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COMBINING ABILITY AND HETEROSIS FOR MORPHOLOGICAL AND AGRONOMICAL TRAITS IN CHILLI (*CAPSICUM ANNUUM* L.)

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ABSTRACT

Enhanced productivity in green chilli and improvement of fruit quality for industrial use in the export market, is a goal of plant breeders worldwide. Genotypes having a broad genetic background, and phenotypic diversity, were chosen as parents and crossed in a 6 × 6 diallel fashion without reciprocals to produce 15 F_1 chilli hybrids to determine the extent of heterosis and to estimate combining ability for quantitative traits. The maximum heterobeltiosis, in the desired direction, was for green fruit yield per plant followed by a number of fruit per plant, weight of green fruit and fruit length. The good combinerscvs. IND-CH-38 and IND-CH-66 were identified based on general combining ability effects and average performance. Hybrids 'IND-CH-38 × IND-CH-45'and 'IND-CH-38 × IND-CH-66' were considered promising for value-added products and export based on average values, heterosis manifested, and relevance of specific combining ability effects. Promising hybrids could also be exploited in segregating generations to identify pure lines with desirable traits.

Keywords : *Capsicum annuum, combining ability, heterobeltiosis.*

Breeding efforts for the development of green chilli pepper (*Capsicum annuum* L.) to enhance productivity have been done. Less attention has been paid to genetic improvement of chilli as a vegetable as well as spices to increase existing productivity (1). Use of local unimproved cultivars, and reduced tolerance of open-pollinated varieties against biotic challenges, are reasons for low productivity (2). Although systemic utilization of existing genetic diversity is important to avoid genetic erosion, the productivity of greenchilli could not be increased using open-pollinated varieties (3). Pungency in chilli fruit is due to capsaicin (8-methyl-N-vanillyl-6-enamide) and 7 closely related alkyl vanillyl amides, collectively referred to as capsaicinoids. Capsaicin and dihydrocapsaicin in the placenta of fruit accounts for >80% of capsaicinoids (4). Analysis of combining the ability of sets of inbred lines plays an important role in chili breeding for inbred lineselection, heterotic group classification, heterotic pattern identification, and hybrid development (2). Reports on simultaneous improvement of green chili yield, and quality traits through heterosis breeding, have been documented (2) but little work on dry fruit yield, and quality improvement, necessitates the present study. Diallel analysis of a fixed set of self-and cross-pollinated populations, used to assess combining ability, is effective for identification of suitable parents for hybridization, estimation of the performance of a parent in a series of crosses, and measurement of heterosis in chilli (5). Heterosis breeding could improve green chilli yield. The investigation was undertaken to assess the extent of heterosis and to identify good combiners, and for genetic improvement in green chilli.

MATERIALS AND METHODS

Field experiments were conducted at Research and Development Farm, Mallasandra, Indigo Seeds Private Limited, Karnataka, in the month of February-December, 2020. The materials are collected from the stock maintained in the seed bank of Indigo Seeds Private Limited, Bangalore. Six parental lines viz., IND-CH-16, IND-CH-22, IND-CH-32, IND-CH-38, IND-CH-45 and IND-CH-66 were selected and crossed in a diallel fashion. From these 6 parental lines, 15 crosses were made and evaluated in the following season.

Fifteen plants were randomly selected from each plot for each replication to record days to 50% flowering, plant height,fruit length, fruit diameter, weight of green fruit, number of fruits/ plant, green fruit yield/plant and capsaicin content. The magnitude of heterosis was estimated in relation to mid parent (MP) and better-parent (BP) values according to (6). Combining ability variances, and effects, were determined according to (7) Model-I and Method-II.

RESULTS AND DISCUSSION

The combining ability indicated that GCA and SCA variances were significant for all traits (Table-1). The GCA effects of parents used for quantitative traits varied (Table-2). The parents differed in GCA effects for all traits. Estimates for combining ability effects indicated the genitors 'IND-CH-38' and 'IND-CH-66'have desired

Table-1 : Analysis of variance (mean squares) for combining ability (Griffing's Model-I and Method-II) of 8 characters of chilli.

Source of variation (d.f.)	Days to 50% flowering	Plant Height	Fruit length	Fruit diameter	Weight of green fruit	Number of fruits/ plant	Green fruit yield/plant	Capsaicin content
GCA (5)	435.35**	3043.94**	73.12**	0.59**	6.77**	122664.71**	1783049.52**	5.66**
SCA (14)	1066.95**	1227.17**	57.88**	1.32**	6.24**	45369.00**	871941.62**	12.69**
Error (40)	315.46	1209.62	11.84	0.16	0.63	10592.48	129349.14	0.09

*, ** Significant at 0.05 and 0.01 level of probability, respectively.

Table-2 : Estimates of general combining ability (g_i) effects and per se performances in 6 parents over 15 F_1s of chilli.

Hybrids	Days to 50% flowering	Plant Height	Fruit length	Fruit diameter	Weight of green fruit	Number of fruits/ plant	Green fruit yield/plant	Capsaicin content
IND-CH-16	0.92*	-6.49**	-1.51**	-0.12**	-0.45**	-54.67**	-223.78**	-0.20**
IND-CH-22	-1.25**	4.61**	-0.01	0.01	0.01	-19.23**	-45.38**	0.26**
IND-CH-32	-2.29**	6.93**	0.30	0.00	0.10**	31.83**	89.37**	-0.19**
IND-CH-38	1.46**	-3.80**	0.51**	0.04*	0.22**	17.89**	104.89**	0.07*
IND-CH-45	2.54**	-0.27	0.63**	-0.03	0.15**	4.10	50.93**	-0.18**
IND-CH-66	-1.38**	-0.98	0.08	0.09**	-0.04*	20.08**	23.97*	0.24**
SE (gi)	0.81	1.59	0.16	0.02	0.04	4.70	16.42	0.01

*, ** Significant at 0.05 and 0.01 level of probability, respectively.

Table-3 : Estimates of specific combining ability (sij) effects and per se performance for 8 characters in 15 F_1 of chilli based on Griffing's Model-I and Method-II.

Hybrids	Days to 50% flowering	Plant Height	Fruit length	Fruit diameter	Weight of green fruit	Number of fruits/ plant	Green fruit yield/plant	Capsaicin content
IND-CH-16×IND-CH-22	1.91**	2.43	0.07	0.00	0.14**	17.50**	73.89**	0.47**
IND-CH-16×IND-CH-32	0.95	-6.18**	-0.45**	-0.17**	-0.14**	-8.16	-69.15**	-0.09*
IND-CH-16×IND-CH-38	2.53**	3.54*	-1.21**	0.06*	-0.51**	-32.32**	-197.64**	-0.56**
IND-CH-16×IND-CH-45	-0.22	-3.69*	-0.38*	-0.03	0.05	-26.58**	-46.12**	-0.02
IND-CH-16×IND-CH-66	-3.97**	1.11	-0.36*	-0.06*	-0.04	-4.74	-26.04	0.14**
IND-CH-22×IND-CH-32	-3.55**	-7.29**	0.28	-0.03	-0.14*	-0.07	-42.35*	0.48**
IND-CH-22×IND-CH-38	5.03**	-2.09	0.65**	-0.04*	0.15**	-31.08**	-36.16*	0.32**
IND-CH-22×IND-CH-45	2.28**	-3.59*	-0.84**	-0.04*	-0.32**	-24.98**	-137.01**	0.40**
IND-CH-22×IND-CH-66	-4.47**	7.72**	-1.63**	0.29**	-0.59**	-10.65*	-189.08**	0.22**
IND-CH-32×IND-CH-38	5.07**	7.84**	1.01**	-0.17**	0.38**	-50.96**	-0.99	-0.60**
IND-CH-32×IND-CH-45	-0.35	-3.09	-1.54**	0.15**	-0.59**	28.90**	-149.19**	-0.06*
IND-CH-32×IND-CH-66	6.24**	0.99	0.46**	-0.03	0.00	-8.33	-18.21	0.53**
IND-CH-38×IND-CH-45	-9.10**	4.40**	1.02**	0.11**	0.37**	42.94**	230.30**	-0.40**
IND-CH-38×IND-CH-66	-8.18**	-9.11**	-1.92**	0.35**	-0.29**	57.63**	68.63**	0.32**
IND-CH-45×IND-CH-66	2.41**	-0.03	1.47**	-0.04*	0.53**	10.52*	195.75**	0.54**
SE (sij)	1.62	3.18	0.31	0.04	0.07	9.40	32.83	0.03

*, ** Significant at 0.05 and 0.01 level of probability, respectively.

general combining ability for green fruit yield per plant and its related traits. Genitor 'IND-CH-66' was a good parent based on days to 50% flowering, fruit diameter, number of fruits/ plant, green fruit yield/plant and capsaicin content. On the basis of GCA effects, or by their combination corroborating results reported by (8, 9) in chilli.In most cases, good general combiners exhibited better average performance regarding yield and quality traits (Table-2). Significant specific combining ability effects, in the desired direction, occurred among hybrids (Table-3). The cross 'IND-CH-38 × IND-CH-66' exhibited the maximum SCA effects in the desired direction for green fruit yield per plant, days to 50% flowering, fruit diameter, number of fruits/plant and capsaicin content.

The cross 'IND-CH-38 × IND-CH-45' exhibited SCA effects in the desired direction for days to 50% flowering, plant height, fruit length, fruit diameter, weight of green fruit, number of fruits/ plant and green fruit yield/plant. The third highest SCA effects in the desired direction for green fruit yield per plant were in the 'IND-CH-22 × IND-CH-32' cross, along with days to 50% flowering, fruit length, fruit diameter, and fruit yield per plant. Specific combining ability effects represent dominance and epistatic components of genetic variation which are not fixable, but crosses with high SCA effects involving good general combiner parents, can be exploited in breeding. Different cross combinations exhibited different SCA effects and only a few crosses showed consistently either

Table-4a : Heterosis percentages (MP-mid parent and BP-better parent) of F_1 hybrids.

Hybrids	Days to 50% flowering		Plant Height		Fruit length		Fruit diameter	
	MP (%)	BP (%)	MP (%)	BP (%)	MP (%)	BP (%)	MP (%)	BP (%)
IND-CH-16×IND-CH-22	-7.96	-7.69	27.27**	15.44**	27.04**	24.18**	5.08	4.16
IND-CH-16×IND-CH-32	-13.51**	-12.20**	23.04**	16.95**	26.95**	25.57**	18.54**	10.04*
IND-CH-16×IND-CH-38	3.72	7.09	14.19**	9.43	38.04**	35.15**	7.17	2.28
IND-CH-16×IND-CH-45	2.33	4.15	21.91**	20.63**	15.14	11.38	8.50	6.14
IND-CH-16×IND-CH-66	-10.28*	-5.26	36.45**	30.34**	3.05	2.71	43.46**	40.87**
IND-CH-22×IND-CH-32	-16.77**	-15.25**	32.68**	26.28**	25.83**	24.33**	31.98**	21.52**
IND-CH-22×IND-CH-38	1.71	4.70	22.81**	15.95**	42.68**	36.62**	-4.94	-8.50
IND-CH-22×IND-CH-45	-4.35	-2.94	14.23**	4.60	8.33	7.18	24.04**	20.30**
IND-CH-22×IND-CH-66	7.46	13.82**	15.91	9.78	28.04**	25.56**	13.66**	12.58**
IND-CH-32×IND-CH-38	5.23	10.36*	-6.23	-7.03	37.67**	33.36**	7.78	-4.16
IND-CH-32×IND-CH-45	-11.50**	-8.54	14.87**	10.29**	40.58**	37.45**	35.08**	28.02**
IND-CH-32×IND-CH-66	-10.76*	-7.24	-13.36**	-13.81**	4.62	3.82	63.66**	49.39**
IND-CH-38×IND-CH-45	5.92	7.43	19.68**	15.86**	36.21**	29.10**	-2.79	-9.15
IND-CH-38×IND-CH-66	-16.03	-15.80**	9.06	8.70	49.92**	46.32**	5.91	2.88
IND-CH-45×IND-CH-66	3.36	11.18*	10.83**	6.95	30.18**	26.33**	5.44	1.32
S.E.	0.11	0.12	0.04	0.05	0.29	0.33	0.04	0.05

*, ** Significant at 0.05 and 0.01 level of probability, respectively.

Table-4b : Heterosis percentages (MP-mid parent and BP-better parent) of F_1 hybrids.

Hybrids	Weight of green fruit		Number of fruits/ plant		Green fruit yield/plant		Capsaicin content	
	MP (%)	BP (%)	MP (%)	BP (%)	MP (%)	BP (%)	MP (%)	BP (%)
IND-CH-16×IND-CH-22	57.60**	41.00**	24.25**	17.62	99.74**	69.11**	-46.43*	-62.00**
IND-CH-16×IND-CH-32	37.88**	30.33**	28.63**	16.30	79.93**	53.69**	163.42**	141.91**
IND-CH-16×IND-CH-38	82.59**	77.13**	19.44	16.02	125.62**	124.99**	237.71**	157.32**
IND-CH-16×IND-CH-45	18.68	4.91	18.12	16.77	42.52*	23.86	136.59**	131.12**
IND-CH-16×IND-CH-66	-2.61	-6.88	21.48*	11.41	19.01	4.27	87.13**	44.17*
IND-CH-22×IND-CH-32	52.00**	43.37**	49.81**	42.68**	134.11**	131.62**	-52.22**	-67.74**
IND-CH-22×IND-CH-38	82.28**	58.77**	26.14**	22.83*	136.18**	99.50**	-67.55**	-80.22**
IND-CH-22×IND-CH-45	-4.17	-5.47	56.91**	50.17**	52.36**	47.73*	-45.60*	-61.94
IND-CH-22×IND-CH-66	29.59**	20.86*	36.56**	32.05**	81.48**	74.37**	16.36	3.23
IND-CH-32×IND-CH-38	73.16**	59.07**	37.39**	27.59**	143.61**	107.60**	266.93**	198.34**
IND-CH-32×IND-CH-45	68.37**	56.79**	48.79**	35.93**	159.52**	154.28**	-9.98	-15.51
IND-CH-32×IND-CH-66	27.17**	25.65**	49.75**	47.42**	94.91**	89.23**	89.33**	37.50
IND-CH-38×IND-CH-45	51.30**	30.27**	29.32**	27.04**	101.49**	74.70**	-9.42	-29.83
IND-CH-38×IND-CH-66	93.14**	79.40**	36.47**	28.62**	172.25**	137.95**	110.39**	88.00**
IND-CH-45×IND-CH-66	31.45**	21.05*	31.77**	22.14*	78.39**	76.72**	-31.94	-48.42*
S.E.	0.69	0.80	0.93	1.07	2.91	3.36	0.57	0.65

*, ** Significant at 0.05 and 0.01 level of probability, respectively.

positive or negative SCA effects for certain traits. The majority of crosses having significant SCA effects in the desirable direction had at least 1 parent with high significant positive GCA effects, indicating that these hybrids will be expected to produce segregates with high yield, and other economic traits of fixable nature in segregating generations through simple pedigree method. Hybrids with high specific combining ability effects, and being involved in at least 1 parent with high, or average GCA effects, for a particular trait is a good strategy for breeding (7). Based on SCA effects and average performance of the cross combinations, 2 crosses 'IND-CH-38 × IND-CH-45' and 'IND-CH-38 × IND-CH-66' were found promising specific combiners for dry fruit yield and other important horticultural traits. The results pertaining to significant SCA effects for different quantitative traits in chilli in the present study are comparable with those of previous workers (10, 11) despite using dissimilar hybrids evaluated in other environments. The magnitude of heterosis, estimated over the mid-parent and better-parent (heterobeltiosis) in promising crosses varied (Table-4a and 4b). Green fruit yield per plant, followed by days to 50% flowering, plant height, fruit length, fruit diameter, weight of green fruit, number of fruits/ plant and capsaicin content exhibited maximum significant heterobeltiosis in the desired direction. The maximum heterobeltiosis for green fruit yield per plant was exhibited by 'IND-CH-38 × IND-CH-66' followed by 'IND-CH-38 × IND-CH-45' a long with a number of fruits per plant,fruit length, fruit diameter, weight of green fruit and capsaicin content. Based on average performance, the highest yielding hybrid was 'IND-CH-38 × IND-CH-45' and 'IND-CH-38 × IND-CH-66'. Significant heterobeltiosisfor fruit yield and quality trait in chilli is comparable with those of previous workers (12) despite using dissimilar parents and hybrids tested in other environments.

CONCLUSION

The genitors 'IND-CH-38' and 'IND-CH-66'were the most promising donors for dry fruit yield along with good horticultural traits, and could be utilized in greenchilli hybridization. The crosses 'IND-CH-38 × IND-CH-45' and 'IND-CH-38 × IND-CH-66' appeared to be promising in respect to green fruit yield and quality traits could be exploited at commercial level after critical evaluation. Promising hybrids could be exploited in segregating generations to identify pure lines with desirable horticultural traits.

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