

Original Research Article

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Heterosis Studies for Yield and Horticultural Traits in Capsicum (*Capsicum annuum* L. var. *grossum* Sendt.)

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ABSTRACT

The present investigation entitled “Heterosis and Combining Ability Studies for Yield and Horticultural Traits in Capsicum (*Capsicum annuum* L. var. *grossum* Sendt.)” was carried out at Vegetable Research and Demonstration Block of Uttarakhand University of Horticulture and Forestry, Bharsar, during 2016-2017. The experiment was laid out in a Randomized Block Design (RBD) with three replications. Six diverse capsicum lines were crossed in a diallel fashion (excluding reciprocals) to obtain fifteen cross combinations to study heterosis and combining ability for yield and other horticultural traits. Significant heterobeltiosis was observed in desirable direction for all traits. Similarly, significant increase or decrease heterosis over check (Indham Bharat) was observed for all the traits under study. Eleven crosses over better parent and three crosses over the commercial check exhibited positive and significant heterosis for yield per plant. The cross California Wonder×LC-10 (18.49%) exhibited maximum heterosis over the better parent and commercial check, followed by California Wonder× SolanBharpur (16.76%) and SolanBharpur×LC-10 (97.08%). Hybrids performed better in yield and other horticultural traits that opened the way for further evaluation and release as hybrids. Hence, California Wonder×LC-10, California Wonder× SolanBharpur and SolanBharpur×LC-10 can be recommended for commercial cultivation after multi-location testing.

Keywords

Heterosis,
Capsicum, Hybrid
breeding, Yield,
Horticultural traits

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Introduction

Capsicum (*Capsicum annuum* L. var. *grossum* Sendt.) belongs to genus *Capsicum* of the nightshade family Solanaceae, comprising of 20 to 30 species. Capsicum is also known as bell pepper, sweet pepper, shimplamirch, green pepper and vegetable paprika. Capsicum is grown worldwide for its delicious taste, pleasant flavour, nutritional qualities and is also the most leading crop under protected

structures. Capsicum fruits are generally blocky, square, thick fleshed, three to four lobed, non-pungent and are eaten raw, used as a vegetable or widely used in stuffing, baking, pizza, preparation of soups and stews for imparting flavour. Nutritionally it is a rich source of Vitamin C ranging from 150-180 mg per 100 g and Vitamin A, constituting up to 12 per cent of total pigment content. Due to low productivity and high demand of capsicum in Uttarakhand, it is important to

develop high yielding and suitable hybrids to boost up the production. The reasons for low yield are, growing of low yielding cultivars. Therefore, exploitation of heterosis is in need. Therefore, the present research under taken with an objective of studying the extent of heterosis in different crosses and their utilization in crop improvement programme.

Materials and Methods

The experimental materials comprised of six diverse parents *viz.*, California Wonder, ArkaMohini, SolanBharpur, LC-8 and LC-10 along with its 15 F₁hybrids generated by half-diallel in all possible combinations excluding reciprocals during 2016-2017. Indham Bharat used as standard check. The experiment was laid out in randomized block design with three replications at the Vegetable Research and Demonstration Block, UUFH, Bharsar, Uttarakhand (India). Each plot consisted of 8 plants. Inter and intra row spacing was kept 60 and 45 cm, respectively. The observations were recorded on five randomly selected plants from each treatment and replications for fourteen characters *viz.*, plant height (cm), number of primary branches per plant, stem girth (cm), days to 50 per cent flowering (days), days to first fruit harvesting (days), fruit length (cm), fruit diameter (cm), average fruit weight (g), fruit pericarp thickness (mm), number of fruits per plant, Fruit shelf life (days), ascorbic acid content (mg/100g) and yield per plant (kg). Heterosis expressed as per cent increase or decrease in hybrids (F₁)over better parent (BP) and standard check (SC) values in desirable direction was calculated using the following formula.

$$\text{Heterosis over better parent (BP)} = \frac{F_1 - \overline{BP}}{\overline{BP}} \times 100$$
$$\text{Increase/decrease over check (c)} = \frac{F_1 - \overline{c}}{\overline{c}} \times 100$$

Results and Discussion

For plant height, the highest heterosis over better parent was recorded in the cross California Wonder × SolanBharpur (28.13%), followed by ArkaMohini×SolanBharpur (28.04%) and ArkaMohini × LC-8 (10.76%), while maximum heterosis over standard check was recorded in California Wonder× SolanBharpur (30.56%), followed by California Wonder×LC-10 (13.25%), and SolanBharpur×EC802552 (10.86%). The results are in conformity with Kamble *et al.*, (2009).

The best cross combinations exhibiting high heterotic effects over better parent for the character number of primary branches per plant were ArkaMohini×LC-8 (10.24%), ArkaMohini × EC802552 (3.46%) and EC802552 ×LC-8 (2.59%). While the crosses with high heterosis over standard check were ArkaMohini×LC-8 (22.35%), EC802552 × LC-8 (13.86%) and ArkaMohini×EC802552 (8.11%). The findings are in conformity with that by Karthik *et al.*, (2009).

The best cross combination exhibiting high heterotic effects over better parent and standard check for the character plant stem girth was ArkaMohini×LC-8 (10.24% and 22.35% respectively). Similar positive heterosis confirmative of results reported by Reddy *et al.*, (2008).

Earliness is one of the most desirable character for capsicum was indicated by days required for 50% flowering and days to first fruit harvesting and the crosses with negative significant heterosis were considered as desirable for this trait. Out of fifteen crosses the best results were obtained from the cross SolanBharpur×LC-10 for days to 50% flowering and EC802552 ×LC-8 for days to first fruit harvesting (Table 1 and 2).

Table.1 Estimation of per cent heterosis over better parent (BP) and commercial check Indham Bharat for important hybrids in capsicum

SL. No	Crosses	Plant Height (cm)		Number of Primary Branches per Plant		Stem Girth (cm)		Days to 50 % Flowering (days)		Days to First Fruit Harvesting (days)		Fruit Length (cm)		Fruit Diameter (cm)	
		BP	Check	BP	Check	BP	Check	BP	Check	BP	Check	BP	Check	BP	Check
1	CW×AM	-26.54**	-25.14**	-1.94**	-5.49**	4.18**	4.69**	-13.20**	-4.52**	-8.52**	-4.34**	-2.39**	-7.23**	8.51**	23.89**
2	CW×SB	28.13**	30.56**	-14.38**	-14.48**	-1.23**	-1.23**	-4.31*	4.41**	-0.60	0.81	11.58**	-6.04**	-20.07**	-8.74**
3	CW× EC2	5.54**	9.07**	-5.02**	-0.75**	-0.99**	-0.99**	-11.60**	-2.76*	-5.67**	-1.36	-28.85**	-17.54**	-13.41**	-1.15**
4	CW× LC-8	-7.09**	-5.33**	-26.32**	-18.23**	-10.62**	-10.62**	-4.25*	5.33**	-4.38**	-0.95	2.03**	-14.08*	-21.78**	-10.69**
5	CW× LC-10	-0.86	13.25**	-2.33**	-5.87**	-2.88**	-0.25**	-1.00	8.90**	0.14	4.70**	0.11	-4.26**	-23.68**	-12.87**
6	AM× SB	28.04**	6.28**	-6.25**	-6.37**	-6.88**	-6.42**	1.51	10.75**	4.51**	5.99**	-9.01**	-13.52**	-21.59**	-11.07**
7	AM× EC2	-17.80**	-15.05**	3.46**	8.11**	6.88**	7.41**	-11.19**	-0.36	-9.09**	-3.86*	9.68**	27.11**	-20.30**	-9.61**
8	AM× LC-8	10.76**	-8.07**	10.24**	22.35**	2.95**	3.46**	-13.35**	-1.81	-4.52**	-1.09	11.40**	5.87**	-18.67**	-7.76**
9	AM× LC-10	-26.74**	-16.31**	-9.24**	-17.85**	-0.48**	2.22**	-1.76	11.20**	-0.42	4.34**	-6.25**	-10.34**	-24.13**	-13.95**
10	SB× EC2	7.27**	10.86**	-15.41**	-11.61**	2.63**	-3.70**	-7.67**	0.74	-5.79**	-4.45**	14.83**	33.09**	-19.56**	-18.08**
11	SB× LC-8	8.47**	-12.48**	-11.02**	-1.25**	-5.00**	-10.86**	2.12	11.43**	4.59**	6.08**	20.12**	-20.72**	-3.25**	-20.74**
12	SB× LC-10	-23.81**	-12.96**	-9.38**	-9.49**	-4.33**	-1.73**	-13.93**	-6.10**	-7.14**	-5.82**	-8.33**	-12.33**	-6.69**	-23.56**
13	EC2× LC-8	-2.93**	0.32	2.59**	13.86**	2.20**	-8.15**	-12.83**	-2.19*	-9.36**	-6.11**	12.75**	30.68**	-25.59**	-24.21**
14	EC2× LC-10	-10.67**	2.06*	-19.35**	-15.73**	-13.94**	-11.60**	-6.08**	5.39**	-2.52*	2.14*	15.95**	34.38**	-22.01**	-20.58**
15	LC-8× LC-10	-5.39**	8.08**	-4.39**	6.12**	-5.05**	-2.47**	-7.22**	5.02**	-4.93**	-1.52	-12.50**	-16.32**	-10.55**	-28.18**
SE		0.83	0.75	0.23	0.21	0.10	0.07	1.10	0.95	0.83	0.70	0.32	0.28	0.14	0.11
CD at 5%		1.84	1.67	0.51	0.47	0.22	0.16	2.44	2.11	1.84	1.55	0.71	0.62	0.31	0.24

*, ** significant at 5% and 1% level, respectively (contd.)

Table.1 Contd.

SL. No.	Crosses	Average Fruit Weight (g)		Fruit Pericarp Thickness (mm)		Number of Fruits per Plant		Shelf Life (days)		Ascorbic Acid Content (mg/100g)		Yield per Plant (kg)	
		BP	Check	BP	Check	BP	Check	BP	Check	BP	Check	BP	Check
1	CW×AM	14.99**	7.21*	32.40**	14.78**	-12.08**	-28.07**	-9.86**	-11.93**	20.61**	4.20*	12.01**	-14.84**
2	CW×SB	-4.45	-19.33**	34.71**	3.55**	-12.52**	26.57**	20.79**	12.00**	25.89**	8.76**	53.45**	16.76**
3	CW× EC2	-8.79*	-22.99**	18.43**	-5.03**	3.74**	-15.13**	20.97**	7.34**	3.30	5.72**	-6.91**	-29.22**
4	CW× LC-8	-34.48**	-44.68**	-1.92**	-24.61**	23.39**	47.27**	-33.48**	-40.98**	1.20	-12.58**	14.11**	-13.24**
5	CW× LC-10	-9.25**	-23.38**	25.87**	-3.25**	39.54**	45.13**	12.73**	0.03	-4.58*	-0.29	55.86**	18.49**
6	AM× SB	-26.44**	-31.42**	-10.06**	-22.03**	-51.26**	-29.48**	-0.34	-2.63**	20.38**	2.42	-30.70**	-50.00**
7	AM× EC2	-0.30	-7.05**	8.61**	-5.84**	21.28**	-9.91**	-20.41**	-22.23**	-32.43**	-30.85**	30.70**	-5.62**
8	AM× LC-8	-13.22**	-19.09**	4.43**	-9.46**	-47.24**	-37.03**	-23.47**	-25.22**	-19.71**	-31.69**	-23.73**	-44.98**
9	AM× LC-10	-18.32**	-23.85**	-11.94**	-23.65**	3.24**	7.38**	7.14**	4.69**	-39.56**	-36.84**	26.58**	-8.68**
10	SB× EC2	13.66**	-33.75**	-10.69**	-28.38**	-3.62**	39.45**	-50.18**	-53.81**	5.51*	7.98**	48.79**	-15.75**
11	SB× LC-8	21.52**	-58.05**	-1.42**	-28.01**	20.01**	73.65**	-39.43**	-43.84**	30.16**	1.22	42.34**	-19.41**
12	SB× LC-10	-0.89	-48.48**	2.13**	-25.45**	23.78**	79.11**	-1.43**	-8.61**	-9.23**	-5.14**	82.49**	7.08**
13	EC2× LC-8	6.58*	-37.87**	4.70**	-16.04**	1.55*	21.20**	64.07**	-8.94**	10.10**	12.68**	76.78**	-14.84**
14	EC2× LC-10	27.46**	-25.70**	24.79**	0.07	-38.80**	-36.35**	0.01	-21.57**	-21.89**	-18.38**	-12.45**	-48.63**
15	LC-8× LC-10	-3.95	-50.08**	4.77**	-23.65**	43.44**	71.20**	46.61**	14.99**	-3.58	0.76	67.70**	-1.60**
	SE	2.50	1.98	0.20	0.22	0.41	0.36	0.58	0.45	1.89	1.55	0.04	0.04
	CD at 5%	5.55	4.40	0.44	0.49	0.91	0.80	1.29	1.00	4.20	3.44	0.09	0.09

*, ** significant at 5% and 1% level, respectively.

Table.2 Top three parents and cross combinations on the basis of their *per se* performance and heterotic values

Traits	Per se performance		Heterosis	
	Parents	Crosses	BP (%)	SC (%)
Plant height (cm)	LC-10 (97.61), EC2 (88.30), C W (87.06).	C W×S B (111.55), C W×LC-10 (97.76), S B ×EC2 (94.72).	C W×S B (28.13), A M ×S B (28.04), A M×LC-8 (10.76).	C W×S B (30.56), C W×LC-10 (13.25), S B ×EC2 (10.86).
Number of primary branches per plant	LC-8 (2.96), EC2 (2.79), S B (2.67).	A M×LC-8 (3.27), A M ×EC2 (2.89), LC-8 ×LC-10 (2.83).	A M×LC-8 (10.24), A M ×E2 (3.46), EC2 ×LC-8 (2.59).	A M×LC-8 (22.35), EC2 × LC-8 (13.86%), A M×EC2 (8.11%).
Stem girth (cm)	LC-10 (1.39), A M (1.36), C W (1.35).	A M ×EC2 (1.45), C W×A M (1.41), A M×LC-8 (1.40).	A M ×EC2 (6.88), C W×A M (4.18), A M×LC-8 (2.95).	A M ×EC2 (7.41), C W×A M (4.69), A M×LC-8 (3.46).
Days to 50 per cent flowering (days)	S B (77.51), EC2 (79.71), LC-10 (80.41).	S B ×LC-10 (66.71), C W×A M (67.83), C W ×EC2 (69.08).	S B ×LC-10 (-13.93), A M×LC-8 (-13.35), C W×A M (-13.20).	S B ×LC-10 (-6.10), C W×A M (67.83), C W ×EC2 (-2.76).
Days to first fruit harvesting (days)	S B (108.89), LC-8 (111.21), C W (112.26).	EC2 ×LC-8 (100.80), S B ×LC-10 (101.12), S B ×EC802552 (102.52).	EC2 ×LC-8 (-9.36), A M ×EC2 (-9.09), C W×A M (-8.52).	EC2 ×LC-8 (-6.11), S B ×LC-10 (-5.82), S B ×EC2 (-4.45).
Fruit length (cm)	EC2 (11.06), LC-10 (9.12), A M (9.07).	EC2 ×LC-10 (12.82), S B ×EC2 (12.70), EC2 ×LC-8 (12.47).	S B × LC-8 (20.12), EC2 ×LC-10 (15.95), S B ×EC2 (14.83).	EC2 ×LC-10 (34.38), S B ×EC2 (33.09), EC2 ×LC-8 (30.68).
Fruit diameter (cm)	C W (7.01), A M (6.96), EC2 (6.25).	C W×A M (7.61), C W ×EC2 (6.07), A M×LC-8 (5.66).	C W×A M (8.51), S B × LC-8 (-3.25), S B × LC-10 (-6.69).	C W×A M (23.89), C W ×EC2 (-1.15), A M×LC-8 (-7.76).
Average Fruit weight (g)	A M (99.38), C W (89.99), EC2 (62.13).	C W×A M (114.27), A M ×EC2 (99.08), A M×LC-8 (86.24)	EC2 ×LC-10 (27.46), S B ×LC-8 (21.52), C W×A M (14.99).	C W×A M (7.21), A M ×EC2 (-7.05), A M×LC-8 (-19.09).
Fruit pericarp thickness (mm)	A M (3.91), EC2 (3.62), C W (3.47).	C W×A M (5.18), C W×S B (4.67), EC2 ×LC-10 (4.51).	C W×S B (34.71), C W×A M (32.40), C W×LC-10 (25.87).	C W×A M (14.78), C W×S B (3.55), C W×LC-10 (-3.25).
Number of fruits per plant	S B (21.91), LC-8 (18.07), LC-10 (15.75).	S B ×LC-10 (27.12), S B ×LC-8 (26.29), LC-8×LC-10 (25.92).	LC-8×LC-10 (43.44), C W×LC-10 (39.54), S B ×LC-10 (23.78).	S B ×LC-10 (79.11), S B ×LC-8 (73.65), LC-8×LC-10 (71.20).
Shelf life (days)	A M (9.80), S B 99.30), C W (8.90).	LC-8×LC-10 (11.53), C W×S B (11.23), C W ×EC2 (10.77).	EC2 ×LC-8 (64.07), LC-8×LC-10 (46.61), C W ×EC2 (20.97).	LC-8×LC-10 (14.99), C W×S B (12.00), C W ×EC2 (7.34).
Ascorbic acid content (mg/100g)	LC-10 (161.42), EC2(158.09), C W (133.45).	EC2 ×LC-8 (174.05), C W×S B (168.00), S B ×EC2 (166.80).	S B ×LC-8 (30.16), C W×S B (25.89), C W×A M (20.61).	EC802552 ×LC-8 (12.68), C W×S B (8.76), S B ×EC2 (7.98).
Yield per plant (kg)	C W (1.11), A M (1.05), LC-10 (0.86).	C W×LC-10 (1.73), C W×S B (1.70), S B ×LC-10 (1.56).	S B ×LC-10 (82.49), EC2 ×LC-8 (76.78), LC-8×LC-10 (67.70).	C W×LC-10 (18.49), C W×S B (16.76), S B ×LC-10 (7.08).

Where, C W= California Wonder, A M= ArkaMohini, S B= SolanBharpur and EC2= EC802552

Early flowering in capsicum hybrids due to negative heterotic effect to a considerable amount have been reported earlier by Dejanet *et al.*, (2010).

For fruit length the cross SolanBharpur× LC-8 (20.12%), showed maximum heterosis over better parent followed by EC802552 ×LC-10 (15.95%) and SolanBharpur×EC802552 (14.83%). While over standard check maximum heterosis was shown by the cross EC802552 × LC-10 (34.38%), followed by SolanBharpur×EC802552 (33.09%) and EC802552 × LC-8 (30.68%). The finding of Shankarnag *et al.*, (2006) also supported the above results.

The best cross showing highest heterotic effect over better parent for the character fruit diameter was California Wonder×ArkaMohini (8.51%) followed by SolanBharpur × LC-8 (-3.25%) and SolanBharpur × LC-10 (-6.69%). The crosses proved better for the character over standard check were California Wonder × ArkaMohini (23.89%), California Wonder ×EC802552 (-1.15%) and ArkaMohini×LC-8 (-7.76%). Similar result was found by Mahmoud and Eslamboly (2015).

For the character average fruit weight the crosses that proved superior were EC802552 × LC-10 (27.46%), SolanBharpur×LC-8 (21.52%) and California Wonder × ArkaMohini (14.99%) over better parent and California Wonder×Arka Mohini (7.21%), ArkaMohini×EC802552 (-7.05%) and ArkaMohini×LC-8 (-19.09%), over standard check showing high and significant magnitudes of heterosis effects. Finding of Mahmoud and Eslamboly (2015) supported the results.

For fruit pericarp thickness the cross California Wonder×SolanBharpur (34.71%) showed highest heterosis over better parent followed by California Wonder×ArkaMohini

(32.40%) and California Wonder×LC-10 (25.87%). While the cross California Wonder×ArkaMohini (14.78%), showed maximum heterosis over standard. The findings are in accordance with that of Khalil and Hatem (2014).

The best cross showing highest heterotic effect over better parent for the character number of fruits per plant was SolanBharpur × LC-10 (27.12%), followed by SolanBharpur×LC-8 (26.29%) and LC-8×LC-10 (25.92%). The crosses proved better for the character over standard check were SolanBharpur × LC-10 (79.11%), SolanBharpur × LC-8 (73.65%) and LC-8 × LC-10 (71.20%). The finding of Afroza *et al.*, (2013) supported the above results.

The best cross combination exhibiting high heterotic effects over better parent and standard check for the character ascorbic acid content was EC802552 ×LC-8 (12.68%). Similar positive heterosis confirmative of results reported by Butcher *et al.*, (2013).

For fruit yield per plant the cross SolanBharpur×LC-10 (82.49%), showed highest heterosis over better parent followed by EC802552 × LC-8 (76.78%) and LC-8×LC-10 (67.70%). While the cross California Wonder × LC-10 (18.49%), showed maximum heterosis over standard check followed by California Wonder × SolanBharpur (16.76%) and SolanBharpur×LC-10 (7.08%). The findings are in accordance with that of Mahmoud and Eslamboly (2015).

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