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Research Article

Combining ability analysis in chilli (*Capsicum annum* L.)

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Abstract
The experiments was undertaken to study the combining ability for yield and yield attributing traits in chilli. The experimental material consisted of seven parents and 42 F_1s produced in diallel mating design including reciprocals. Analysis of variance for combining ability exhibited the significance for *gca* and *sca* effects for all the characters studied. BC-28 was good general combiner for both red as well as green fruit yield plant^{-1}, Konkan kirti and Jayanti good general combiner for red fruit yield, while Jwala and Selection-2 were the best general combiners for green fruit yield plant^{-1}(g) which can be exploited breeding programme. The highest sca effect for red fruit yield plant^{-1} in F_1 generation was noted in the reciprocal cross of BC-28 x Konkan kirti, reciprocal cross of Selection-2 x PANT-C-3 and reciprocal cross of Selection-2 x konkan kirti. The maximum sca effect for green fruit yield plant^{-1} in F_1 generation was recorded in reciprocal cross of Selection-2 x DPL-C-4, reciprocal cross of Selection-2 x Konkan kirti and reciprocal cross of Jwala x BC-28, were the good specific combinations and would be used as a heterotic hybrids after rigorous screening through various yield, pest and disease screening trials.

Key words:
Capsicum, combining ability diallel analysis

Introduction:

Chilli (*Capsicum annuum* L.) is an important commercial crop of India grown for its green fruits as vegetable and red form as spice. It belongs to the family *Solanaceae* and has a chromosome number 2n = 24. Many food industries have extracted the oleoresin from chilli and is being used in preparation of processed products and pharmaceutical preparations. Chillies have two important qualities, biting pungency attributes to capsaicin and captivating red colour due to pigment capsanthin. In any breeding programme, the proper choice of parents based on their combining ability is a prerequisite which not only provides necessary information regarding the choice of parents but also simultaneously illustrate the nature and magnitude of gene action involved in the expression of desirable traits. Accordingly, the present investigation was undertaken to have an idea of the nature of gene action for dry fruit yield and other important attributes in chilli. Several biometrical methods are available for studying the combining ability and gene action. As the diallel cross gives a fairly good idea of both general and specific combining abilities of parents and hybrid combinations respectively. Study of combining ability is important for selecting parents for hybridization. Sprague and Tatum (1942), first time proposed the concepts of general combining ability and specific combining ability. According to them, GCA variance is due to additive variance and SCA variance is due to non-additive variance, both acts as an important diagnostic tool in selection of suitable parents and cross combination. The study reported here was designed to gather information on the genetics of the characters studied and on the extent of combining ability for yield and its yield attributing traits in chilli.

Material and Methods:

Seven parents *viz* Jwala, Selection-2, PANT-C-3, BC-28, DPL-C-4, Konkan kirti and Jayanti were selected for crossing in full diallel mating design to generate 42 F_1 hybrids. Seven parents and the 42 F_{1S} were evaluated in randomized block design with three replications at Department of Botany Farm, College of Agriculture, Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth, Dapoli during *Rabi* 2012. It is situated in the tropical region on 17.7667^0 North and 73.1833^0 East. The mean sea level height is 240 meters. The mean annual rainfall is 3500 mm generally distributed between May to October. Mean annual maximum and minimum temperature are 31.0 and 29.1^0 C, respectively. Mean relative humidity is 91.7 per cent. The soil type is lateritic. The nursery was sown on November, 2012 and transplanted in the field on December, 2012. The spacing of 60 cm between row to row and 45 cm between plants to plant was adopted. Two lines each with ten plants for parents and F_1s were planted in net experimental plot of 30 m x 27 m. FYM @ 15 t/ha was mixed at the time of field preparation. The chemical fertilizers, N:P:K@150:50:50 kg/ha were applied in form of urea, single super phosphate and muriate of potash. The complete dose of phosphorus and potash and half dose of nitrogen were applied at the time of transplanting and remaining dose of nitrogen was applied in two

splits, thirty and sixty days after transplanting. The observations on five randomly selected plants in each treatment under each replication were recorded for days to first flowering, days to first picking, plant height (cm), number of branches plant^{-1}, fruit length (cm), fruit diameter (mm), number of seed fruit^{-1}, number of fruits plant^{-1} (green), green fruit yield plant^{-1}(g), number of fruits plant^{-1} (red), red fruit yield plant^{-1} (g), days to last picking and capsaicin content. To estimate the combining ability analysis to the parents and the hybrid combinations, method I, model I given by Griffing, 1956 was used.

Result and Discussion:

The knowledge of combining ability is necessary for selection of appropriate parents in hybridization. Since it gives an idea whether a particular parent combines well in a cross and also denote the specific performance of a cross combination against the expectations from the gca of the parents. On the contrary, the reciprocal effect gives an idea about which parent could be used as female or which as male so as to maximize performance of the crop that was predicted on the basis of gca of parent and sca of the cross. Sprague and Tatum in 1942 used the term combining ability to describe the average performance of a line in a series of cross combinations. The analysis of variance for combining ability was carried out for all thirteen characters of F_1 diallel progenies (Table 1). The variance due to treatment were further partitioned using appropriate expectations of the observed mean squares in to components of variations attributed to general combining ability (gca) variance, specific combining ability (sca) variance and reciprocal effects. The mean squares due to gca, sca and reciprocal effects were significant for all the characters, indicating substantial genetic variations for gca, sca and reciprocal effect for all the characters studies.

It is revealed from the Table 2, parent BC-28 was the best general combiner for green fruit yield plant^{-1}(g) along with seven other contributing characters. Konkan kirti which had given significant gca effects for eight characters ranked second followed by Jwala and Selection-2 significant gca effect for seven characters including green fruit yield plant^{-1}(g). These four parents viz,. BC-28, Konkan kirti, Jwala and Selection-2 were identified as good general combiners for yield per plant and its component characters like days to first flowering, days to first picking, plant height, number of branches plant $^{-1}$, fruit length (cm), fruit diameter, number of seed fruit $^{-1}$, number of fruits plant^{-1} (green), number of fruits plant^{-1} (red) and days to last picking. Similar kind of results was also reported by Gandhi *et al.* (2000), Jagadeesha and Wali (2005) and Mohite Patil (2011),identified Jwala as best general combiner for days to first flowering and yield per plant which confirms the results of the present research. The good general combining ability for number of fruit plant $^{-1}$, fruit length and fruit girth was reported by Lippert (1974) and significant gca effect for all character by Gandhi *et al.* (2000). All these reports confirm the findings of the present investigation.

Specific combining ability effects are indicative of heterosis. Similarly they represent both dominant and epistatic gene actions. The promising F_1 hybrids based on specific combining ability effect for yield and its components are presented in table 3.

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), Sarala Devi and Arumugum (1999) and Mohite Patil (2011).

The highest sca effect for red fruit yield plant^{-1} in F_1 generation was noted in the reciprocal cross of BC-28 x Konkan kirti. This cross also showed significant sca effect for four other component characters in F_1, like number of red fruits plant^{-1}, number of green fruits plant^{-1}, green fruit yield plant^{-1}(g) and days to last picking. The reciprocal cross of Selection-2 x PANT-C-3 exhibited significant sca effect for fruit length, number of seeds fruit^{-1}, number of red fruits plant^{-1}, number of green fruits plant^{-1} and green fruit yield plant^{-1}(g). Beside red fruit yield plant^{-1} reciprocal cross of Selection-2 x konkan kirti recorded significant effect for number of branches plant^{-1}, number of red fruits plant^{-1}, number of green fruits plant^{-1} and green fruit yield plant^{-1}. The maximum sca effect for green fruit yield plant^{-1} in F_1 generation was recorded in reciprocal cross of Selection-2 x DPL-C-4. This cross also showed significant sca effect for nine other component characters in F_1, like days to first flower, days to first picking, fruit diameter, fruit length, number of seeds fruit^{-1}, number of red fruits plant^{-1}, number of red fruits plant^{-1} and number of green fruits plant^{-1} Reciprocal cross of Selection-2 x Konkan kirti exhibited significant sca effect for number of green fruits plant^{-1} and four other characters viz., number of branches plant^{-1}, number of red fruits plant^{-1}, red fruit yield plant^{-1} and number of green fruits plant^{-1}. Besides significant sca effect for green fruit yield plant^{-1} in reciprocal cross of Jwala x BC-28 sca effect for number of seeds fruit^{-1}, number of red fruits plant^{-1}, red fruit yield plant^{-1} and number of green fruits plant^{-1}. Similar kinds of results were also reported by Shekhawat *et al.* (2007), Prasath and Ponnuswami (2008). Similarly, many other crosses have showed desirable sca effects for more than one component character along with yield per

plant in F_1 generation. The crosses which have exhibited high desirable sca effect for component characters excluding yield per plant are practically of no use in general plant breeding programme, but can be used for the improvement of these characters.

Thus, it appears that the selection of crosses merely on the basis of *per se* performance and sca effects may not be helpful, but gca effects of the parents should be considered. An ideal combination to be exploited is one with higher degree of sca with higher *per se* performance and at least one parent with good general combining ability.

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Table 1. Analysis of variance for combining ability

Source	DF	Days to first flowering	Days to first Picking	Plant height (cm)	No. of branches plant^{-1}	Fruit Diameter (mm)	Fruit length (cm)	No. of seeds fruit^{-1}	No. of fruits plant^{-1} (red)	Red fruit yield plant^{-1} (g)	Days to last Picking	No. of fruits plant^{-1} (green).	Green fruit yield plant^{-1} (g)	Capsecin content (%)
GCA	6	108.35**	109.29**	51.98**	0.821**	3.932**	5.689**	877.39**	332.23**	139.287**	104.424**	1376.24**	15323.24**	0.01039**
SCA	21	58.08 **	57.32**	37.09**	1.187**	0.707**	2.021**	491.76**	250.544**	105.725**	57.274**	401.84**	3797.59**	0.0172**
Reciprocal	21	35.40 **	33.02**	35.10**	0.479**	0.502**	1.614**	325.11**	231.098**	133.387**	34.180**	1367.75**	12431.49**	0.00066**
Error	96	0.226	0.31	0.47	0.027	0.0399	0.022	0.913	0.852	0.622	0.294	33.07	40.12	0.00007
σ^2A / σ^2D		0.266	0.273	0.200	0.097	0.833	0.404	0.255	0.189	0.188	0.0261	0.520	0.581	0.890

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

Table 2. Estimates of general combining ability effects of parents

Parents	Days to first flowering	Days to first Picking	Plant height (cm)	No. of branches plant^{-1}	Fruit Diameter (mm)	Fruit length (cm)	No. of seeds fruit^{-1}	No. of fruits plant^{-1} (red)	Red fruit yield plant^{-1} (g)	Days to last Picking	No. of fruits plant^{-1} (green).	Green fruit yield plant^{-1} (g)	Capsecin content (%)
Jwala	2.759**	2.734**	-0.201	0.411**	-0.358**	0.797**	1.732**	3.486**	-0.319	2.505**	11.253**	31.240**	0.040**
Selection-2	0.887**	0.982**	2.978**	0.168**	0.564**	0.293**	-5.384**	-7.852**	-0.033	1.095**	-10.537**	18.002**	0.030**
PANT-C-3	-2.227**	-2.109**	-2.224**	-0.089 *	-0.416**	-0.262**	-3.992**	3.867**	-1.141**	-2.210**	-13.624**	-56.144**	-0.010**
BC-28	-4.170**	-4.333**	-0.303	0.082 *	-0.109 *	0.329**	-8.170**	1.248**	6.115**	-4.119**	3.136 *	36.316**	0
DPL-C-4	0.616**	0.496**	2.156**	-0.256**	0.925**	-1.140**	14.770**	-0.712**	-2.785**	0.514**	-5.571**	-28.068**	0.001
Konkan kirti	-1.484**	-1.380**	-0.577**	-0.046	-0.385**	0.337**	-4.097**	5.060**	1.474**	-1.414**	9.668**	1.242	-0.030**
Jayanti	3.620**	3.610**	-1.829**	-0.270**	-0.222**	-0.354**	5.141**	-5.095**	-3.311**	3.629**	5.673**	-2.587	-0.031**
SE (gi)	0.118	0.138	0.17	0.041	0.049	0.037	0.237	0.228	0.195	0.134	1.423	1.567	0.001

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

Table 3. Promising crosses based on specific combining ability in chilli

Characters	Crosses	sca effects	*gca* effects of parents
Days to first flowering	Konkan kirti x Jayanti (RC)	-9.90	(-1.484 **, 3.620 **)
	Jwala x Konkan kirti (RC)	-9.77	(2.759**, -1.484 **)
	Selection- 2 x DPL-C-4 (RC)	-8.57	(0.887 **, 0.616 **)
	Jwala x DPL-C-4 (DC)	-7.61	(2.759**, 0.616 **)
	Selection-2 x Jayanti (DC)	-.658	(0.887 **, 3.620 **)
Days to first Picking	Jwala x Konkan kirti (RC)	-9.83	(2.734 **, -1.380 **)
	Konkan kirti x Jayanti (RC)	-9.60	(-1.380 **, 3.610 **)
	Selection- 2 x DPL-C-4 (RC)	-8.63	(0.982 **, 0.496 **)
	Jwala x DPL-C-4 (DC)	-7.65	(2.734 **, 0.496 **)
	PANT-C-3 x Jayanti (DC)	-6.52	(-2.109 **, 3.610 **)
Plant height (cm)	Selection- 2 x Jayanti (DC)	-10.78	(2.978 **, -1.829 **)
	Jwala x Selection- 2 (DC)	-4.68	(-0.201, 2.978 **)
	Selection- 2 x Jayanti (RC)	-4.57	(2.978 **, -1.829 **)
	PANT-C-3 x BC-28 (RC)	-4.40	(-2.224 **, -0.303)
	Selection- 2 x Konkan kirti (DC)	-2.94	(2.978 **, -0.577 **)
No. of branches plant^{-1}	Jwala x BC-28 (DC)	0.88	(0.411 **, 0.082 *)
	Jwala x DPL-C-4 (RC)	0.77	(0.411 **, -0.256 **)
	Jwala x Jayanti (DC)	0.76	(0.411 **, -0.270 **)
	PANT-C-3 x Konkan kirti (RC)	0.60	(-0.089 *, -0.046)
	DPL-C-4 x Jayanti (DC)	0.56	(-0.256 **, -0.270 **)
Fruit Diameter (mm)	Jwala x Jayanti (DC)	1.06	(-0.358 **, -0.222 **)
	Konkan kirti x Jayanti (RC)	1.00	(-0.385 **, -0.222 **)
	DPL-C-4 x Konkan kirti (RC)	0.89	(0.925 **, -0.385 **)
	Selection- 2 x DPL-C-4 (RC)	0.86	(0.564 **, 0.925 **)
	Selection- 2 x BC-28 (RC)	0.85	(0.564 **, -0.109 *)
Fruit length (cm)	Selection- 2 x Konkan kirti (DC)	1.71	(0.293 **, 0.337 **)
	Selection- 2 x BC-28 (RC)	1.68	(0.293 **, 0.329 **)
	Jwala x BC-28 (DC)	1.59	(0.797 **, 0.329 **)
	Jwala x Selection- 2 (RC)	1.30	(0.797 **, 0.293 **)
	Jwala x PANT-C-3 (DC)	1.22	(0.797 **, -0.262 **)
Number of seeds fruit^{-1}	DPL-C-4 x Konkan kirti (DC)	32.72	(14.770 **, -4.097 **)
	DPL-C-4 x Konkan kirti (RC)	33.60	(14.770 **, -4.097 **)
	BC-28 x Konkan kirti (DC)	27.39	(-8.170 **, -4.097 **)
	Selection- 2 x DPL-C-4 (DC)	21.87	(-5.384 **, 14.770 **)
	Jwala x Jayanti (DC)	20.25	(1.732 **, 5.141 **)
Number of fruits plant $^{-1}$ (red)	Jwala x Konkan kirti (RC)	22.90	(3.486 **, 1.474 **)
	Jwala x PANT-C-3 (DC)	18.18	(3.486 **, 3.867 **)
	PANT-C-3x DPL-C-4 (RC)	16.80	(3.867 **,-2.785 **)
	Jwala x BC-28 (RC)	14.80	(3.486 **, 1.248 **)
	BC-28 x Konkan kirti (RC)	14.80	(1.248 **, 1.474 **)
Red fruit yield plant^{-1} (g)	BC-28 x Konkan kirti (RC)	14.33	(6.115 **, 1.474 **)
	Selection- 2 x PANT-C-3 (RC)	11.45	(-0.033, -1.141 **)
	Selection- 2 x Konkan kirti (RC)	11.38	(-0.033, 1.474 **)
	PANT-C-3 x BC-28 (DC)	10.69	(6.115 **, 6.115 **)
	Jwala x Selection- 2 (DC)	10.28	(-0.319, -0.033)
Days to last Picking	Jwala x Konkan kirti (RC)	-10.07	(2.505 **, -1.414 **)
	Konkan kirti x Jayanti (RC)	-9.77	(-1.414 **, 3.629 **)
	Selection- 2 x DPL-C-4 (RC)	-8.53	(1.095 **, 0.514 **)
	Jwala x BC-28 (DC)	-7.66	(2.505 **, -4.119 **)
	PANT-C-3 x Jayanti (DC)	-6.43	(-2.210 **, 3.629 **)
Number of fruits plant^{-1} (green)	Jwala x Konkan kirti (RC)	50.12	(11.253 **,9.668 **)
	Selection- 2 x Konkan kirti (RC)	32.87	(-10.537 **9.668 **)
	Jwala x Jayanti (DC)	31.72	(11.253 **,5.673 **)
	Jwala x BC-28 (RC)	31.70	(11.253 **,3.136 *)
	Konkan kirti x Jayanti (RC)	31.37	(9.668 **,5.673 **)
Green fruit yield plant^{-1} (g)	Selection- 2 x DPL-C-4 (RC)	133.55	(18.002 **,36.316 **)
	Selection- 2 x Konkan kirti (RC)	111.93	(18.002 **1.242)
	Jwala x BC-28 (RC)	110.21	(31.240 **, 36.316 **)
	DPL-C-4 x Konkan kirti (DC)	77.84	(36.316 **1.242)
	Jwala x Jayanti (DC)	75.11	(31.240 **,-2.587)
Capsaicin content %	Jwala x BC-28 (RC)	0.057	(0.040 **, 0)
	Jwala x PANT-C-3 (DC)	0.047	(0.040 **, -0.010 **)
	DPL-C-4 x Konkan kirti (DC)	0.041	(0.001, -0.030 **)
	Selection- 2 x Jayanti (DC)	0.038	(0.030 **, -0.031 **)
	Selection- 2 x PANT-C-3 (DC)	0.026	(0.030 **, -0.010 **)