J. Hortl. Sci.
Vol. 16(2) : 199-205, 2021

Original Research Paper

Combining ability studies to develop superior hybrids in bell pepper (*Capsicum annuum* var. *grossum* L.)

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ABSTRACT

General combining ability (GCA) among parents and specific combining ability (SCA) of crosses were studied to identify horticulturally superior crosses for growth, yield and component traits in bell pepper. Experimental material included 21 F_1 hybrids developed by crossing seven parents in half diallel mating design. Parents and crosses were planted in randomized complete block design (RCBD) during *Rabi* 2019 to estimate the effects of combining ability. Among parents, Arka Mohini showed good GCA effects for most of the traits (number of secondary branches, early flowering and harvesting, fruit weight and yield) whereas among crosses, Arka Mohini × CW308, Arka Mohini× California Wonder and Yolo Wonder × California Wonder were identified as potential hybrids for yield and attributing traits based on SCA effects.

Key words : Bell pepper, half-diallel mating, general combining ability, hybrids, specific combining ability and yield

INTRODUCTION

Bell pepper (*Capsicum annuum* var. *grossum*), also known as capsicum, sweet pepper or Shimla mirch is a popular vegetable worldwide for its pleasant flavour and delicate taste. Further, it is an abundant source of ascorbic acid, vitamin A and other minerals (Sharma *et al.* 2013). It belongs to the family Solanaceae and have a diploid chromosome number 2n=24. Both green as well as coloured (red and yellow) fruits of bell pepper have gained a status of high value crop in India. The demand for bell pepper in recent years has increased with the emergence of continental food industry (Sood *et al.* 2010). It always fetches premium price in the market because of its regular demand and inadequate supply owing to average productivity. The basic reason for this is lack of superior quality indigenous varieties and hybrids with high yield and tolerance to biotic as well as abiotic stresses. Indian bell pepper seed market is dominated by imported private sector hybrids and varieties, which increases the input cost for the farmers. Hence, there is an urgent need to strengthen the crop improvement programme for developing new varieties or hybrids in this crop capable of satisfying the needs of farmers as well as consumers. For development of F_1 hybrids, selection of parents is of utmost importance. Parents are generally selected based on their combining ability. Here, combining ability refers to the ability of lines or parents to combine well during hybridization process so that desirable genes or characters get transmitted to their progenies (Fasahat *et al.* 2016). General combining ability and specific combining ability are the two main types of combining ability. The study on general combining ability of parents and specific combining ability of the crosses helps in identification of best parents and crosses respectively. Further, the combining ability of the parents also depends upon the nature of genetic system operating in them which predicts the efficiency of selection. Keeping this in view, the objective of this investigation was to work out general combining ability (GCA) among parents and specific combining ability of crosses (SCA) to identify the promising hybrids.

MATERIALS AND METHODS

The study was conducted at ICAR- Indian Institute of Horticultural Research, Hessaraghatta lake post, Bengaluru-89 during the year 2019-2020 for two seasons. During *Kharif,* 2019 hybrids were developed using seven diverse and elite capsicum genotypes *viz*., Arka Mohini, Arka Gaurav, Arka Basant, Yolo Wonder, California Wonder, UHFBP-4 and CW-308. They were crossed in half diallel fashion to obtain twenty-one cross combinations/hybrids. In *Rabi*, 2020, seedlings of 7 parents and 21 crosses were transplanted in open field in randomized block design with three replications at a spacing of 60x30 cm. The standard cultural practices were followed as per the package of practices of bell pepper by Indian Institute of Horticulture Research, 2011.Observations were recorded on number of primary branches (NPB), number of secondary branches (NSB), plant height (cm) (PH), days to 50% flowering (DF), days to first harvest (DFH), fruit length in cm (FL), fruit width in cm (FW), number of lobes per fruit (NLF), pericarp thickness in cm (PT), average fruit weight in gm (AFW) , number of fruits per plant (NFP), total yield per plant in gm (YP). Indostat software was used for statistical analysis of the data.

RESULTS AND DISCUSSION

Analysis of variance for GCA was found significant for all the traits except NPB and analysis of variance for SCA was found significant for all the traits (Table 1).With respect to GCA and SCA variance, there was predominance of SCA for all the studied traits indicating the presence of non-additive gene action which could be attributed to dominance and epistatic components like dominance x dominance and additive 'x' dominance type of interactions indicating sufficient scope for heterosis breeding. The parents and crosses were scored based on their GCA and SCA status. Significantly negative GCA and SCA was scored as "-1" and non-significant GCA and SCA was scored as "0" whereas "+1" score was given to significantly positive GCA and SCA effects. By taking these scores into consideration, parents and hybrids were classified as poor, average and good combiners (Table 2 & 3). Arka Mohini was identified as good general combiner for NSB, DF, DFH, AFW and YP. Arka Basant for PH, DFH, FL and NFP whereas, Yolo wonder for DFH and PT (Table 2).

In SCA studies, crosses based on Arka Mohini, Arka Basant and Yolo Wonder as one of the parents exhibited good combining effects. Arka Mohini x Yolo Wonder, Arka Mohini x CW308, Arka Mohini x UHFBP4, Arka Basant x California Wonder and Arka Basant x CW308, Yolo Wonder x California Wonder exhibited good SCA effects for most of the traits (Table 3). Arka Mohini based crosses showed higher yield attributed to more number of big and heavy fruits per plant. Arka Mohini x Yolo Wonder showed good SCA for traits like NPB, NSB, PT, AFW and YP; Arka Mohini x CW308 for PH, FW, NFP, AFW and YP; Arka Mohini x UHFBP4 for NSB, PT, NFP, AFW and YP whereas, Arka Basant based hybrids showed earliness along with higher yield. Arka Basant x California Wonder exhibited good SCA for PH, DF, DFH, NFP, AFW and YP; and Arka Basant x CW308 for FL, PT, NFP, AFW and YP. Yolo Wonder x California Wonder exhibited good SCA for NPB, NSB, NLF, PT, NFP, AFW and YP. The results Obtained indicates that traits like NPB, NPS, PH, DF, DFH, FW, PT, NFP, AFW and YP are governed by non-additive genes hence, highly amenable for exploitation through heterosis. Similar results were reported by Hegde (2019), Praveen *et al*. (2017) and Aditika (2018) for NPB, NSB and PH in capsicum. Kaur *et al.* (2018), Praveen *et al.* (2017) and Devi *et al.* (2018) reported non additive gene action for earliness traits in capsicum. Kamble *et al*. (2009), Hegde (2016), Praveen *et al*. (2017) and Devi *et al*. (2018) have also reported good SCA for fruit length and fruit width. Kaur *et al.* (2018), Aditika (2018) and Devi *et al*. (2018) have reported high SCA effects for pericarp thickness and average number of fruits per plant. Good SCA for average fruit weight and yield has been reported by Galal *et al.* (2018) and Aditika (2018) supporting the present investigation. Based on the general combining ability of parents and specific combining ability of crosses, only three crosses showing good SCA coupled with good or, average GCA of the parents involved in it *viz*., Arka Mohini x CW308, Arka Mohini x Yolo Wonder and Yolo Wonder x California Wonder with GG and GA interactions (table 3) are identified for future considerations. Further studies on the heterosis of the traits in the developed crosses will be useful in identifying the best heterotic combinations among them.

Table 1. ANOVA for combining ability

	df	NPB	NSB	PH	DF	DFH	FL	FW	NLF	PT	NFP	AFW	YP
GCA	6	0.05	0.24*	50.19*	47.62*	71.10*	1.12*	0.15*	0.08*	0.003*	1.12*	159.13*	9763.45 *
SCA	21	0.05*	0.24 *	18.01 *	27.90 *	32.65 *	1.81*	0.07*	0.05*	0.007*	1.39*	133.86*	34156.48*
Error	54	0.03	0.06	5.03	8.16	6.13	0.29	0.04	0.03	0.001	0.06	2.92	43.88

*: Significance at p= 0.05; GCA: General combining ability, SCA: Specific combining ability, NPB: No. of primary branches, NSB: No. of secondary branches, PH: Plant height, DF: Days to 50% flowering, DFH: Days to first harvest, FL: Fruit length, FW: Fruit width, NLF: No. of lobes per fruit, PT: pericarp thickness, AFP: Average fruit per plant, AFW: Average fruit weight, YP: Yield per plant

Table 2. Overall general combining ability (GCA) of parents for different traits

Sl. No.	Parents	NPB	NSB	PH	DF	DFH	FL	FW	NLF	PT	NFP	AFW	YP	Total		GCA
														+ve	-ve	
1.	Arka Mohini	0	+1	-1	+1	+1	0	0	0	0	0	+1	+1	5	1	Good
2.	Arka Gaurav	0	0	0	-1	0	0	0	+1	0	-1	-1	-1	1	4	Poor
3.	Arka Basant	0	0	+1	0	+1	+1	-1	-1	0	+1	-1	-1	4	4	Average
4.	Yolo Wonder	0	0	0	0	+1	0	0	0	+1	0	+1	0	3	0	Good
5.	California Wonder	0	0	+1	0	0	-1	0	0	-1	0	0	+1	2	2	Average
6.	UHFBP-4	0	0	0	0	0	0	0	0	0	-1	-1	-1	0	3	Poor
7.	CW308	0	0	0	-1	0	0	+1	0	+1	0	0	0	2	1	Good

NPB: No. of primary branches, NSB: No. of secondary branches, PH: Plant height, DF: Days to 50% flowering, DFH: Days to first harvest, FL: Fruit length, FW: Fruit width, NLF: No. of lobes per fruit, PT: pericarp thickness, NFP: Number of fruits per plant, AFW: Average fruit weight, YP: Yield per plant

Table 3. Overall specific combining ability (SCA) of crosses for different traits

S.No.	Crosses	NPB	NSB	PH	DF	DFH	FL	FW	NLF	PT	NFP	AFW	YP	Total		SCA effects	
														+ve	-ve	Crosses	Parents
1.	AM x AG	0	0	0	-1	-1	0	0	0	+1	0	0	-1	1	3	P	G x P
2.	AM x AB	0	0	-1	+1	0	0	0	0	-1	+1	+1	+1	4	2	A	G x P
3.	AM x YW	+1	+1	0	-1	-1	0	0	0	+1	0	+1	+1	5	2	G	G x G
4.	AM x CW	0	-1	0	0	0	0	0	0	0	-1	-1	-1	0	4	P	G x A
5.	AM x UHF BP4	0	+1	-1	0	-1	0	0	0	+1	+1	+1	+1	5	2	G	G x P
6.	AM x CW308	0	0	+1	-1	-1	0	+1	0	-1	+1	+1	+1	5	3	G	G x G
7.	AG x AB	0	0	+1	0	0	0	+1	0	+1	0	-1	-1	3	2	A	P x P
8.	AG x YW	0	0	0	0	-1	0	0	+1	-1	0	+1	-1	2	3	P	P x G
9.	AG x CW	0	+1	0	0	0	0	0	0	+1	0	+1	+1	4	0	A	P x A
10.	AG x UHFBP4	0	-1	0	0	0	0	0	+1	-1	0	+1	+1	3	2	A	P x P
11.	AG x CW308	0	0	0	0	0	0	0	0	+1	0	-1	+1	2	1	A	P x G
12.	AB x YW	0	0	0	0	0	0	0	0	+1	-1	-1	-1	1	3	P	P x G
13.	AB x CW	0	0	+1	+1	+1	+1	0	0	-1	+1	+1	+1	7	1	G	P x A
14.	AB x UHFBP4	0	0	0	-1	0	0	0	+1	-1	0	+1	-1	2	3	P	P x P
15.	AB x CW308	0	0	0	-1	-1	+1	0	0	+1	+1	+1	+1	5	2	G	P x G
16.	YW x CW	+1	+1	0	0	0	0	0	+1	+1	+1	+1	+1	7	0	G	G x A
17.	YW x UHFBP4	0	0	0	0	0	+1	0	0	+1	0	-1	+1	3	1	A	G x P
18.	YW x UHFCW308	0	0	0	0	0	-1	0	0	0	0	+1	-1	1	2	P	G x G
19.	CW x UHFBP4	0	+1	+1	-1	-1	-1	0	0	0	0	+1	+1	4	3	A	A x P
20.	CW x CW308	0	0	-1	0	0	0	0	0	0	0	+1	+1	2	1	A	A x G
21.	UHFBP4 x CW308	0	0	0	0	0	+1	0	0	+1	0	-1	-1	2	2	A	P x G

NPB: No. of primary branches, NSB: No. of secondary branches, PH: Plant height, DF: Days to 50% flowering, DFH: Days to first harvest, FL: Fruit length, FW: Fruit width, NLF: No. of lobes per fruit, PT: pericarp thickness, NFP: Number of fruits per plant, AFW: Average fruit weight, YP: Yield per plant, AM: Arka Mohini, AG: Arka Gaurav, AB: Arka Basant, YW: Yolo Wonder, CW: California Wonder

Supplementary Table 1 : General combining ability effects (GCA) of parents growth and yield parameters

Sl.No.	Parents	NPB	NSB	PH	DF	DFH	FL	FW	NLF	PT	NFP	AFW	YP
1.	Arka Mohini	0.09	0.28*	-4.72*	3.55*	2.89*	-0.25	0.05	-0.003	-0.01	0.08	8.19 *	47.37*
2.	Arka Gaurav	0.02	-0.12	0.08	-2.49*	-3.88	-0.08	0.10	0.14 *	0.01	-0.58 *	-1.86 *	-35.07*
3.	Arka Basant	-0.02	-0.007	1.87*	2.14	3.45*	0.50 *	-0.18 *	-0.14*	0.01	0.60 *	-3.78 *	-39.91*
4.	Yolo Wonder	-0.04	0.07	-1.28	-1.12	2.11*	0.27	-0.02	-0.06	0.02 *	0.002	2.38 *	3.33
5.	California Wonder	-0.09	-0.15	1.93*	0.21	-1.95	-0.57 *	-0.03	0.06	-0.03 **	0.05	-0.97	35.80*
6.	UHFBP-4	0.10	0.08	1.08	0.36	-0.92	-0.05	-0.13	0.04	-0.01	-0.19 *	-3.81 *	-12.19*
7.	CW308	-0.06	-0.17	1.03	-2.64*	-1.69	0.17	0.20 *	-0.03	0.02*	0.04	-0.15	0.67
SEm±		0.05	0.07	0.69	0.88	0.76	0.05	0.06	0.05	0.001	0.073	0.53	2.04
CD at 5%		0.12	0.19	1.69	2.16	1.87	0.41	0.14	0.12	0.01	0.18	1.29	5.00

*: Significance at p= 0.05; NPB: No. of primary branches, NSB: No. of secondary branches, PH: Plant height, DF: Days to 50% flowering, DFH: Days to first harvest, FL: Fruit length, FW: Fruit width, NLF: No. of lobes per fruit, PT: pericarp thickness, AFP: Average fruit per plant, AFW: Average fruit weight, YP: Yield per plant

Supplementary Table2 : Specific combining ability effects (SCA) for crosses

Sl.No.	Crosses	NPB	NSB	PH	DF	DFH	FL	FW	NLF	PT	NFP	AFW	YP
1.	AM×AG	-0.12	0.28	-2.48	-6.23*	-4.71*	0.41	0.11	0.03	0.10*	-0.13	0.43	-47.83*
2.	AM×AB	0.19	0.34	-5.23*	7.14*	0.95	-0.36	0.08	0.05	-0.03*	1.06*	9.75*	223.50*
3.	AM×YW	0.38*	0.49*	-1.08	-7.27 *	-5.05*	-0.10	0.07	0.004	0.06*	0.53	5.89*	115.16*
4.	AM×CW	-0.23	-0.55*	-2.29	3.07	2.36	0.28	-0.02	-0.08	-0.02	-1.18*	-4.46*	-202.04*
5.	AM×UHFBP4	0.24	0.76*	-4.20*	-3.08	-4.01*	0.23	0.13	0.17	0.06*	1.33*	7.79*	150.59*
6.	AM×CW308	0.13	-0.22	9.61*	-5.08*	-6.57*	0.18	0.41*	0.004	-0.05*	1.16*	8.72*	202.99*
7.	AG×AB	0.07	-0.09	5.86*	-3.15	-3.27	-0.14	0.41*	0.007	0.07*	-0.11	-11.32*	-159.49*
8.	AG×YW	0.18	-0.38	-3.16	-1.57	-5.27*	0.44	-0.049	0.36*	-0.06*	0.12	5.72*	-30.76*
9.	AG×CW	-0.03	0.72*	3.56	3.10	-1.86	-0.16	-0.02	0.007	0.13*	0.44	0.94*	117.23*
10.	AG×UHFBP4	0.04	-0.51*	1.51	-3.04	-1.89	0.08	0.08	0.32*	-0.03*	0.52	16.84*	182.83*
11.	AG×CW308	0.16	0.30	0.83	3.29	3.55	-0.23	0.18	-0.11	0.07*	0.76	-8.12*	85.39*
12.	AB×YW	0.23	0.39	3.29	-2.53	-3.93	-0.96	0.03	-0.22	0.07*	-0.96*	-8.23*	-107.83*
13.	AB×CW	0.19	-0.12	3.64*	7.81*	8.14*	1.91*	0.10	-0.07	-0.10*	1.29*	2.02*	135.08*
14.	AB×UHFBP4	-0.05	-0.15	-1.31	8.99*	3.77	-0.73	-0.11	0.31*	-0.14*	-0.46	3.52*	-59.20*
15.	AB×CW308	-0.19	-0.32	-1.06	-4.68*	-8.45*	3.08*	0.09	-0.06	0.09*	2.31*	21.28*	286.86*
16.	YW×CW	0.36*	0.50*	0.062	-3.60	-0.86	-0.30	0.33	0.28*	0.06*	1.93*	14.99*	211.16*
17.	YW×UHFBP4	-0.16	0.07	0.78	2.92	2.77	3.36*	0.24	0.13	0.09*	-0.56	-13.91*	133.23*
18.	YW×CW308	-0.24	-0.24	1.69	1.92	-3.79	-1.14*	0.12	-0.07	0.002	-0.22	7.60*	-42.61*
19.	CW×UHFBP4	-0.006	0.73*	7.90*	-4.75*	-4.82*	-0.74*	0.02	-0.16	0.01	0.63	12.22*	137.06*
20.	CW×CW308	0.02	0.32	-4.98*	-1.08	-1.38	0.13	0.02	0.18	-0.02	-0.63	3.93*	34.75*
21.	UHFBP4×CW308	0.087	-0.38	-1.26	-1.23	-2.75	1.14*	0.10	0.13	0.08*	-0.53	-9.21*	-78.02*
	SEm±	**0.12**	**0.19**	**1.71**	**2.18**	**1.89**	**0.41**	**0.14**	**0.12**	**0.01**	**0.41**	**0.14**	**0.12**
	CD at 5%	**0.26**	**0.40**	**3.57**	**4.55**	**3.94**	**0.86**	**0.29**	**0.25**	**0.03**	**0.86**	**0.29**	**0.25**

*: Significance at p= 0.05; NPB: No. of primary branches, NSB: No. of secondary branches, PH: Plant height, DF: Days to 50% flowering, DFH: Days to first harvest, FL: Fruit length, FW: Fruit width, NLF: No. of lobes per fruit, PT: pericarp thickness, AFP: Average fruit per plant, AFW: Average fruit weight, YP: Yield per plant; AM: Arka Mohini, AG: Arka Gourav, AB: Arka Basant, YW: Yolo Wonder, CW: California Wonder

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(Received on 26.08.2021, Revised on 26.11.2021 and Accepted on 30.11.2021)