

Combining Ability Studies for Growth and Yield Characters in Bell Pepper (*Capsicum annuum* L.)

Praveen Yadahalli, V. Srinivasa, D. Lakshamana,
 Basavaraj Hadapad

Received 12 August 2016; Accepted 16 September 2016; Published online 4 October 2016

Abstract The combining ability analysis involving 6 parents was carried out for 11 characters for yield and its related traits using complete diallel mating design including reciprocals. The variance due to GCA and SCA showed that non-additive gene action was predominant for yield and its related traits, though the additive component was also significant for some characters. Among the parents Arka Mohini, California Wonder and Yolo Wonder were good general combiners for yield and its related traits. The crosses California Wonder × Yolo Wonder and Arka Mohini × Solan Bharpur were found good specific combiners for yield and its related traits.

Keywords Bell pepper, General combining ability, Specific combining ability, Yield, Diallel.

Introduction

Bell pepper (*Capsicum annuum* L.) is popular among the vegetables, for its delicate taste and pleasant flavor. In India, sweet pepper mainly grown for its

immature fruits and it is very rich in vitamin A and C. There are very few varieties available for cultivation and these too are not widely adapted to different agro-climate conditions. This is because of lack of requisite variability in cultivated bell pepper, which has led to near genetic uniformity among the improved cultivars. This necessitates the knowledge of combining ability in the selection of parents and hybrids, which can provide superior progenies for the characters of interest. It also provides the nature of gene action involved in the expression of quantitative traits of economic importance. Diallel analysis is an efficient method for the study of combining ability to identify the desirable parents and crosses, so also the gene action. Analysis of combining ability is one of the potential tools for identifying prospective parents to develop commercial F_1 hybrids [1]. General and specific combining ability effects and variance obtained from a set of F_1 's would enable a breeder to select desirable parents and crosses for each of the quantitative traits separately [2]. Therefore, the present study was undertaken to estimate combining ability of parents and hybrids for growth and yield characters in bell pepper.

Materials and Methods

Six genetically diverse parents viz. Arka Mohini (AM), California Wonder (CW), Yolo Wonder (YW), Solan Bharpur (SB), Tarihal Local (TL) and Yelavigi Collection (YC) were crossed in complete diallel mating design including reciprocals to get 30 hybrids. The resulted 30 hybrids along with six parents and one commercial check Indra were evaluated in ran-

P. Yadahalli*, V. Srinivasa, D. Lakshamana, B. Hadapad
 Department of Vegetable Science, College of Horticulture,
 Mudigere 577132
 University of Agricultural and Horticultural Sciences,
 Shivamogga, Karnataka, India
 e-mail: paviraj59@gmail.com
 *Correspondence

Table 1. Analysis of variance for combining ability and reciprocal hybrids effects in bell pepper. *-Significant at 5% level. **-Significant at 1% level.

Source of variation	Degree of freedom	Plant height (cm)	Stem girth at 60 days (mm)	Number of primary branches	Number of secondary branches	Days to 50% flowering
GCA effects	5	75.70**	0.53**	0.06**	0.35**	186.48**
SCA effects	15	39.75**	0.49**	0.08**	0.31**	10.05**
Reciprocal effects	15	28.21**	0.98**	0.04**	0.10**	12.97**
Error	35	0.457	0.003	0.008	0.014	0.10

Table 1. Continued.

Source of variation	Degree of freedom	Number of fruits per plant	Average fruit weight (g)	Yield per plant (kg)	Yield per plot (kg)	Fruit length (cm)	Fruit width (cm)
GCA effects	5	31.60**	4280.05**	0.60**	59.66**	15.51**	2.85**
SCA effects	15	9.99**	282.03**	0.14**	14.45**	0.77**	0.41**
Reciprocal effects	15	9.10**	446.4**	0.10**	10.33**	0.56**	0.73**
Error	35	0.092	0.111	0	0.003	0.004	0.003

domized complete block design with two replications during *rabi* of 2015-16. Each entry was represented by 10 plants each on beds under naturally ventilated polyhouse with spacing of 60 cm between rows and 45 cm between plants within rows. Five competitive plants from each entry were selected at random and data recorded for various characters viz. plant height, stem girth, leaf area, number of primary and secondary branches, days to 50% flowering, number of fruits per plant, average fruit weight, fruit length, fruit width, yield per plant, yield per plot and statistical analysis were carried out by adopting Model-1, Method-2 of Griffing [1].

Results and Discussion

Analysis of variance for combining ability of 11 characters are presented in the Table 1. GCA effects, SCA effects and also reciprocal effects were highly significant for all the characters studied i.e. plant height, stem girth, number of primary and secondary branches, days to 50% flowering, number of fruits per plant, average fruit weight, fruit yield per plant, fruit yield per plot, fruit length and fruit width. This significant difference indicates the enhanced ability for general and specific combination made under this study. SCA variance was greater than GCA variance indicating the predominance of non-additive (domi-

nant) gene action for most of the yield related traits. Similar results were found by Sood and Kaul [3]. Prasath and Ponnuswami [4] and Singh et al. [5].

The general combining ability and *per se* value of parents are presented in Tables 2 and 3 respectively. Among the parents Arka Mohini, California Wonder and Yolo Wonder exhibited the significant positive GCA effect in desirable direction for most of yield and yield related traits. The parent, California Wonder was good general combiner for yield per plant (0.29), days to 50% flowering (-4.44) and fruit width (0.57). Parent Yolo Wonder was best general combiner for average fruit weight (19.26). For number of primary branches Tarihah Local showed high significant GCA effect (0.08) and also for plant height (3.13). Whereas, Solan Bharpur showed highest significant GCA effect for stem girth (0.20), number of secondary branches (0.19) and number of fruits per plant (2.06). California Wonder was best general combiner among all parents for most of yield traits because this parent has highest yield per plant (1.20 kg), fruit width (7.80 cm), days to 50% flowering (49.90 days), stem girth (8.75 mm) and has better fruit weight (85.10 g) (Table 3). The GCA to SCA ratio is more than unity for average fruit weight and fruit length expressed the role of additive gene action and remaining yield traits showed less than unity for GCA to SCA ratio result-

Table 2. Estimation of general combining ability for different characters in diallel study of bell pepper parents. * -Significant at 5% level. ** - Significant at 1% level.

Sl. No.	Parents	Plant height (cm)	Stem girth (mm)	Number of primary branches	Number of secondary branches	Days to 50% flowering	Number of fruits per plant
1	Arka Mohini	-0.71**	0.05**	0.03	0.15**	2.72**	-1.72**
2	California wonder	1.52**	0.19**	0.04	0.05	-4.44**	-.23**
3	Yolo Wonder	-3.41**	-0.05**	-0.04	-0.10**	-3.65**	-1.98**
4	Solan Bharpur	-2.16**	0.20**	-0.12**	0.19**	-2.45**	2.06**
5	Tarihal local	3.13**	-0.01	0.08**	-0.003	4.48**	0.57**
6	Yelavigi collection	1.63**	-0.38**	0.01	-0.28**	3.34**	1.29**
7.	SEm $\pm$	0.28	0.02	0.04	0.049	0.13	0.12
	CD @ 5%	0.71	0.06	0.10	0.13	0.33	0.32
	CD @ 1%	1.11	0.09	0.15	0.20	0.52	0.50

Table 2. Continued.

Sl. No.	Parents	Average fruit weight (g)	Yield per plant (kg)	Yield per plot (kg)	Fruit length (cm)	Fruit width (cm)
1	Arka Mohini	13.37**	0.09**	0.88**	1.26**	0.47**
2	California wonder	17.86**	0.29**	2.91**	0.48**	0.57**
3	Yolo Wonder	19.26**	0.18**	1.84**	1.09**	0.201**
4	Solan Bharpur	-10.23**	-0.08**	-0.85**	-0.24**	-0.64**
5	Tarihal local	-19.93**	-0.23**	-2.29**	-1.41**	-0.20**
6	Yelavigi collection	-20.33**	-0.25**	-2.50**	-1.19**	-0.40**
	SEm $\pm$	0.14	0.004	0.02	0.03	0.02
	CD @ 5%	0.35	0.01	0.06	0.07	0.05
	CD @ 1%	0.55	0.01	0.09	0.11	0.09

ing the role of non-additive gene action. These results are in confirmation with the findings of Singh et al. [5] Payakhapaab et al. [6].

The specific combining ability of 15 direct

crosses for different traits are presented in Table 4. The hybrids California Wonder $\times$ Yolo Wonder (0.60), Arka Mohini $\times$ Solan Bharpur (0.39) and Arka Mohini $\times$ California Wonder (0.23) showed significant positive SCA effect for yield. This might be due to Califor-

Table 3. *Per se* performance of parents for different growth and yield characters.

Parents	Plant height (cm)	Stem girth (mm)	Number of primary branches	Number of secondary branches	Days to 50% flowering	Number of fruits per plant	Average fruit weight (g)	Yield per plant (kg)	Yield per plot (kg)	Fruit length (cm)	Fruit width (cm)
Arka Mohini	57.60	7.15	2.60	6.10	67.00	10.30	100.80	1.05	10.45	10.25	6.50
California wonder	61.80	8.75	2.80	6.40	49.90	13.80	85.10	1.20	11.96	7.96	7.80
Yolo Wonder	58.20	8.59	2.90	5.50	54.00	9.70	94.20	1.07	10.65	8.05	6.42
Solan Bharpur	51.10	8.72	2.90	6.90	57.60	22.90	37.20	0.85	8.47	5.64	4.47
Tarihal local	76.60	8.48	3.20	6.30	68.30	20.90	32.10	0.71	7.09	5.08	5.20
Yelavigi collection	75.10	7.90	3.30	6.10	64.60	19.00	32.00	0.62	6.23	5.35	5.14
SEm $\pm$	0.71	0.05	0.09	0.12	0.32	0.30	0.33	0.01	0.06	0.07	0.05
CD @ 5%	2.03	0.15	0.26	0.34	0.91	0.86	0.94	0.03	0.17	0.20	0.15
CD @ 1%	2.72	0.20	0.35	0.46	1.21	1.15	1.27	0.03	0.22	0.26	0.20

Table 4. Estimation of specific combining ability of fifteen direct crosses for eleven characters in bell pepper. * - Significant at 5% level, ** - Significant at 1% level.

Sl. No.	Hybrids	Plant height (cm)	Stem girth (mm)	Number of primary branches	Number of secondary branches	Days to 50% flowering	Number of fruits per plant
1	AM × CW	-3.64**	-0.47**	0.21**	0.56**	-2.81**	2.48**
2	AM × YW	1.64**	0.43**	-0.01	-0.14	3.40**	-0.92**
3	AM × SB	7.38**	0.26**	0.12*	0.42**	-1.25**	0.47*
4	AM × TL	-0.30	0.30**	0.07	-0.44**	-0.63**	0.88**
5	AM × YC	1.85**	0.63**	0.11	-0.06	0.66**	-1.19**
6	CW × YW	3.31**	0.32**	0.03	0.36**	-2.44**	3.14**
7	CW × SB	4.06**	-0.11**	0.16**	-0.38**	0.26	-2.36**
8	CW × TL	3.72**	0.14**	-0.14**	-0.54**	1.73**	-0.61**
9	CW × YC	-0.28	-0.05	-0.16**	-0.16*	5.42**	-1.43**
10	YW × SB	3.29**	0.33**	-0.06	0.07	-0.68**	-2.56**
11	YW × TL	-3.64**	-0.68**	-0.06	0.46**	0.98**	-0.31
12	YW × YC	-3.69**	-0.90**	-0.04	-0.31**	-1.63**	2.47**
13	SB × TL	-2.30**	-0.27**	-0.23**	-0.08	0.53*	-1.16**
14	SB × YC	-1.90**	-0.34**	-0.31**	-0.41**	-0.43*	2.28**
15	TL × YC	-1.89**	0.20**	0.14*	0.44**	-1.01**	-3.08**
	SEm ±	0.62	0.05	0.08	0.11	0.29	0.28
	CD @ 5%	1.32	0.10	0.18	0.23	0.62	0.59
	CD @ 1%	1.84	0.14	0.25	0.32	0.86	0.82

Table 4. Continued.

Sl. No.	Hybrids	Average fruit weight (g)	Yield per plant (kg)	Yield per plot (kg)	Fruit length (cm)	Fruit width (cm)
1	AM × CW	0.20	0.23**	-2.31**	-0.02	-0.58**
2	AM × YW	-9.50**	-0.31**	-3.06**	0.62**	-0.47**
3	AM × SB	19.74**	0.39**	3.88**	-0.03	0.85**
4	AM × TL	-18.36**	-0.20**	-2.02**	-0.93**	0.02
5	AM × YC	-5.56***	-0.07**	-0.72**	-0.48**	0.20**
6	CW × YW	24.82**	0.60**	6.09**	0.03	0.31**
7	CW × SB	-5.50**	-0.22**	-2.12**	0.81**	-0.52**
8	CW × TL	1.90**	-0.02**	-0.32**	-0.32**	-0.17**
9	CW × YC	-10.25**	-0.31**	-3.03**	-0.61**	0.10**
10	YW × SB	-11.95**	-0.26**	-2.63**	0.63**	0.11**
11	YW × TL	4.60**	0.09**	0.91**	-0.16**	0.02
12	YW × YC	-3.10**	0.08**	0.82**	-0.10*	-0.39**
13	SB × TL	-2.86**	-0.11**	-1.08**	-0.28**	-0.12**
14	SB × YC	3.49**	0.09**	0.86**	-0.34**	-0.47**
15	TL × YC	3.34**	-0.01	-0.07*	0.69**	0.43**
	SEm ±	0.30	0.01	0.05	0.06	0.05
	CD @ 5%	0.65	0.02	0.11	0.13	0.10
	CD @ 1%	0.91	0.02	0.15	0.18	0.14

nia Wonder and Arka Mohini was found to be good general combiner for yield (Table 2). The GCA to SCA ratio was less than unity for yield traits indicating the preponderance of non-additive gene action for yield (Table 5). These results are in accordance of Prasath and Ponnuswami [4] and Singh et al. [5].

With respect to plant height (7.38) and fruit width (0.85) the cross Arka Mohini × Solan Bharpur was best combiner, this might be due to non additive or dominance effect [7] (Table 4). The cross California Wonder × Yolo Wonder had recorded significant SCA effect for number of fruits per plant and average fruit

Table 5. Variance due to general combining ability and specific combining ability for different characters in bell pepper. GCA- General combining ability, SCA-Specific combining ability, DAT-Days after transplanting.

Sl. No.	Characters	GCA	SCA	GCA: SCA
1	Plant height (cm)	6.270	39.295	0.160
2	Stem girth (mm)	0.044	0.483	0.092
3	Number of primary branches	0.004	0.067	0.063
4	Number of secondary branches	0.028	0.300	0.0-94
5	Days to 50% flowering	15.532	9.951	1.561
6	Number of fruits per plant	2.626	9.899	0.265
7	Average fruit weight (g)	356.662	281.922	1.265
8	Yield per plant (kg)	0.050	0.144	0.345
9	Yield per plot (kg)	4.971	14.444	0.344
10	Fruit length (cm)	1.292	0.761	1.698
11	Fruit width (cm)	0.238	0.403	0.589

weight. Among 15 hybrids, Arka Mohini × California Wonder showed highest significant SCA effect for number of primary branches (0.21), number of secondary branches (0.56) and days to 50% flowering (-2.81) and for stem girth (0.63) Arka Mohini × Yelavigi Collection was best specific combiner. The presence of additive gene action was recorded in fruit length and days to 50% flowering because of higher GCA to SCA ratio while, remaining traits exhibited non-additive gene action since GCA to SCA ratio was less than unity (Table 5). These results are in line with the study of Prasath and Ponnuswami [4], Hasanuzzaman et al. [7] and Welegama et al. [8].

Thus the present investigation revealed that, among the parents Arka Mohini, California Wonder and Yolo Wonder were good general combiners for

yield and yield related traits. The cross California Wonder × Yolo Wonder and Arka Mohini × Solan Bharpur were good specific combiners in relation to yield characters. Thus these hybrids should be evaluated in the farmer's field on large scale to know the stability of yield characters before going for commercialization.

References

1. Griffing B (1956) Concept of general and specific combining ability in relation to diallel crossing system. Aust J Biol Sci 9 : 463—493.
2. Sprague GF, Tatum LA (1942) General versus specific combining ability in single crosses of corn. J Am Soc Agron 34 :923—932.
3. Sood S, Kaul S (2006) Combining ability in bell pepper, Veg Sci 33 : 73—75.
4. Prasath D, Ponnuswami V (2008) Heterosis and combining ability for morphological, yield and quality characters in paprika type chilli hybrids. Ind J Hort 65 : 441—445.
5. Singh P, Cheema DS, Dhaliwal MS, Garg N (2014) Heterosis and combining ability for earliness, plant growth, yield and fruit attributes in hot pepper (*Capsicum annuum* L.) involving genetic and cytoplasmic-genetic male sterile lines. Scientia Hort 168 : 175—188.
6. Payakhapaab S, Boonyakiat D, Nikornpun M (2012) Evaluation of heterosis and combining ability of yield components in chillies. J Agric Sci 4 : 154—161.
7. Hasanuzzaman M, Hakim MA, Fersdous J, Islam MM, Rahman L (2012) Combining ability and heritability analysis for yield and yield contributing characters in chilli (*Capsicum annuum*) landraces. Pl Omics J 5 : 337—344.
8. Welegama HMT, Jayarathna RGYH, Alwis LMHR, Fonseka H (2015) Estimation of combining ability, heritability and heterosis in tomato (*Solanum lycopersicum* L.) using full diallel mating design. Ann Sri Lanka Dep Agric 17 : 242—259.