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Research Article

Estimation of combining ability in bottle gourd [*Lagenaria siceraria* (Mol.) Standl.]

Mohan Singh[1], Kapil Dev Ameta[1], Ram Avtar Kaushik[1], R.B. Dubey[2], Deepak Meena[2]*, Rajesh Meena[1] and Mukesh Kumar Yadav[2]

[1]Department of Horticulture, Maharana Pratap University of Agriculture and Technology, Udaipur-313 001, Rajasthan, India
[2]Department of Genetics and Plant Breeding, Maharana Pratap University of Agriculture and Technology, Udaipur-313 001, Rajasthan, India
*E-Mail: deepakmeena152@gmail.com

Abstract
This study was conducted to estimate combing ability in bottle gourd. Fifty eight bottle gourd genotypes comprising 45 hybrids, 10 parents and 3 checks were evaluated in three different environments. The data were analyzed as per Method-II, Model-I of Griffing (1956). Significant GCA effects in desirable direction was evident in the inbred lines P_6, P_2 and SCA in hybrids P_9 x P_{10}, P_4 x P_6 for days to first harvest on pooled basis for number of branches per vine. The lines with significantly positive GCA effects for number of branches per vine were P_5, P_6 and hybrids for SCA effects were P_3 x P_8, P_3 x P_6 on pooled basis for days to first harvest. For rind thickness the lines with significantly positive GCA effects for rind thickness were P_1, P_5 and hybrids with significant SCA effects were P_8 x P_{10}, P_1 x P_9, and P_1 x P_8 on pooled basis. On pooled basis, inbred line P_9 was the best general combiner with highly significant and positive GCA effect and the hybrids with significant SCA effects in desirable direction were possessed by P_7 x P_{10} for flesh thicknes. Significantly positive GCA effects for rind thickness were noted in the inbreds, P_1, P_5 and significant SCA effects in the hybrids were noted in P_8 x P_{10} P_1 x P_9 on pooled basis for fruit diameter. Significant GCA effects, On pooled basis, in positive direction, was observed in the inbred lines P_8, P_4 and SCA effects in hybrids P_6 x P_9 in positive direction followed by the hybrid P_6 x P_8, P_7 x P_8, P_4 x P_7 and P_4 x P_{10} for yield per square meter. These genotypes could be useful in future breeding programmes for development of hybrids in bottle gourd.

Keywords: Bottle gourd, general combiner, specific combiner, yield

INTRODUCTION

Bottle gourd [*Lagenaria siceraria* (Mol.) Standl.] is one of the important cucurbit in the world as well as in India.It is also called white-flowered gourd or calabash gourd. This running or climbing vine belongs to the gourd family *i.e.,* Cucurbitaceae. The chromosome number of *Lagenaria* is 2n = 22 with normal meiosis of 11 bivalents, a median centromere and stable taxon cytology (Sharma *et al*., 1983; Beevy and Kuriachan, 1996). In India, vegetable crops alone contribute 58.73% of total horticulture production (329.86 million MT) with a production of 196.27 million MT from 10.8 million ha of land (Anonymous, 2020-21). Bottle gourd is cultivated in 187 thousand hectare area, 3165 thousand metric tonnes of production and a productivity of 16.49 MT/ha (Anonymous, 2020-21). It is a monoecious species with male and female flowers found on the same plant's leaf axils (Morimoto and Mevere *et al*., 2004 and Singh, 2008). Heterosis breeding depends mainly on the choice of superior parents for hybridization and the knowledge of combining ability and gene actions. Combining ability is an effective tool to identify the suitable parents and crosses for their effective crop improvement programme (Sprague and

Tatum, 1942). The concept of combining ability plays a pivotal role together with *per se* performance of parents, hybrids and heterotic response , which helps breeders in selecting potential parents, which combine well in producing promising hybrids for systematic breeding programme. It is also helpful to identify the nature of gene action and genetic variation in the population, which is essential to work out appropriate breeding strategy. Evaluation of parents for combining ability also permits an indication of relative magnitude of additive and non-additive variance for characters under study. Diallel cross techniques has been frequently used to estimate combining ability variance and types of gene action for several major economic traits of bottle gourd, including yield by Choudhary and Singh (1971) and Sharma *et al*.(1993). Therefore, there is an urgent need to develop F_1 hybrids with commercial heterosis, earliness, desirable fruit character as per market demand, wide adaptability and resistance. Thus, in the present study, ten inbreds were evaluated over three seasons along with their hybrids in diallele fashion (without reciprocals) to know their combining ability and gene action.

MATERIALS AND METHODS

The experimental material comprised of 10 inbred lines *viz.* DVBG-1 (P_1), VRBG-5 (P_2), VRBG-1 (P_3), DR-2017 (Long) (P_4), VRBG-2-1-1 (P_5), VRBG-34 (P_6), VRBG-27-1 (P_7), VRBG-11-1 (P_8), VRBG-59 (P_9), IC-594545 (P_{10}), 45 F_1s and 3 checks *viz*. Parag (C-1), Prince (C-2) and Mahy Warad (C-3). The 45 F_1s were obtained by crossing 10 inbred lines in a diallel mating (excluding reciprocal) design in the rainy season (July to February) of 2019-2020. The experimental material 58 genotypes were evaluated in randomized block design with three replications in three different environments during 2021 *viz.*E_1– Summer 2021 at open field of Hi-tech unit, Rajasthan College of Agriculture, Udaipur; E_2– *Kharif* 2021 at open field of Hi-tech unit, Rajasthan College of Agriculture, Udaipur and E_3– *Kharif* 2021 at KrishiVigyan Kendra, Chittorgarh.

The seeds were sown on the ridges with a spacing of 2.5 m between the rows and 0.5 m between the plants. The combining ability analysis over the environments was carried out using the method suggested by Singh (1973 and 1979), which is an extension of Griffing's method II, model I (1956) to estimate the interactions of general and specific combining ability effects with environments, besides determining the significance of general and specific combining ability variance.

RESULTS AND DISCUSSION

The pooled analysis of variance revealed that parents and hybrids and crosses x environment interaction were significant for all characteristics, The environment-wise combining ability analysis revealed significant differences in GCA and SCA variances for all of the characters studied, indicating the importance of both additive and non-additive gene effects in the genetic control of all of the characters studied. GCA/SCA showed a predominance of non-additive gene action in inheritance for most of the characters (**Table 1**)

The significant GCA effects in desirable direction was evident in the inbred lines P_6 (-1.86), P_2 (-1.66) and P_3 (-1.26) on pooled basis for days to first harvest, therefore, indicating their good general combining ability for above trait, which indicated their superiority in transmitting desirable genes for earliness. Significant GCA effects in desirable direction for earliness was also reported by Janaranjani *et al.* (2016) and Quamruzzaman *et al*. (2020) in bottle gourd. Six hybrids exhibited desirable and significant SCA effects on pooled basis and among them highest magnitude in desirable direction was evident in hybrid P_9 x P_{10} (-2.16) followed by the hybrids P_4 x P_6 (-2.13), P_3 x P_8 (-1.94), and P_3 x P_9 (-1.78) . Significant SCA for earliness was also observed by Janaranjani *et al.* (2016) and Shinde *et al*. (2016) in bottle gourd. Results revealed that the lines with significantly positive GCA effects for number of branches per vine were P_5 (0.35), P_6 (0.14) and P_1 (0.13). Significant GCA effect for this trait were also reported by Kumar *et al*. (2014), Shinde *et al*. (2016). In case of SCA effects of hybrids, the top five hybrids for number of branches per vine on the basis of positive and significant SCA effects were P_3 x P_8 (1.59),

Table 1. Combining ability mean square and EMS over the environments for different characters

S.No.	Characters	Source						Bartlet
		Env	GCA	SCA	GCA x E	SCA x E	Pooled Error	
	Degrees of freedom	[2]	[9]	[45]	[18]	[90]	[324]	[2]
1	Number of branches per vine	0.56**	1.26**	1.83**	0.32**	0.40**	0.09	2.04
2	Days to first harvest	1.18	114.31**	3.57**	4.32**	1.38**	0.50	1.78
3	Fruit diameter (cm)	0.02	47.07**	2.34**	0.02	0.02*	0.02	46.22**
4	Rind thickness (mm)	0.01	0.22**	0.33**	0.01	0.01**	0.00	30.85**
5	Flesh thickness (mm)	1.83	4733.39**	240.44**	1.84	2.31**	1.59	49.52**
6	Yield per square meter (kg)	0.15	20.98**	4.17**	0.23**	0.18**	0.10	0.90

*,** Significant at 5% and 1%, respectively (Model I)

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Table 2. GCA and SCA effects for different traits in bottle guard

S. No.	Genotype	Days to first harvest	Number of branches per vine	Rind thickness (mm)	Flesh thickness (mm)	Fruit diameter (cm)	Yield per square meter (kg)
		Pool	Pool	Pool	Pool	Pool	Pool
1	P_1	-0.68*	0.13**	0.09**	-10.60*	-1.04*	-0.10
2	P_2	-1.66*	-0.18*	0.05**	-10.05*	-1.00*	-1.00*
3	P_3	-1.26*	-0.26*	-0.13*	-9.65*	-0.99*	-1.63*
4	P_4	-0.94*	0.02	-0.04*	-11.37*	-1.14*	0.68**
5	P_5	-0.25*	0.35**	0.09**	-12.41*	-1.22*	0.07
6	P_6	-1.86*	0.14**	0.03*	9.49**	0.95**	0.11*
7	P_7	-0.44*	-0.16*	-0.01	10.49**	1.05**	0.36**
8	P_8	1.17**	-0.07	-0.13*	10.78**	1.05**	0.81**
9	P_9	2.60**	-0.12*	0.02	13.26**	1.33**	0.20**
10	P_{10}	3.32**	0.12*	0.03*	10.07**	1.01**	0.51**
11	$P_1 \times P_2$	0.74	0.54**	0.01	10.94**	1.09**	0.41*
12	$P_1 \times P_3$	0.30	0.31	-0.59**	11.41**	1.02**	0.57**
13	$P_1 \times P_4$	-0.64	0.06	-0.20**	6.34**	0.59**	1.14**
14	$P_1 \times P_5$	-0.14	-0.04	0.00	4.46**	0.45**	0.19
15	$P_1 \times P_6$	-1.77**	-0.03	0.40**	3.57**	0.44**	-1.07**
16	$P_1 \times P_7$	-0.21	0.59**	-0.31**	-5.19**	-0.58**	1.07**
17	$P_1 \times P_8$	-0.28	-1.01**	0.49**	-18.51**	-1.75**	-0.44**
18	$P_1 \times P_9$	1.57**	0.51**	0.53**	-10.77**	-0.97**	-0.03
19	$P_1 \times P_{10}$	-0.95*	0.50**	-0.24**	-8.11**	-0.86**	-0.05
20	$P_2 \times P_3$	-0.63	-0.07	0.27**	12.05**	1.26**	1.35**
21	$P_2 \times P_4$	-0.97*	0.71**	-0.15**	4.51**	0.42**	-1.58**
22	$P_2 \times P_5$	-0.27	0.25	0.04	8.94**	0.90**	0.31
23	$P_2 \times P_6$	0.13	-0.35*	-0.61**	-6.44**	-0.77**	-0.34*
24	$P_2 \times P_7$	0.19	-0.98**	0.19**	-8.13**	-0.78**	-0.77**
25	$P_2 \times P_8$	-0.53	0.85**	0.28**	-0.89	-0.03	-1.34**
26	$P_2 \times P_9$	0.28	0.63**	0.39**	-13.18**	-1.24**	-0.50**
27	$P_2 \times P_{10}$	1.05**	-0.15	-0.22**	-10.40**	-1.08**	-2.12**
28	$P_3 \times P_4$	0.30	-0.50**	-0.13**	8.01**	0.77**	-0.41*
29	$P_3 \times P_5$	0.07	-0.37*	0.19**	1.00	0.14*	0.49**
30	$P_3 \times P_6$	0.62	1.06**	-0.12**	-6.08**	-0.63**	-0.11
31	$P_3 \times P_7$	0.83*	-0.53**	0.02	-7.04**	-0.70**	-0.70**
32	$P_3 \times P_8$	-1.94**	1.74**	0.38**	-8.27**	-0.75**	-1.94**
33	$P_3 \times P_9$	-1.78**	-1.14**	-0.12**	-11.02**	-1.13**	-0.80**
34	$P_3 \times P_{10}$	-1.35**	0.35*	0.27**	-10.04**	-0.95**	-0.86**
35	$P_4 \times P_5$	-0.36	0.59**	0.30**	6.30**	0.69**	-0.10
36	$P_4 \times P_6$	-2.13**	-0.90**	0.49**	-7.67**	-0.67**	0.63**
37	$P_4 \times P_7$	0.21	0.18	-0.08*	-8.07**	-0.82**	1.56**
38	$P_4 \times P_8$	0.40	-1.07**	-0.02	-9.39**	-0.94**	-0.32
39	$P_4 \times P_9$	0.89*	-0.40*	-0.07*	0.35	0.02	0.03
40	$P_4 \times P_{10}$	3.11**	1.34**	0.25**	-9.04**	-0.85**	1.41**
41	$P_5 \times P_6$	0.62	0.49**	-0.38**	-7.00**	-0.77**	0.19
42	$P_5 \times P_7$	-0.54	1.53**	-0.27**	-4.79**	-0.53**	0.33*
43	$P_5 \times P_8$	0.57	-0.78**	-0.10**	-4.35**	-0.46**	0.39*
44	$P_5 \times P_9$	-0.41	0.77**	-0.00	-7.09**	-0.71**	0.65**

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Table 2. Continued...

S. No.	Genotype	Days to first harvest	Number of branches per vine	Rind thickness (mm)	Flesh thickness (mm)	Fruit diameter (cm)	Yield per square meter (kg)
		Pool	Pool	Pool	Pool	Pool	Pool
45	P_5 x P_{10}	0.28	0.31	-0.32**	-4.65**	-0.53**	0.10
46	P_6 x P_7	-0.69	-0.44**	0.15**	0.99	0.13	-1.23**
47	P_6 x P_8	0.41	0.45**	-0.70**	3.58**	0.22**	2.01**
48	P_6 x P_9	1.76**	-0.19	0.33**	9.60**	1.03**	2.71**
49	P_6 x P_{10}	0.78*	0.59**	0.09*	2.90**	0.31**	-0.92**
50	P_7 x P_8	-0.39	0.26	0.00	1.24	0.12	2.01**
51	P_7 x P_9	0.06	0.87**	-0.23**	8.12**	0.77**	-1.64**
52	P_7 x P_{10}	1.18**	-0.88**	0.17**	21.15**	2.15**	0.59**
53	P_8 x P_9	0.14	-0.97**	-0.56**	15.45**	1.43**	0.52**
54	P_8 x P_{10}	0.31	-0.50**	0.66**	1.16	0.25**	0.86**
55	P_9 x P_{10}	-2.16**	0.16	0.09*	-1.37*	-0.12	0.11
				Standard error			
	Gi	0.11	0.05	0.01	0.20	0.02	0.05
	Gi-Gj	0.17	0.07	0.02	0.30	0.03	0.07
	Sii	0.34	0.14	0.03	0.60	0.06	0.15
	Sij	0.38	0.16	0.04	0.67	0.07	0.17
	Sij-ik	0.56	0.23	0.05	0.98	0.10	0.24
	Sij-Skl	0.53	0.22	0.05	0.94	0.09	0.23

*,** Significant at 5% and 1%, respectively

P_3 x P_6 (1.19), P_5 x P_7 (1.16), P_4 x P_{10} (1.16) and P_7 x P_9 (0.89). Kumar *et al*. (2014) also reported significant SCA effect for branches per vine in bottle gourd. Rajaguru *et al*. (2020) reported significant GCA and SCA effect for dats to first harvest and number of branches in cucumber.

Results revealed that the lines with significantly positive GCA effects for rind thickness wereP_1 (0.09), P_5 (0.09) and P_2 (0.05) on pooled basis. Quamruzzaman *et al*. (2020) also observed the best general combiner for exocarp thickness in bottle gourd. The estimates of SCA effects for hybrids revealed that 19 hybrids expressed significant values in positive direction for rind thickness. The significant SCA effects were evident in the hybrids, P_8 x P_{10} (0.66), P_1 x P_9 (0.53), P_1 x P_8 (0.49), P_4 x P_6 (0.49) and P_1 x P_6 (0.40) on pooled basis for this trait. Quamruzzaman *et al*. (2020) also observed the best specific combiner for exocarp thickness in bottle gourd. On pooled basis, inbred line P_9 was best general combiner with highly significant and positive GCA effect 13.26 followed by P_8, P_7, P_{10} and P_6 with significant GCA effects 10.78, 10.49, 10.07 and 9.49, respectively. Significant GCA was found for flesh thickness by Janaranjani *et al.* (2016) also in bottle gourd. In case of SCA effects of 45 hybrids, 16 hybrids on pooled basis expressed significant values in positive direction for flesh thickness. The maximum significant SCA effects in desirable direction were possessed by the hybrid P_7 x P_{10} (21.15), followed by P_8 x P_9 (15.45), P_2 x P_3(12.05), P_1 x P_3 (11.41) and P_1 x P_2 (10.94) on pooled basis for flesh thickness. Significant SCA effect was found for flesh thickness by Janaranjani *et al.* (2016) in bottle gourd.The significant and positive values for GCA effects were obtained by five inbreed lines on pooled basis for fruit diameter. The highest magnitude of significant GCA effect in desirable direction was observed in inbreds, P_9 (1.33), P_7 (1.05), P_8 (1.05), P_{10} (1.01), and P_6 (0.95) on pooled basis.The significant GCA effect for fruit diameter was also reported by Shinde *et al.* (2016) while working with bottle gourd. Out of the 45 hybrids, 18 hybrids on pooled basis expressed positive and significant SCA effects for fruit diameter. The top five hybrids with highest magnitude of significant SCA effects for fruit diameter in desirable direction were P_7 x P_{10} (2.15), P_8 x P_9 (1.43), P_2 x P_3, (1.26) P_1 x P_2 (1.09) and P_6 x P_9 (1.03) on pooled basis (Table 3). Significant SCA for fruit diameter were also reported by Rani and Reddy (2017) and Patel and Mehta (2021) in bottle gourd.

Among the 10 inbred lines, seven lines showed desirable and significant GCA effects for yield per square meter on pooled basis. The highest significant GCA effects in positive direction was obtained by the inbred lines P_8

(0.81), P_4 (0.68), P_{10} (0.51), P_7 (0.36), P_9 (0.20) and P_6 (0.11).Significant GCA effect was reported by Kumar *et al*. (2014) for yield per plant in bottle gourd. In case of SCA effects of 45 hybrids, 18 hybrids divulged positive and significant SCA effects on pooled basis and among them hybrids P_6 x P_9 recorded the highest significant SCA effect 2.71 in positive direction followed by the hybrid P_6 x P_8, P_7 x P_8, P_4 x P_7 and P_4 x P_{10} with SCA effects of 2.01, 2.01, 1.56 and 1.41, respectively.

The analysis of variance revealed a high level of variability among parents and crosses for majority of the traits. The estimates to combining ability effects indicated that the line P_{10} (IC-594545) was best parent with high positive GCA effect and the hybrid P_7 x P_8 (VRBG-27-1 x VRBG-11-1) was the best hybrid with positive significant SCA effect for yield per square meter. These could be useful in future breeding programmes for development of hybrids in bottle gourd.

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