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Diallel analysis for yield and yield attributing traits in capsicum (*Capsicum annuum* L. var *grossum* Sendt)

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Abstract : The present investigation was carried out to study heterosis and combining ability for yield and its yield attributing traits in capsicum. The experimental material consisted of twelve parents and 66 F_1S produced in diallel mating design excluding reciprocals. Analysis of variance for combining ability exhibited the significance for *gca* and *sca* effects of all the characters studied. The remarkable heterosis for yield and its yield attributing traits was also observed. The high performing crosses for all the characters studied showed that in general these crosses involved high x high, low x low, high x low and low x high general combiners. The low x low crosses giving high *sca* value may be due to genetic diversity of the parents and non allelic interactions. On the basis of heterosis and *sca* effects, Feroj x SP-6, DARL-70 x DARL-71, Capsicum Violet x California Wonder SP-6 x Dark Green and Feroj x DARL-71 were identified as promising hybrids.

Key words: Capsicum, combining ability, heterosis, diallel analysis

Introduction

Sweet pepper (*Capsicum annuum* L var. *grossum* Sendt) is an annual herbaceous vegetable crop with specific identity, also known as bell pepper, shimla mirch, green pepper and capsicum. It is considered one of the most important remunerative crops in the pockets of mid hills of Uttarakhand. The fruits are either sold in local markets or supplied to distant places as green fruits fetching a good return to the farmers. It is one of the most suitable crops for exploitation of heterosis in the form of F_1 hybrid as the hybrids are the most efficient forms to get increase in productivity in per unit area which can be achieved by utilizing hybrid vigor. Today hybrids are gaining popularity due to their high productivity, better quality, and adaptation to environmental conditions. Information on combining ability facilitates the choice of suitable parents for hybridization program to develop F_1 hybrids. Hence the diallel cross gives a fairly good idea of both general and specific combining abilities of parents and hybrid combinations respectively. The presence of heterosis for yield and yield attributing traits in capsicum has also been reported earlier by several workers. (Sood and Kaul 2006, Sood *et al.,* 2007 and Jagdeesha and Wali 2005). The development of F_1 hybrids and identification of superior genotypes becomes imperative for promoting its production, productivity and quality of the produce. The study reported here was designed to gather information on the genetics of the characters studied and on the extent of heterosis and combining ability for yield and its yield attributing traits in capsicum.

Materials and Methods

Twelve parents *viz.* Feroj, SP-24, DARL-70, DARL-71, EC-579997, SP-701, SP-19, SP-6, SP-7, Dark Green, Capsicum Violet and California Wonder were selected for diallel cross mating to generate 66 F_1 hybrids. The twelve parents and the 66 F_1S were evaluated in randomized block design with three replications at Defence Institute of Bio Energy Research (DRDO), Pithoragarh, situated in western Himalayas, extends from 29^0 29' N to 30^0 49' N latitude and 85^0 05 E' to 81^0 31' E longitude. The temperatures of the valley range from a maximum of 35^0C in summer to a low of -2^0C during winters. The nursery was sown on 22^{nd} February, 2011 and transplanted in the field on 13^{th} April, 2011. Eighteen plants in each treatment were transplanted at row and plant spacing of 60 cm. Net plot size was 6.48 m^2. Besides the application of farmyard manure @ 3 tonnes per hectare, basal dose of chemical fertilizers were applied as per recommended package of practices (50 kg each of NPK per hectare). The observations on five randomly selected plants in each treatment under each

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replication were recorded for fruit length (cm), fruit width (cm), fruit weight (g), number of fruits per plant, fruit yield per plant (kg), fruit yield per plot (kg), ascorbic acid (mg/100g) and total chlorophyll (mg/kg). The chemical analyses of fresh fruits included determination of ascorbic acid by 2, 6 di chlorophenol indophenol titration methods (AOAC, 1970) and total chlorophyll as described by Rangana (1976). Heterosis was expressed as percent deviation of the F_1 from mid parent (relative heterosis). The procedure outlined by Griffing, 1956 method 2, model 1 was used to estimate the combining ability.

Result and Discussion

Analysis of variance for combining ability, estimates of general combining ability of parents in diallel fashion and top five hybrids selected separately on the basis of heterosis and *sca* effects were presented in Table 1, 2 and 3 respectively. Combining ability analysis revealed that variance due to general combining ability was significant for all the characters studied. The higher magnitude of *gca* variances compared to *sca* variances was higher inducing the predominance of additive type of gene action in the expression of all the characters under study. These findings are in agreement with the findings of Srivastava *et al.,* (2004). The significance of variance due to *gca* and *sca* for the characters studied indicated the role of both additive and non additive gene action. These reflect much scope of improvement in yield through heterosis breeding and recurrent selection (Table 1). The ratio σ2A/ σ2D was less than one for fruit width and ascorbic acid content showing preponderance of non additive gene effect for these characters, whereas all other characters showed preponderance of additive gene action. Similar observations have also been made earlier by Khereba *et al.*, (1995).

Magnitude of *gca* effects for parents were presented in Table 2. The estimation of *gca* effects showed that, parents SP-19 was good general combiner for fruit length and ascorbic acid content, DARL-71 for fruit width and fruit weight, SP-6 for number of fruits per plant, fruit yield per plant and fruit yield per plot and California Wonder for Total Chlorophyll. The information regarding *gca* effect of the parent is of prime importance as it helps in successful prediction of genetic potentiality of the crosses. Intermating the population involving all the possible with high *gca* and simultaneously subjecting them to mass selection or biparental mating in early generation would offer maximum scope for multiparental recombinations which could generate high yielding promising lines (Patil *et al.* 2010).

Table 1. Analysis of variance for combining ability

Source	DF	Fruit length (cm)	Fruit width (cm)	Fruit weight (g)	No. of fruits /plant	Fruit yield/plant (kg)	Fruit yield/plot (kg)	Total chlorophyll (mg/100g)	Ascorbic acid (mg/100g)
GCA	11	3.916**	27.15**	1548.32**	124.32**	0.1878**	59.07**	462.07**	2844.57**
SCA	66	1.342**	27.35**	159.07**	73.07**	0.1598**	29.21**	288.70**	1693.05**
Error	154	.0409	.3249	17.34	2.33	.0084	1.243	0.1546	9.134
σ2A/σ2D		4.03	0.941	7.82	3.84	9.85	9.82	2.61	0.274

*, ** Significant at 5 and 1% level.

Table 2. Estimates of General Combining Ability of Parents in Diallel Fashion

Parents	Fruit length (cm)	Fruit width (cm)	Fruit weight (g)	No. of fruits /plant	Fruit yield/plant (kg)	Fruit yield/plot (kg)	Total chlorophyll (mg/100g)	Ascorbic acid (mg/100g)
1. Feroj	0.10**	0.14**	-0.05	-0.89	-0.01**	-1.59**	6.85**	0.72**
2. SP-24	0.29**	2.38**	18.66**	-0.79	0.16**	-0.59**	1.29**	2.40**
3. DARL-70	0.36**	0.91**	-0.70	-5.65**	-0.14**	-1.29**	-7.26**	-4.69**
4. DARL-71	0.18**	2.38**	18.35**	-4.84**	-0.04**	--2.68**	-2.46**	3.30**
5. EC-579997	-0.06**	-2.00**	-11.65	3.28**	-0.05**	-0.86**	-3.78**	12.17**
6. SP-701	0.43**	-0.14**	-0.33	1.90**	0.05**	-0.64**	-0.97**	6.63**
7. SP-19	0.84**	-0.50**	-0.58	2.61**	0.09**	-1.15**	-1.10**	24.03**
8. SP-6	0.66**	0.98**	7.99**	3.25**	0.23**	4.89**	-2.24**	7.63**
9. SP-7	-0.16**	-1.30**	-8.31**	0.30	-0.08**	-0.02	1.94**	6.80**
10. Dark Green	-0.38**	-0.91**	-5.22**	2.61**	0.03**	2.37**	-2.54**	-11.87**
11.Capsicum Violet	-1.13**	-0.82**	-14.98**	-0.32	-0.14**	-0.09**	-4.12**	-29.52**
12. California Wonder	-0.22**	-0.85**	-3.19**	-1.46**	-0.09**	1.65**	14.40**	-17.60**
SE (gi)	.0026	0.212	1.135	0.1529	.00010	.0814	.0101	0.5980

*, ** Significant at 5 and 1% level.

With regard to specific combining ability *sca* effects (Table 3), the cross Feroj x SP-6 was found superior cross combination for fruit yield per plant and fruit yield per plot showing *sca* effects 0.97 and 11.36 respectively. 14 crosses out of 66 crosses exhibited significant *sca* effects for yield per plant, indicating the presence of dominance and epistatic (non additive) type of gene action. Similar results were reported by Jankiram and Sirohi (1991).

The top five crosses selected separately on the basis of high *sca* effects and heterosis over mid parent for various characters are presented in Table 3. Significant and high relative heterosis was revealed in ascorbic acid (208.02%) followed by total chlorophyll (133.61%), fruit yield per plant(113.65%), fruit weight (77.70%), fruit yield per plot (51.12%), number of fruits per plant (50.41%), fruit length (39.44%) and fruit width (25.93%). For the character fruit yield/plant, cross Feroj x SP 6 showed maximum heterosis (113.65) followed by Feroj x California Wonder (43.38). The heterosis response observed in most of the hybrids further supported the predominant role of non additive

Table 3. Crosses selected on the basis of Heterosis and combining ability effects

Crosses with high heterosis	Crosses with high *sca* effects	*gca* effects of parents
Fruit length		
Capsicum Violet x California Wonder (39.44**)	Capsicum Violet x California Wonder (Value) (2.57**)	(-1.13**,-0.22**)
Dark Green x Capsicum Violet (28.74**)	Dark Green x Capsicum Violet (2.53**)	(-0.38**, -1.13**)
SP 19 x Capsicum Violet (23.87**)	Feroj x SP19 (2.13**)	(0.10**, 0.84**)
Feroj x SP6 (20.80**)	SP 6 x Dark Green (1.94**)	(0.66**, -0.38**)
SP 19 x Dark Green (20.63**)	SP 19 x Capsicum Violet (1.78**)	(0.84**,-1.13**)
Fruit width		
Capsicum Violet x California Wonder (25.93**)	Capsicum Violet x California Wonder (4.93**)	(-0.82**,-0.85**)
SP 24 x SP 701(24.24**)	DARL 70 x EC 579997(4.61**)	(0.91**, -2.00**)
DARL 70 x EC 579997(23.50**)	SP 24 x SP 701(4.69**)	(2.38**, -0.14**)
Dark Green x Capsicum Violet(17.72**) Feroj x SP	Feroj x SP 6(3.42**)	(0.14**, 0.98**)
6(15.03**)	Dark Green x Capsicum Violet(2.66**)	(-0.91**, -0.82**)
Fruit weight		
Capsicum Violet x California Wonder (77.78**)	Capsicum Violet x California Wonder (38.96**)	(-14.98**,-3.19**)
Dark Green x Capsicum Violet (54.55**)	SP 24 x DARL 70 (39.49**)	(18.66**,-0.70)
SP 24 x DARL 70(47.37**)	Feroj x SP 6 (29.51**)	(-0.05, 7.99**)
Feroj x SP 6(36.47**)	DARL 70 x SP 701(19.44**)	(-0.70,-0.33)
EC 579997 x SP 701(23.64**)	Dark Green x Capsicum Violet (17.66**)	(-5.22**, -14.98**)
Fruit no./plant		
Feroj x SP 6(50.41**)	EC 579997 x SP 701(45.33**)	(3.28**,1.90**)
SP 6 x SP 7(47.71**)	SP 6 x SP 7(41.33**)	(3.25**, 0.30)
DARL 70 x DARL 71(36.08**)	Dark Green x Capsicum Violet(36.00**)	(2.61**, -0.32)
EC 579997 x SP 701(25.93**)	SP 19 x SP 7(12.67**)	(2.61**, 0.30)
Feroj x DARL 71(25.00**)	Dark Green x California Wonder(34.33**)	(2.61**, -1.46**)
Fruit yield/plant		
Feroj x SP 6(113.65**)	Feroj x SP 6(0.97**)	(-0.01**, 0.23**)
SP 6 x Dark Green(43.38**)	Capsicum Violet x California Wonder(0.70**)	(-0.14**, -0.09**)
SP 19 x Capsicum Violet(41.82**)	SP 6 x Dark Green(0.63**)	(0.23**, 0.03**)
Feroj x SP 24 (39.47**)	SP 19 x Capsicum Violet(0.63**)	(0.09**, -0.14**)
SP 701 x SP 6(33.42**)	Dark Green x Capsicum Violet(0.61**)	(0.03**, -0.14**)
Fruit yield/plot		
Feroj x SP 6(51.12**)	EC 579997 x SP 701(11.36**)	(-0.86**, -0.64**)
Feroj x SP 24(37.51**)	Feroj x SP 24(9.79**)	(-1.59**, -0.59**)
SP 6 x Dark Green(34.96**)	Dark Green x California Wonder (9.78**)	(2.37**, 1.65**)
EC 579997 x SP 6(30.78**)	Capsicum Violet x California Wonder (8.84**)	(-0.09**,1.65**)
Capsicum Violet x California Wonder(24.26**)	EC 579997 x SP 6(8.80**)	(-0.86**, 4.89**)
Total chlorophyll		
DARL 70 x DARL 71(133.61**)	SP 24 x SP 7(40.71**)	(1.29**, 1.94**)
SP 701 x SP19(97.32**)	DARL 70 x DARL 71(41.65**)	(-7.26**, -2.46**)
SP 24 x SP 7(43.24**)	SP 701 x SP19(28.10**)	(-0.97**, -1.10**)
SP 701 x SP 7(30.37**)	SP 701 x SP 7(23.91**)	(-0.97**, 1.94**)
SP 701 x SP 6(27.02**)	Feroj x DARL 71(21.70**)_	(6.85**, -2.46**)
Ascorbic acid		
Feroj x DARL 71(208.02**)	SP 6 x SP 7(134.64**)	(7.63**,6.80**)
SP 6 x SP 7(147.68**)	EC 579997 x SP 19(126.30**)	(12.17**, 24.03**)
EC 579997 x SP 19(123.88**)	Feroj x DARL 71(102.70**)	(0.72**, 3.30**)
Feroj x SP 701(118.30**)	SP19 x SP 7(52.89**)	(24.03**, 6.80**)
Feroj x SP 19(116.43**)	DARL 70 x DARL 71(50.88*)	(-4.69**, 3.30**)

*, ** Significant at 5 and 1% level.

component in the inheritance of the character studied. Some of these crosses were observed superior for *sca* effects and heterosis both. The cross Capsicum Violet x California Wonder exhibited maximum relative heterosis (39.44, 25.93, 77.78) with high *sca* effect (2.57, 4.39, 38.96) for the character fruit length, fruit width and fruit weight respectively. The cross DARL 70 X DARL 71 was found best specific combiner (40.71) along with high heterosis over mid parent value (40.71%) for chlorophyll content. For ascorbic acid content, the cross combination Feroj x DARL 71 exhibited maximum heterosis percentage (208.02) with *sca* effect (102.70). The crosses having significant high *sca* effects having high x high, low x low, high x low and low x high *gca* status indicating that these characters having interaction between both additive and non additive type of non allelic which are non fixable. The crosses involving both the parents as poor combiners showing high *sca* must be due to intra-inter allelic interactions and these crosses can be used for commercial exploitation of hybrid vigour as the non additive genes seem to play a greater role.

The parents Capsicum Violet, California Wonder, Feroj, DARL-70 and DARL-71 may be used in the hybridization program for exploitation of heterosis based on specific combining ability and relative heterosis. The five crosses viz Feroj x SP-6, DARL-70 x DARL-71, Capsicum Violet x California Wonder SP-6 x Dark Green and Feroj x DARL-71 may be further evaluated for yield and other economic traits for performance under different agro climatic conditions for commercial exploitation of hybrid vigor. On the basis of above findings it can be concluded that improvement in capsicum for yield and its yield attributing traits may be brought out through recurrent selection and hybridization.

सारांश

मिर्च में संकर क्षमता एवं उत्पादन में अपनी उपज अभिलक्षण के दृष्टिकोण के लिय यह अध्ययन किए गए थे। प्रायोगिक बारह पालक एवं उत्पन्न 66 एफ–1 रेसिप्रोकल को छोड़कर डायलेल समागम डिजाइन किया गया। विचरण का विश्लेषण करने की क्षमता के संयोजन एवं जीसीए के महत्व के प्रदर्शन के लिए और सभी का एससीए के प्रभाव के लिए उल्लेखनीय दिखाई दिया। सभी करेक्टर के क्रास अध्ययन से पता चला है कि सामान्य रूप से इन उच्च कम x कम उच्च x कम और कम x उच्च सामान्य क्रास कम्बाइनर शामिल है। कम x कम क्रास एससीए मूल्य देने के माता–पिता और गैर एसिलिक बातचीत की अनुवांशिक विविधता के कारण हो सकता है। संकर एवं एससीए प्रभाव, फिरोज एसपी–6 x डार्ल–70 x डार्ल–71 शिमला मिर्च वायलेट x कैलिफोनिर्या एसपी–6 आश्चर्य एक्स डार्क जीन और फिरोज डार्ल–71 x होनहार संकर के रूप में पहचान की गई।

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