12 *	0.02 **	4.51 **	6.55	1.43
CA 6 x CA 8	5.23 **	-2.16 **	20.08 **	-0.37	0.18	-0.05	5.28	54.97 *	17.77 **	-0.04	-0.002	7.34 **	-7.82 *	-7.61
CA 6 x CA 23	7.87 **	-1.62 *	47.71 **	2.71 **	-1.23 **	0.78	4.40	334.69 **	47.10 **	3.40 **	0.002	0.15	-17.65 **	29.45 **
CA 6 x CA 32	-2.74	-0.75	5.42	0.39	0.29	-0.16	3.19	121.72 **	2.26	-0.86	0.01 *	-3.57 **	2.28	3.35
CA 8 x CA 23	2.99	-3.03 **	25.08 **	0.42	0.07	-0.06	-6.72	205.67 **	29.53 **	-0.08	0.01	-1.46 *	-10.89 **	-3.23
CA 8 x CA 32	-1.70	0.56	18.13 **	0.86	0.01	0.63	11.73	115.05 **	15.53 **	2.41 *	0.07 **	1.80 **	17.69 **	9.75 *
CA 23 x CA 32	7.70 **	-4.86 **	14.75 **	1.06	0.01	1.79 **	6.19	286.05 **	27.24 **	-0.38	0.001	3.61 **	16.30 **	-28.36 **

*Significant at 5 per cent level, **Significant at 1 per cent level

Table.7 Evaluation of hybrids on the basis of mean performance, *sca* effects and standard heterosis in chilli for important characters

Character	Mean performance	*sca* effects	Standard heterosis	Superior hybrids
Days to first harvest	CA 5 x CA 32, CA 23 x CA 32, CA 6 x CA 8, CA 8 x CA 23	CA 23 x CA 32, CA 5 x CA 32, CA 3 x CA 6, CA 8 x CA 23	CA 5 x CA 32, CA 6 x CA 8, CA 23 x CA 32, CA 8 x CA 23	CA 5 x CA 32, CA 23 x CA 32, CA 8 x CA 23
Green fruit yield per plant (g)	CA 23 x CA 32, CA 6 x CA 23, CA 8 x CA 32, CA 6 x CA 32, CA 8 x CA 23, CA 5 x CA 23, CA 5 x CA 32, CA 6 x CA 8	CA 23 x CA 32, CA 6 x CA 23, CA 5 x CA 23, CA 8 x CA 23, CA 3 x CA 5, CA 6 x CA 32, CA 8 x CA 32, CA 5 x CA 32, CA 6 x CA 8	CA 23 x CA 32, CA 6 x CA 23, CA 8 x CA 32, CA 6 x CA 32, CA 5 x CA 23, CA 8 x CA 23, CA 5 x CA 32, CA 6 x CA 8	CA 23 x CA 32, CA 6 x CA 23, CA 8 x CA 32, CA 6 x CA 32, CA 8 x CA 23, CA 5 x CA 23, CA 5 x CA 32, CA 6 x CA 8
Dry fruit yield per plant (g)	CA 6 x CA 23, CA 8 x CA 32, CA 23 x CA 32, CA 5 x CA 23, CA 5 x CA 32, CA 8 x CA 23, CA 6 x CA 8	CA 6 x CA 23, CA 5 x CA 23, CA 8 x CA 23, CA 23 x CA 32, CA 6 x CA 8, CA 8 x CA 32, CA 5 x CA 32	CA 6 x CA 23, CA 8 x CA 32, CA 5 x CA 23, CA 23 x CA 32, CA 5 x CA 32, CA 8 x CA 23, CA 6 x CA 8	CA 6 x CA 23, CA 8 x CA 32, CA 5 x CA 23, CA 23 x CA 32 CA 5 x CA 32, CA 8 x CA 23, CA 6 x CA 8
Driage (%)	CA 8 x CA 32, CA 5 x CA 32, CA 6 x CA 23, CA 5 x CA 23	CA 8 x CA 32, CA 5 x CA 32	--	--
Capsaicin (%)	CA 3 x CA 5, CA 8 x CA 32, CA 5 x CA 6, CA 5 x CA 32, CA 3 x CA 6, CA 6 x CA 32	CA 3 x CA 5, CA 8 x CA 32, CA 5 x CA 6, CA 3 x CA 6, CA 5 x CA 32, CA 6 x CA 32	CA 3 x CA 5, CA 8 x CA 32, CA 5 x CA 6	CA 3 x CA 5, CA 8 x CA 32, CA 5 x CA 6
Oleoresin (%)	CA 6 x CA 8, CA 3 x CA 6, CA 8 x CA 32, CA 3 x CA 8	CA 6 x CA 8, CA 3 x CA 6, CA 5 x CA 32, CA 23 x CA 32	CA 6 x CA 8, CA 3 x CA 6, CA 8 x CA 32, CA 3 x CA 8	CA 6 x CA 8, CA 3 x CA 6
Ascorbic acid (mgper100g)	CA 3 x CA 5, CA 8 x CA 32, CA 3 x CA 6, CA 5 x CA 32	CA 3 x CA 6, CA 3 x CA 5, CA 8 x CA 32, CA 23 x CA 32	CA 3 x CA 5, CA 8 x CA 32, CA 5 x CA 32, CA 3 x CA 6	CA 3 x CA 5, CA 3 x CA 6, CA 8 x CA 32
Colour (ASTA units)	CA 5 x CA 23, CA 6 x CA 23, CA 8 x CA 32, CA 3 x CA 32	CA 5 x CA 23, CA 6 x CA 23, CA 3 x CA 32, CA 3 x CA 8	CA 5 x CA 23	CA 5 x CA 23

CA 8 x CA 32



CA 5 x CA 32

Dual purpose chilli F1 hybrids

Here the hybrids CA 23 x CA 32, CA 6 x CA 23, CA 8 x CA 32, CA 6 x CA 32, CA 8 x CA 23, CA 5 x CA 23, CA 5 x CA 32 and CA 6 x CA 8 having highest yield per plant based on high mean value, *sca* effect and standard heterosis. Fifteen hybrids showed significant positive heterosis over mid parent, 13 hybrids over better parent and 10 hybrids over check. These results are in conformation with the results of earlier workers Prasath and Ponnuswami (2008), Tembhurne and Rao (2012) and Navhale *et al.,* (2014) (Table 4).

Among 15 F_1 hybrids, 6 exhibited more than 50% heterobeltiosis for total green fruit yield per plant. These crosses were CA 6 x CA 23 (123.13%), CA 23 x CA 32 (77.66%), CA 5 x CA 23 (77.62%), CA 8 x CA 23 (68.78%), CA 8 x CA 32 (55.50%) and CA 6 x CA 32 (54.39%).

All of these 6 hybrids had significant positive *sca* effect indicating the importance of non-additive gene action. However the superior hybrids CA 23 x CA 32 (57.90%), CA 6 x CA 23(49.67%), CA 8 x CA 32(38.21%), CA 6 x CA 32(37.22%), CA 8 x CA 23(32.23%), CA 5 x CA 23(29.76%) and CA 5 x CA 32(23.92%) exhibited desirable standard heterosis for seven characters *viz.*, days to first harvest, fruit length, fruit girth, fruit weight, seeds per fruit, green fruit yield per plant and dry fruit yield per plant. Similar findings were also reported by Patel *et al.,* (2014) for both heterobeltiosis and standard heterosis. Tembhurne and Rao (2012) also reported significant and positive standard heterosis for green fruit yield (Tables 5-7).

Dry fruit yield per plant (g)

The hybrids CA 6 x CA 23 (22.52%), CA 8 x CA 32 (22.36%), CA 5 x CA 23 (18.04%), CA 23 x CA 32 (16.93%), CA 5 x CA 32 (13.85%), CA 8 x CA 23 (13.07%) and CA 6 x CA 8(13.07%) were having highest yield per plant based on high mean value, standard heterosis and *sca* effect. Of 15 F_1 hybrids, four exhibited more than 50% heterobeltiosis for total dry fruit yield per plant. These hybrids were CA 6 x CA 23 (96.71 %), CA 5 x CA 23 (91.74 %), CA 8 x CA 23 (60.12 %) and CA 6 x CA 8 (59.33 %). Similar findings have also been reported by earlier workers Kumar *et al.,* (2014) and Navhale *et al.,* (2014). Yield per plant had close relationship between the *per se* performance of the parents and corresponding *gca* effect, which suggest importance of *per se* performance of line along with *gca* effect for selecting better parents in hybridization programme as suggested by Bhagyalakshmi *et al.,* (1991) (Table 7).

Driage (%)

With respect to mean performance CA 8 x CA 32, CA 5 x CA 32, CA 6 x CA 23 and CA 5 x

CA 23 were superior. The male parent CA 32 was good general combiners for this trait. CA 8 x CA 32 and CA 5 x CA 32 were found good with regard to *sca* effect. No hybrid exhibited positive standard heterosis over standard check while CA 6 x CA 23 and CA 8 x CA 32 had significant relative heterosis as well as heterobeltiosis for driage. CA 8 x CA 32 and CA 5 x CA 32 were projected as the best hybrids for driage. Similar findings have also been reported by earlier worker Singh and Hundal (2001).

Capsaicin (%)

Capsaicin is the active component of chilli and capsaicin is an important parameter deciding consumer preference. The hybrids CA 3 x CA 5, CA 8 x CA 32 and CA 5 x CA 6 were different from other hybrids in having high mean value with *sca* effect and standard heterosis. Among the parents CA 3, CA 5, CA 6 and CA 32 were good general combiners for this trait. CA 5 x CA 32, CA 3 x CA 6 and CA 6 x CA 32 hybrids also had high mean performance and with *sca* effect but standard heterosis was not satisfactory. Eight hybrids had positive and significant average heterosis while seven hybrids had positive heterobeltosis. Similar results were observed by Prasath and Ponnuswami (2008), Chaudhary *et al.,* (2013) and Navhale *et al.,* (2014).

Oleoresin (%)

Oleoresin is another important character which represents the total flavour of extract of ground spice. Based mean performance and standard heterosis the hybrids CA 6 x CA 8, CA 8 x CA 32, CA 3 x CA 8 and CA 3 x CA 6 were superior. The parents CA 6, CA 8 and CA 32 were good general combiners for oleoresin. The hybrids CA 6 x CA 8, CA 3 x CA 6 and CA 5 x CA 32 were exhibited positive *sca* effect. Seven hybrids showed significant standard heterosis while six hybrids were showed significant heterobeltiosis. Among the hybrids CA 6 x CA 8 and CA 3 x CA 6 were best for oleoresin. Similar findings have also been reported by earlier workers, Prasath and Ponnuswami (2008) and Chaudhary *et al.,* (2013).

Ascorbic acid (mg/100 g)

Chilli is considered to be rich source of ascorbic acid and minerals. It is the source for commercial preparation of vitamin C. With respect to mean performance, *sca* effect and standard heterosis CA 3 x CA 5, CA 3 x CA 6 and CA 8 x CA 32 hybrids were superior. The parents CA 5 and CA 32 were good general combiners for this trait. CA 5 x CA 32 had significant standard heterosis with good mean performance. Seven hybrids showed significant standard heterosis. CA 3 x CA 5, CA 3 x CA 6 and CA 8 x CA 32 projected as the best hybrids for ascorbic acid. Similar finding were reported by Sharma *et al.,* (2013).

Colour (ASTA units)

The colour value is the principal criterion for assessing the quality of chilli. The hybrids CA 5 x CA 23, CA 6 x CA 23 and CA 3 x CA 32 were superior based on mean performance, *sca* effect. With respect to mean performance CA 8 x CA 32 and CA 6 x CA 32 were superior but *sca* effect was not satisfactory. The parents CA 5, CA 6, CA 8 and CA 32 were good general combiners for colour. CA 5 x CA 23 alone exhibited positive standard heterosis while four hybrids showing significant heterobeltiosis and ten hybrids showing significant average heterosis. Similar results were observed by Prasath and Ponnuswami (2008). In these investigations, the results indicated the preponderance of non-additive gene action in the inheritance of fruit traits and quality, suggesting the occurrence of hybrid vigour. Based on mean performance, standard heterosis and *sca* effects CA 8 x CA 32 and CA 5 x CA 32 were adjudged as superior dual purpose hybrids and CA 23 x CA 32 and CA 6 x CA 23 hybrids suitable for green fruit yield. The parallelism of per se performance, *sca* effects and heterosis suggests the possibility of direct exploitation of these hybrids at commercial level.

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