Biological Forum – An International Journal 13(2): 187-200(2021)

ISSN No. (Print): 0975-1130
ISSN No. (Online): 2249-3239

Determining Combining Ability for Fruit Yield and its Component Traits in Bottle Gourd [*Lagenaria siceraria* (Mol.) Standl.]

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(Received 02 April 2021, Accepted 08 June, 2021)
(Published by Research Trend, Website: www.researchtrend.net)

ABSTRACT: The present experiment was carried out with nine diverse parents to develop thirty-six F_1's and F_2's by using half-diallel mating design to estimate the combining ability for fruit yield and its components in bottle gourd [*Lagenaria siceraria* (Mol.) Standl.]. The analysis of variance for combining ability in F_1 and F_2 generations revealed highly significant mean square differences for general and specific combining ability for the studied traits. Parent Santosh was found good general combiner for number of fruits per plant, fruit girth, fruit yield per plant and total soluble solids in both the generations. Likewise, parent Punjab Long was found good general combiner for fruit length, fruit girth and average fruit weight in both the generations. Pusa Naveen was good general combiner for number of nodes on main vine, vine length, number of fruits per plant and fruit length in F_1 and F_2 generations. Similarly, parent JBGL-43 was good general combiner for total soluble solids in both generations. These four parents could be used in the hybridization programme to isolate superior segregants. The cross combination, Arka Bahar × Santosh and Punjab Long × Santosh were found to be most promising for fruit yield per plant on the basis of *per se* performance and sca effects in F_1 generation which could be expected to throw desirable transgressive segregants in later generations and genetic improvement in bottle gourd for fruit yield and its attributes may be expected either through heterosis breeding or population improvement by recurrent selection for sca.

Keywords: Combining ability, Half-diallel mating design, Yield, Bottle gourd

INTRODUCTION

Bottle gourd is commonly cultivated plant in tropical and subtropical areas of the world. Tropical Africa is the primary gene centre of origin (Whitaker, 1971; Chakravarty, 1982 and Heiser, 1979) which is the only species that has been used worldwide since prehistoric times. It is known for its rich genetic diversity and is cultivated widely throughout the warmer regions of the world.

The information on combining ability provides guidelines to the plant breeders in selecting the elite parents and desirable cross combinations to be used in formulation of efficient breeding programme; to know the transmitting ability of parents utilized; and to know the nature and magnitude of inheritance of various polygenic traits. It is necessary to the plant breeders for chalking out an efficient breeding methodology. The role of fixable and non-fixable gene effects in the inheritance patterns of different traits can be known from the nature and magnitude of combining ability variances and effects.

MATERIALS AND METHODS

The experiment consists of nine diverse genotypes *viz.*, Pusa Naveen, Arka Bahar, Aruna, Punjab Long, NDBG-15, Santosh, JBOGL-01-42, JBGL-43 and PBOG-88 to develop thirty-six F_1's during *Summer* 2019 and F_2's during *Kharif* 2019 at Vegetable Research Station, Junagadh Agricultural University, Junagadh. The final evaluation trial comprised of parents along with F_1's, F_2's and standard check (GABGH-1) in Randomized Block Design (RBD) with two replications during *Summer* 2020 at the Instructional Farm, College of Agriculture, Junagadh Agricultural University, Junagadh. The parents, F_1's and F_2's were grown in plot with spacing 2.0 m × 1.0 m. Each plot of parents and F_1's was consisted of a single row of 10 plants, while F_2 was consisted of three rows of 10 plants for each genotype. The recommended package of practices and necessary plant protection measures imperative to raise a good crop was timely and uniformly adopted. Observations were recorded on five competitive plants excluding border ones and was selected randomly from each single row plot of each parents and F_1's as wells as 20 competitive plants of F_2's were selected in each replication for fruit yield per plant and its components *viz.*, number of nodes on main vine, vine length (m), number of fruits per plant, fruit length (cm), fruit girth (cm), average fruit weight (g) and total soluble solids (˚Brix).

The combining ability analysis for different characters was carried out following the Method-2 and Model-I of Griffing (1956), for two separate sets (i) parents + F_1's and (ii) parents + F_2's data. Fixed effect model was used in the present study as advocated by Hayman (1960) that fixed model is appropriate if the number of parents does not exceed ten.

RESULTS AND DISCUSSION

The analysis of variance for combining ability in F_1 and F_2 generations revealed that GCA and SCA mean squares were significant for all the traits (Table 1), suggesting that both additive and non-additive gene effects were involved in the expression of the studied traits in both F_1 and F_2 generations. The GCA/SCA variance ratio was less than unity indicated the importance of non-additive gene action for all the characters under investigation. These findings were in close agreement with those reported by Adarsh *et al.* (2016), Malaviya *et al.* (2017), Rani and Reddy (2017), Mishra *et al.* (2018), Jayanth *et al.* (2019) and Hadiya *et al.* (2020) in bottle gourd.

Table 1: Analysis of variance for combining ability in F_1's and F_2's generations for different characters in bottle gourd.

Effect	Generation	d. f.	Mean square							
			Number of nodes on main vine	Vine length (m)	Number of fruits per plant	Fruit length (cm)	Fruit girth (cm)	Average fruit weight (g)	Fruit yield (kg/plant)	Total soluble solids (˚Brix)
GCA	F_1	8	61.477**	0.784**	5.188 **	22.187 **	4.310 **	38472.401 **	4.798**	0.753**
	F_2	8	38.580**	0.785**	5.249 **	20.161 **	9.305 **	43895.727 **	7.719**	0.726**
SCA	F_1	36	20.131**	0.241**	1.094 **	4.093 **	1.707 **	22185.084 **	2.933**	0.205**
	F_2	36	27.208**	0.405**	3.460 **	4.341 **	1.661 **	18432.951 **	5.559**	0.460**
Error	F_1	44	2.015	0.130	0.237	0.484	0.150	842.003	0.218	0.008
	F_2	44	1.992	0.079	0.342	0.328	0.121	615.506	0.279	0.009
σ^2gca	F_1		5.405	0.059	0.450	1.973	0.378	3420.945	0.416	0.067
	F_2		3.326	0.064	0.446	1.803	0.834	3934.565	0.676	0.065
σ^2sca	F_1		18.115	0.111	0.857	3.609	1.556	21343.080	2.715	0.196
	F_2		25.215	0.326	3.117	4.013	1.539	17817.444	5.280	0.451
σ^2gca/σ^2sca	F_1		0.298	0.532	0.524	0.546	0.242	0.160	0.153	0.343
	F_2		0.131	0.196	0.143	0.449	0.542	0.220	0.128	0.144

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

Number of nodes on main vine. The gca effects **(Table 2)** estimates ranged from -3.060 (JBGL-43) to 3.659 (Aruna) and -3.300 (JBGL-43) to (2.087) in F_1 and F_2 generations, respectively. A critical examination of the two sets of data indicated that three parents *viz.*, Pusa Naveen, Arka Bahar and Aruna showed consistently significant and positive gca effects over both the generations and appeared to be good general combiners for this character.

The magnitude of sca effects (Table 3) varied from -6.764 (Pusa Naveen x JBGL-43) to 8.441 (Arka Bahar x JBGL-43) in F_1 and -7.044 (Pusa Naveen x Arka Bahar) to 13.142 (Arka Bahar x JBGL-43) in F_2 generation. After reviewing two generations data, it was noticed that the ten cross combinations *viz.*, Pusa Naveen x Punjab Long, Pusa Naveen x PBOG-88, Arka Bahar x Santosh, Arka Bahar x JBGL-43, Aruna x Punjab Long, Aruna x NDBG-15, Punjab Long x JBOGL-01-42, NDBG-15 x JBOGL-01-42, NDBG-15 x PBOG-88 and JBOGL-01-42 x PBOG-88 exhibited significant and positive sca effects in both the generations.

Four crosses were common which reported high *per se* performance with significant and positive sca effects in F_1 generation *viz.*, Pusa Naveen x Arka Bahar (P_1 x P_2), Aruna x Punjab Long (P_3 x P_4), Aruna x NDBG-15 (P_3 x P_5) and Arka Bahar x JBGL-43 (P_2 x P_8), as well as in F_2 generation, four crosses were common *viz.*, Arka Bahar x JBGL-43 (P_2 x P_8), Arka Bahar x Santosh (P_2 x P_6), Pusa Naveen x PBOG-88 (P_1 x P_9) and Punjab Long x JBOGL-01-42 (P_4 x P_7). Among all these crosses, Arka Bahar x JBGL-43 (P_2 x P_8) was best in its performance to have high *per se* performance with significant and positive sca effects in both F_1 and F_2 generations (Table 7). This finding is in confirmation with the findings of Malaviya *et al.* (2017) in bottle gourd.

Table 2: Estimation of general combining ability (gca) effects of parents in F_1's and F_2's generations for fruit yield (kg/plant) and its component traits in bottle gourd.

Parents	Number of nodes on main vine		Vine length (m)		Number of fruits per plant		Fruit length (cm)		Fruit girth (cm)		Average fruit weight (g)		Fruit yield (kg/plant)		Total soluble solids (°Brix)	
	F_1	F_2	F_1	F_2	F_1	F_2	F_1	F_2	F_1	F_2	F_1	F_2	F_1	F_2	F_1	F_2
Pusa Naveen	0.409**	0.167*	0.585**	1.023**	0.585**	1.023**	0.576**	0.697**	-0.269*	0.324**	-20.871*	14.695*	0.242	0.942**	-0.027	-0.174**
Arka Bahar	-0.182*	-0.242**	0.048	-0.352*	0.048	-0.352*	-0.476*	-0.473**	-0.005	-0.338**	-6.197	-16.625*	0.050	-0.382*	0.001	-0.017
Aruna	0.000	-0.879**	-0.515**	-0.497**	-0.515**	-0.497**	-1.579**	-1.752**	-0.587**	-1.305**	-66.334**	-86.655**	-1.031**	-1.092**	-0.074**	0.013
Punjab Long	-0.409**	-0.242**	-0.674**	-0.842**	-0.674**	-0.842**	3.023**	2.028**	1.124**	1.238**	131.306**	90.352**	0.673**	0.104	-0.463**	-0.345**
NDBG-15	0.000	0.030	0.376**	-0.006	0.376**	-0.006	-0.617**	-1.057**	-0.310**	-0.312**	-20.129*	-49.723**	0.110	-0.583**	-0.114**	-0.138**
Santosh	0.727**	0.939**	1.276**	1.210**	1.276**	1.210**	0.446*	0.999**	0.606**	0.846**	11.915	55.477**	1.179**	1.511**	0.117**	0.062*
JBOGL-01-42	-0.773**	0.303**	-0.956**	-0.399*	-0.956**	-0.399*	0.858**	1.510**	0.428**	1.120**	45.655**	77.561**	-0.402*	0.429**	-0.195**	-0.182**
JBGL-43	0.273**	-0.152*	-0.161	-0.238	-0.161	-0.238	-1.384**	-1.460**	-0.093	-0.734**	-23.635**	-59.481**	-0.329**	-0.726**	0.387**	0.485**
PBOG-88	-0.045	0.076	0.021	0.101	0.101	0.101	-0.847**	-0.492**	-0.894**	-0.839**	-51.700**	-25.600**	-0.492**	-0.203	0.308**	0.295**
S. E. (G_i) ±	0.077	0.073	0.138	0.166	0.166	0.166	0.197	0.162	0.110	0.099	8.248	7.052	0.132	0.150	0.025	0.028
S. E. (G_i - G_j) ±	0.115	0.110	0.207	0.249	0.249	0.249	0.296	0.244	0.165	0.148	12.373	10.578	0.199	0.225	0.038	0.042

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

Table 3: Estimation of specific combining ability (sca) effects of hybrids for number of nodes on main vine and vine length (m).

Sr. No.	Crosses	Number of nodes on main vine		Vine length (m)	
		F_1	F_2	F_1	F_2
1	Pusa Naveen × Arka Bahar	5.964**	-7.044**	0.568**	-0.888**
2	Pusa Naveen × Aruna	-0.482	4.147**	0.309*	0.870**
3	Pusa Naveen × Punjab Long	1.891**	5.436**	-0.406**	0.102
4	Pusa Naveen × NDBG-15	3.027**	-5.376**	-0.013	-0.071
5	Pusa Naveen × Santosh	1.755**	-5.162**	0.657**	-0.365**
6	Pusa Naveen × JBOGL-01-42	-0.091	2.377**	-0.005	0.063**
7	Pusa Naveen × JBGL-43	-6.764**	-2.705**	-0.750**	-0.366**
8	Pusa Naveen × PBOG-88	6.782**	9.608**	0.672**	0.869**
9	Arka Bahar × Aruna	1.023	0.079	0.388**	-0.256*
10	Arka Bahar × Punjab Long	-0.355	-1.142*	-0.162	-0.140
11	Arka Bahar × NDBG-15	-6.468**	-7.579**	-0.639**	-0.677**
12	Arka Bahar × Santosh	3.559**	9.510**	0.031	0.874**
13	Arka Bahar × JBOGL-01-42	2.114**	-4.327**	-0.030	-0.514**
14	Arka Bahar × JBGL-43	8.441**	13.142**	0.860**	1.353**
15	Arka Bahar × PBOG-88	0.586	2.855**	-0.109	0.178
16	Aruna × Punjab Long	8.000**	3.608**	0.679**	-0.286*
17	Aruna × NDBG-15	6.886**	1.472**	0.667**	-0.628**
18	Aruna × Santosh	-3.786**	-0.339	0.218	0.902**
19	Aruna × JBOGL-01-42	-0.332	-6.926**	-0.164	-0.720**
20	Aruna × JBGL-43	2.895**	-0.707	-0.179	0.176
21	Aruna × PBOG-88	-2.359**	-1.844**	-0.297*	0.036
22	Punjab Long × NDBG-15	-1.091*	-1.399*	0.132	0.123
23	Punjab Long × Santosh	0.236	1.464**	0.322*	0.429**
24	Punjab Long × JBOGL-01-42	5.791**	7.553**	0.000	0.721**
25	Punjab Long × JBGL-43	-1.082	-0.454	0.455**	0.368**
26	Punjab Long × PBOG-88	-1.236*	-5.590**	-0.138	-0.927**
27	NDBG-15 × Santosh	-1.677**	-1.722**	0.025	-0.059
28	NDBG-15 × JBOGL-01-42	2.077**	5.817**	0.304*	0.644**
29	NDBG-15 × JBGL-43	1.905**	-1.640**	0.389**	0.030
30	NDBG-15 × PBOG-88	1.350*	4.548**	0.025	0.375**
31	Santosh × JBOGL-01-42	-1.595**	4.255**	0.394**	1.049**
32	Santosh × JBGL-43	3.832**	-1.527**	-0.041	-0.249*
33	Santosh × PBOG-88	1.777**	-4.513**	0.361*	-0.584**
34	JBOGL-01-42 × JBGL-43	0.686	-2.263**	0.237	-0.916**
35	JBOGL-01-42 × PBOG-88	1.032	4.326**	-0.121	0.779**
36	JBGL-43 × PBOG-88	-0.341	-1.306*	0.354*	-0.045
	S. E. (S_{ij}) ±	1.298	1.291	0.330	0.257
	S. E. (S_{ij} - S_{ik}) ±	1.914	1.903	0.486	0.379
	S. E. (S_{ij} - S_{kl}) ±	1.816	1.805	0.461	0.359

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

Vine length (m): Significant and positive gca effects (Table 2) observed in six parents in F_1 and four parents in F_2 generation. General combining ability effects varied from -0.309 (NDBG-15) to 0.389 (Aruna) in F_1 and -0.444 (NDBG-15) to 0.368 (JBOGL-01-42) in F_2. Three parents *viz.*, Pusa Naveen, Arka Bahar and Aruna registered significant and positive gca effects for F_1 generation, whereas two parents *viz.*, Pusa Naveen and JBOGL-01-42 exhibited significant and positive gca effects for F_2 generation and appeared as good general combiners for this trait.

Estimates of sca effects (Table 3) showed that 19 and 26 crosses reported significant sca effects in F_1 and F_2 generations, respectively. The corresponding ranges observed were -0.750 (Pusa Naveen x JBGL-43) to 0.860 (Arka Bahar x JBGL-43) in F_1 and -0.927 (Punjab Long x PBOG-88) to 1.353 (Arka Bahar x JBGL-43) in F_2 generation. Significant and positive sca effects was observed in cross Arka Bahar x JBGL-43 followed by Aruna x Punjab Long and Pusa Naveen x PBOG-88 in F_1, whereas in F_2, cross Arka Bahar x JBGL-43 followed by Santosh x JBOGL-01-42 and Aruna x Santosh had registered significant and positive sca effects for this trait.

Three crosses *viz.*, Pusa Naveen x Arka Bahar (P_1 x P_2), Aruna x Punjab Long (P_3 x P_4) and Arka Bahar x PBOG-88 (P_2 x P_9) in F_1 generation and three crosses *viz.*, Santosh x JBOGL-01-42 (P_6 x P_7), Pusa Naveen x Aruna (P_1 x P_3) and Arka Bahar x JBGL-43 (P_2 x P_8) in F_2 generation exhibited high *per se* performance with significant sca effects (Table 7). Similar results were reported by Kanzaria *et al.* (2012) in bottle gourd; Bhatt *et al.* (2017) and Mishra *et al.* (2020) in bitter gourd and Chandan *et al.* (2019) in ridge gourd.

Number of fruits per plant: The estimates of gca effects (Table 2) indicated that six parents showed significant gca effects in F_1 and F_2 generations. General combining ability effects ranged from -0.952 (JBOGL-01-42) to 1.276 (Santosh) in F_1 and -0.497 (Aruna) to 1.210 (Santosh) in F_2. A critical examination of the two sets of data indicated that two parents *viz.*, Pusa Naveen and Santosh showed consistently significant and positive gca effects over both the generations and were considered good general combiners.

Out of thirty-six crosses, twenty-two crosses in F_1 and thirty-two crosses in F_2 differed significantly for sca effects in both the generations (Table 4). The magnitude of sca effects varied from -1.816 (Santosh x JBOGL-01-42) to 2.311 (Arka Bahar x JBOGL-01-42) in F_1 and -2.993 (Punjab Long x NDBG-15) to 2.998 (Arka Bahar x JBGL-43) in F_2 generations, respectively. Eight cross combinations *viz.*, Pusa Naveen x JBGL-43, Pusa Naveen x PBOG-88, Arka Bahar x Santosh, Aruna x NDBG-15, Punjab Long x Santosh, Punjab Long x JBOGL-01-42, Punjab Long x JBGL-43 and NDBG-15 x PBOG-88 were good specific combiners in both F_1 and F_2 generations, as evident by their significant and postive sca effects.

Two cross combinations *viz.*, Punjab Long x Santosh (P_4 x P_6) and NDBG-15 x PBOG-88 (P_5 x P_9) observed high *per se* performance with significant sca effects in F_1 generation, whereas three crosses *viz.*, Pusa Naveen x PBOG-88 (P_1 x P_9), Aruna x Santosh (P_3 x P_6) and NDBG-15 x PBOG-88 (P_5 x P_9) reported high *per se* performance with significant sca effects in F_2 generation. The cross combination NDBG-15 x PBOG-88 (P_5 x P_9) was observed best among the top five crosses, which had consistent performance for *per se* performance and sca effects in both F_1 and F_2 generations (Table 7). The results are akin to the results of Sreevani *et al.* (2005) and Rani and Reddy (2017) in bottle gourd; Bhatt *et al.* (2017) and Alhariri *et al.* (2020) in bitter gourd and Krishnamoorthy *et al.* (2020) in ridge gourd.

Fruit length (cm): The significant and positive gca effects (Table 2) among F_1's was observed in parent Punjab Long (3.023) followed by JBOGL-01-42, Pusa Naveen and Santosh, while lowest was observed in parent Aruna (-1.579). Among F_2's, parent Punjab Long (2.028) showed maximum, significant and positive gca effects followed by JBOGL-01-42, Santosh and Pusa Naveen, while parent Aruna (-1.752) exhibited minimum, significant and negative gca effect for fruit length.

Significant and positive sca effects (Table 4) were recorded in seventeen crosses, in F_1 and eighteen and thirteen combinations possessed positive and negative sca effects in F_2, respectively. Thirteen cross combinations *viz.*, Pusa Naveen x Aruna, Pusa Naveen x Punjab Long, Pusa Naveen x NDBG-15, Pusa Naveen x JBOGL-01-42, Arka Bahar x NDBG-15, Arka Bahar x Santosh, Arka Bahar x PBOG-88, Punjab Long x NDBG-15, Punjab Long x JBOGL-01-42, NDBG-15 x Santosh, Santosh x JBOGL-01-42, Santosh x JBGL-43 and JBGL-43 x PBOG-88 were good specific combiners for fruit length in both the generations owing to significant and positive sca effects.

Two and four crosses *viz.*, Santosh x JBOGL-01-42 (P_6 x P_7) and Punjab Long x NDBG-15 (P_4 x P_5) and Santosh x JBOGL-01-42 (P_6 x P_7), Punjab Long x JBOGL-01-42 (P_4 x P_7), Arka Bahar x Santosh (P_2 x P_6) and JBOGL-01-42 x PBOG-88 (P_7 x P_9), respectively, displayed high *per se* performance with significant sca effects in both F_1 and F_2 generations. The cross combination Santosh x JBOGL-01-42 (P_6 x P_7) performed consistently in both F_1 and F_2 generations for high *per se* performance and significant sca effects (Table 7). Similar findings were observed by Kanzaria *et al.* (2012), Malaviya *et al.* (2017) and Rani and Reddy (2017) in bottle gourd; Patel and Desai (2008) in sponge gourd and Sundharaiya and Venkatesan (2007) in bitter gourd.

Fruit girth (cm): Seven and nine parents in F_1 and F_2 generations, respectively showed significant gca effects (Table 2). Punjab Long, Santosh and JBOGL-01-42 had significant and positive gca effects in both the generations; hence these parents were good general combiners for improving fruit girth. However, three parents *viz.*, Aruna, NDBG-15 and PBOG-88 recorded significant and negative gca effects in both the generations. The gca effects varied from -0.894 (PBOG-88) to 0.606 (Santosh) and -0.839 (PBOG-88) to 1.238 (Punjab Long) in F_1 and F_2, respectively.

Table 4: Estimation of specific combining ability (sca) effects of hybrids for number of fruits per plant and fruit length (cm).

Sr. No.	Crosses	Number of fruits per plant		Fruit length (cm)	
		F_1	F_2	F_1	F_2
1	Pusa Naveen × Arka Bahar	-0.130	-2.989**	-0.349	-1.870**
2	Pusa Naveen × Aruna	0.234	1.457**	1.605**	3.144**
3	Pusa Naveen × Punjab Long	-0.907 **	0.827**	1.473**	0.955**
4	Pusa Naveen × NDBG-15	0.243	-0.534*	0.982**	0.755**
5	Pusa Naveen × Santosh	1.443 **	-1.175**	-0.161	-2.317**
6	Pusa Naveen × JBOGL-01-42	-0.525 **	-0.441	1.978**	0.657**
7	Pusa Naveen × JBGL-43	0.679 **	2.348**	-0.531	1.472**
8	Pusa Naveen × PBOG-88	1.097 **	2.634**	-1.197**	-0.725**
9	Arka Bahar × Aruna	0.670 **	-1.293**	0.807**	0.200
10	Arka Bahar × Punjab Long	-0.071	-0.073	-0.435	-1.090**
11	Arka Bahar × NDBG-15	-0.021	-2.009**	1.304**	0.445*
12	Arka Bahar × Santosh	1.079 **	2.325**	2.841**	3.993**
13	Arka Bahar × JBOGL-01-42	2.311 **	-0.666**	-1.341**	-2.623**
14	Arka Bahar × JBGL-43	0.015	2.998**	-0.649*	0.468*
15	Arka Bahar × PBOG-88	0.134	2.334**	1.015**	1.465**
16	Aruna × Punjab Long	-0.507 **	-1.377**	0.659*	-1.956**
17	Aruna × NDBG-15	0.443 *	0.511*	-0.232	-0.411
18	Aruna × Santosh	0.343	2.795**	-0.575*	1.222**
19	Aruna × JBOGL-01-42	0.375 *	-0.095	0.803**	-0.899**
20	Aruna × JBGL-43	-0.321	-1.457**	0.345	-0.244
21	Aruna × PBOG-88	0.697 **	-0.295	-0.371	-0.921**
22	Punjab Long × NDBG-15	-0.598 **	-2.993**	3.326**	0.854**
23	Punjab Long × Santosh	1.802 **	2.141**	-0.167	1.037**
24	Punjab Long × JBOGL-01-42	1.284 **	2.375**	0.941**	2.571**
25	Punjab Long × JBGL-43	0.838 **	0.614**	1.033**	-0.348
26	Punjab Long × PBOG-88	0.056	-2.050**	0.437	-0.951**
27	NDBG-15 × Santosh	-0.748 **	-0.520*	0.962**	0.782**
28	NDBG-15 × JBOGL-01-42	0.184	1.239**	0.150	1.146**
29	NDBG-15 × JBGL-43	0.188	-0.698**	-1.038**	-1.783**
30	NDBG-15 × PBOG-88	1.406 **	2.814**	-0.444	-0.756**
31	Santosh × JBOGL-01-42	-1.816 **	-0.502*	4.548**	5.170**
32	Santosh × JBGL-43	-0.412 *	-1.914**	2.319**	1.045**
33	Santosh × PBOG-88	0.606 **	-2.877**	0.413	-0.753**
34	JBOGL-01-42 × JBGL-43	0.320	-0.680**	-0.482	-1.431**
35	JBOGL-01-42 × PBOG-88	0.238	1.607**	0.291	2.691**
36	JBGL-43 × PBOG-88	-0.957 **	-2.330**	2.683**	1.982**
	S. E. (S_{ij}) ±	0.445	0.535	0.636	0.524
	S. E. (S_{ij} - S_{ik}) ±	0.656	0.789	0.938	0.772
	S. E. (S_{ij} - S_{kl}) ±	0.623	0.748	0.890	0.732

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

Table 5: Estimation of specific combining ability (sca) effects of hybrids for fruit girth (cm) and average fruit weight (g).

Sr. No.	Crosses	Fruit girth (cm)		Average fruit weight (g)	
		F_1	F_2	F_1	F_2
1	Pusa Naveen × Arka Bahar	0.480 **	-1.381**	27.597*	-73.143**
2	Pusa Naveen × Aruna	1.202 **	2.136**	153.013**	203.857**
3	Pusa Naveen × Punjab Long	0.471 **	0.268	49.393**	85.799**
4	Pusa Naveen × NDBG-15	-0.765 **	0.608**	69.089**	90.575**
5	Pusa Naveen × Santosh	-0.971 **	-1.920**	-127.726**	-122.845**
6	Pusa Naveen × JBOGL-01-42	0.078	-0.829**	114.399**	32.241**
7	Pusa Naveen × JBGL-43	-0.632 **	0.740**	-20.075	93.733**
8	Pusa Naveen × PBOG-88	-0.971 **	-0.845**	-46.111**	-61.448**
9	Arka Bahar × Aruna	0.508 **	0.154	28.349*	11.927
10	Arka Bahar × Punjab Long	-0.353 *	-1.345**	4.279	-50.980**
11	Arka Bahar × NDBG-15	0.501 **	-0.790**	80.304**	-2.354
12	Arka Bahar × Santosh	0.626 **	2.232**	160.830**	196.896**
13	Arka Bahar × JBOGL-01-42	0.674 **	-0.632**	-166.130**	-129.448**
14	Arka Bahar × JBGL-43	-0.086	-0.268	-7.159	-1.546
15	Arka Bahar × PBOG-88	1.016 **	1.578**	94.045**	115.973**
16	Aruna × Punjab Long	-1.271 **	-2.053**	-5.115	-108.865**
17	Aruna × NDBG-15	-0.097	-0.768**	-39.119**	-33.155**
18	Aruna × Santosh	0.788 **	-0.171	-79.064**	59.730**
19	Aruna × JBOGL-01-42	0.306 *	-0.820**	71.407**	-60.159**
20	Aruna × JBGL-43	1.486 **	0.174	42.947**	-11.977
21	Aruna × PBOG-88	0.798 **	-0.295*	31.062**	-52.203**
22	Punjab Long × NDBG-15	1.682 **	0.539**	255.071**	110.118**
23	Punjab Long × Santosh	-1.384 **	1.966**	14.666	150.008**
24	Punjab Long × JBOGL-01-42	0.194	2.082**	85.437**	160.844**
25	Punjab Long × JBGL-43	2.110 **	-1.119**	115.897**	-6.964
26	Punjab Long × PBOG-88	1.416 **	0.496**	82.022**	-15.205
27	NDBG-15 × Santosh	2.310 **	-0.644**	163.822**	14.293
28	NDBG-15 × JBOGL-01-42	-1.062 **	0.492**	23.342*	102.809**
29	NDBG-15 × JBGL-43	-0.991 **	-1.019**	-94.727**	-94.263**
30	NDBG-15 × PBOG-88	0.390 *	1.056**	-29.033*	9.271
31	Santosh × JBOGL-01-42	1.433 **	2.404**	366.198**	358.309**
32	Santosh × JBGL-43	1.263 **	-0.057	146.808**	41.152**
33	Santosh × PBOG-88	0.125	-1.146**	-97.487**	-88.329**
34	JBOGL-01-42 × JBGL-43	-0.948 **	-1.351**	-8.202	-91.233**
35	JBOGL-01-42 × PBOG-88	1.603 **	1.214**	10.053	137.687**
36	JBGL-43 × PBOG-88	0.433 **	0.484**	127.953**	118.079**
	S. E. (S_{ij}) ±	0.354	0.319	26.537	22.688
	S. E. (S_{ij} - S_{ik}) ±	0.523	0.470	39.126	33.452
	S. E. (S_{ij} - S_{kl}) ±	0.496	0.446	37.119	31.736

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

The results on sca effects (Table 5) reported that 31 and 30 crosses differed significantly for sca effects among F_1 and F_2, respectively. Estimates of sca varied from -1.384 (Punjab Long x Santosh) to 2.310 (NDBG-15 x Santosh) and -2.053 (Aruna x Punjab Long) to 2.404 (Santosh x JBOGL-01-42) in F_1 and F_2 generations, respectively. Reviewing the data of two generations, it was noticed that nine cross combinations *viz.*, Pusa Naveen x Aruna, Arka Bahar x Santosh, Arka Bahar x PBOG-88, Punjab Long x NDBG-15, Punjbab Long x PBOG-88, NDBG-15 x PBOG-88, Santosh x JBOGL-01-42, JBOGL-01-42 x PBOG-88 and JBGL-43 x PBOG-88 recorded significant and positive sca effects in both the generations; hence, they were good specific combiners for this trait.

Four crosses *viz.*, Punjab Long x JBGL-43 ($P_4 \times P_8$), NDBG-15 × Santosh ($P_5 \times P_6$), Punjab Long × NDBG-15 ($P_4 \times P_5$) and Santosh × JBOGL-01-42 ($P_6 \times P_7$) in F_1 generation, while three crosses in F_2 generation *viz.*, Punjab Long × JBOGL-01-42 ($P_4 \times P_7$), Santosh × JBOGL-01-42 ($P_6 \times P_7$) and Arka Bahar × Santosh ($P_2 \times P_6$) exhibited high *per se* performance with significant sca effects. For high *per se* performance and significant sca effects in both F_1 and F_2 generations the consistently performed cross was Santosh × JBOGL-01-42 ($P_6 \times P_7$) (Table 7). Akin results were noticed by Malaviya *et al.* (2017) and Rani and Reddy (2017) in bottle gourd; Muthaiah *et al.* (2017) in ridge gourd and Shukla *et al.* (2014) in bitter gourd.

Average fruit weight (g): Out of nine parents studied, seven parents in F_1 and all parents in F_2 showed significant gca effects (Table 2). The range of gca effects was observed from -66.334 (Aruna) to 131.306 (Punjab Long) and -86.655 (Aruna) to 90.352 (Punjab Long) in F_1 and F_2, respectively. Two parents *viz.*, Punjab Long and JBOGL-01-42 registered significant and positive gca effects over both the generations, suggesting that both were good general combiners for average fruit weight.

Estimates of sca effects (Table 5) showed that out of 36 crosses studied in both generations, 29 and 28 crosses exhibited significantly sca effects in F_1 and F_2 generations, respectively. Of these, twenty-one and sixteen crosses had positive sca effects in F_1 and F_2, respectively. Whereas eight crosses in F_1 and twelve crosses in F_2 had negative sca effects. Twelve crosses *viz.*, Pusa Naveen x Aruna, Pusa Naveen x Punjab Long, Pusa Naveen NDBG-15, Pusa Naveen x JBOGL-01-42, Arka Bahar x Santosh, Arka Bahar x PBOG-88, Punjab Long x NDBG-15, Punjab Long x JBOGL-01-42, NDBG-15 x JBOGL-01-42, Santosh x JBOGL-01-42, Santosh x JBGL-43 and JBGL-43 x PBOG-88 registered significant and positive sca effects and were good specific combiners over both generations.

Two crosses, Santosh x JBOGL-01-42 (P_6 x P_7) and Arka Bahar x Santosh (P_2 x P_6) showed high *per se* performance with significant sca effects in both F_1 and F_2 generations (Table 7). Similar findings were reported by Rani and Reddy (2017) and Singh and Mamta (2018) in bottle gourd; Muthaiah *et al.* (2017), Chandan *et al.* (2019) and Krishnamoorthy *et al.* (2020) in ridge gourd and Alhariri *et al.* (2020) in bitter gourd.

Fruit yield (kg/plant): Among nine parents for fruit yield per plant, two parents *viz.*, Punjab Long and Santosh in F_1 generation, and three parents *viz.*, Pusa Naveen, Santosh and JBOGL-01-42 in F_2 generation, showed significant and positive gca effects and were good general combiners for this trait (Table 2). On the other hand, four parents *viz.*, Aruna, JBOGL-01-42, JBGL-43 and PBOG-88 in F_1 generation and four parents *viz.*, Arka Bahar, Aruna, NDBG-15 and JBGL-43 in F_2 generation showed significant and negative gca effects. The highest, significant and positive gca effect was recorded by Santosh (1.179) followed by Punjab Long (0.673) in F_1 and Santosh (1.511) followed by JBOGL-01-42 (0.429) in F_2. Only one parent, Santosh recorded significant and positive gca effects in both the generations.

The range for sca effects (Table 6) among the F_1 was between -0.804 (NDBG-15 x JBGL-43) and 2.948 (Arka Bahar x Santosh), while for F_2, the range was from -3.117 (Santosh x PBOG-88) to 4.287 (Arka Bahar x Santosh). Out of which, highest, significant and positive sca effects in F_1 generation was observed in Arka Bahar x Santosh (2.948) followed by Punjab Long x Santosh (2.225), Punjab Long x JBOGL-01-42 (1.935), Punjab Long x JBGL-43 (1.878) and Pusa Naveen x Aruna (1.730), whereas among F_2, Arka Bahar x Santosh (3.775) followed by Punjab Long x JBOGL-01-42 (3.667), Pusa Naveen x Aruna (3.215) and Arka Bahar x PBOG-88 (3.051) recorded higher, significant and positive sca effects. On reviewing the data of two generations, eleven crosses *viz.*, Pusa Naveen x Aruna, Pusa Naveen x NDBG-15, Pusa Naveen x JBGL-43, PusaNaveen x PBOG-88, Arka Bahar x Santosh, Arka Bahar x PBOG-88, Punjab Long x Santosh, Punjab Long x JBOGL-01-42, NDBG-15 x JBOGL-01-42, NDBG-15 x PBOG-88 and Santosh x JBOGL-01-42 exhibited significant and positive sca effects over both the generations and were found to be good specific combiners for this trait.

Four crosses *viz.*, Arka Bahar x Santosh (P_2 x P_6), Punjab Long x Santosh (P_4 x P_6), Punjab Long x NDBG-15 (P_4 x P_5) and Punjab Long x JBGL-43 (P_4 x P_8) in F_1 generation and three crosses *viz.*, Arka Bahar x Santosh (P_2 x P_6), Punjab Long x Santosh (P_4 x P_6) and Punjab Long x JBOGL-01-42 (P_4 x P_7) in F_2 generation exhibited high *per se* performance with significant sca effects. Among top five cross studied, two cross combinations *viz.*, Arka Bahar x Santosh (P_2 x P_6) and Punjab Long x Santosh (P_4 x P_6) performed consistently in both F_1 and F_2 generations for high *per se* performance and significant sca effects (Table 7). These two crosses are most desirable to increase fruit yield which could be utilized in further plant breeding programme. Gayakwaed *et al.* (2016), Janaranjani *et al.* (2016), Malaviya *et al.* (2017), Mishra *et al.* (2018) and Hadiya *et al.* (2020) in bottle gourd.

Table 6: Estimation of specific combining ability (sca) effects of hybrids for fruit yield (kg/plant) and total soluble solids (˚Brix).

Sr. No.	Crosses	Fruit yield (kg/plant)		Total soluble solids (˚Brix)	
		F_1	F_2	F_1	F_2
1	Pusa Naveen × Arka Bahar	0.175	-3.059**	0.640**	0.677**
2	Pusa Naveen × Aruna	1.730**	3.215**	-0.250**	-0.393**
3	Pusa Naveen × Punjab Long	-0.418*	1.609**	-0.396**	0.510**
4	Pusa Naveen × NDBG-15	1.060**	0.486*	-0.065	-0.122**
5	Pusa Naveen × Santosh	-0.239	-2.168**	-0.676**	-0.442**
6	Pusa Naveen × JBOGL-01-42	0.641**	-0.181	-0.073*	-0.268**
7	Pusa Naveen × JBGL-43	0.389*	2.920**	-0.346**	-0.745**
8	Pusa Naveen × PBOG-88	0.427*	1.366**	0.248**	0.905**
9	Arka Bahar × Aruna	0.752**	-1.010**	-0.058	0.565**
10	Arka Bahar × Punjab Long	-0.171	-0.682**	-0.728**	-0.783**
11	Arka Bahar × NDBG-15	0.752**	-1.524**	0.483**	0.136**
12	Arka Bahar × Santosh	2.948**	4.287**	-1.293**	-1.544**
13	Arka Bahar × JBOGL-01-42	0.183	-1.826**	-0.176**	0.765**
14	Arka Bahar × JBGL-43	-0.165	2.144**	0.062	-0.257**
15	Arka Bahar × PBOG-88	1.014**	3.051**	0.135**	0.042
16	Aruna × Punjab Long	-0.645**	-2.017**	-0.349**	-0.152**
17	Aruna × NDBG-15	-0.057	0.090	-0.308**	0.121**
18	Aruna × Santosh	-0.596**	2.776**	0.391**	0.381**
19	Aruna × JBOGL-01-42	0.929**	-0.792**	-0.051	-0.394**
20	Aruna × JBGL-43	0.071	-1.146**	0.161**	0.693**
21	Aruna × PBOG-88	0.850**	-0.704**	0.070*	-0.262**
22	Punjab Long × NDBG-15	1.704**	-2.051**	-0.588**	-0.982**
23	Punjab Long × Santosh	2.225**	3.775**	0.736**	0.468**
24	Punjab Long × JBOGL-01-42	1.935**	3.667**	0.263**	0.958**
25	Punjab Long × JBGL-43	1.878**	0.332	0.586**	1.156**
26	Punjab Long × PBOG-88	0.791**	-1.986**	-0.346**	0.105**
27	NDBG-15 × Santosh	1.188**	-0.218	0.497**	0.506**
28	NDBG-15 × JBOGL-01-42	0.444*	2.024**	-0.391**	0.631**
29	NDBG-15 × JBGL-43	-0.804**	-1.195**	0.272**	0.229**
30	NDBG-15 × PBOG-88	0.829**	2.356**	0.235**	0.128**
31	Santosh × JBOGL-01-42	1.435**	2.771**	-0.147**	-1.219**
32	Santosh × JBGL-43	1.407**	-1.374**	-0.139**	0.734**
33	Santosh × PBOG-88	-0.585**	-3.117**	0.399**	1.033**
34	JBOGL-01-42 × JBGL-43	0.157	-1.422**	0.043	0.068
35	JBOGL-01-42 × PBOG-88	0.295	2.725**	-0.328**	-0.742**
36	JBGL-43 × PBOG-88	0.308	-0.985**	-0.061	-0.299**
	S. E. (S_{ij}) ±	0.427	0.483	0.082	0.090
	S. E. (S_{ij} - S_{ik}) ±	0.630	0.712	0.122	0.134
	S. E. (S_{ij} - S_{kl}) ±	0.598	0.676	0.116	0.127

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

Total soluble solids (˚Brix): The estimates of gca effects (Table 2) revealed that seven parents each in F_1 and F_2 generations expressed significant gca effects. The gca effects varied from -0.463 (Punjab Long) to 0.383 (JBGL-43) as well as -0.345 (Punjab Long) to 0.485 (JBGL-43) in F_1 and F_2 generations, respectively. Consistently, significant and positive gca effects over both the generations were recorded by three parents *viz.*, Santosh, JBGL-43 and PBOG-88. On the other hand, three parents *viz.*, Punjab Long, NDBG-15 and JBOGL-01-42 exhibited significant and negative gca effects over both the generations.

Table 7: Best parents for *per se* and gca effects and best cross combinations for *per se* and sca effects in F_1's and F_2's generations for studied characters in bottle gourd.

Sr. No.	Characters	Best parents			Best cross combinations				*per se* performance and gca effects		*per se* performance and sca effects	
		per se	GCA		*per se*		SCA					
			F_1	F_2	F_1	F_2	F_1	F_2	F_1	F_2	F_1	F_2
1	Number of nodes on main vine	Aruna	Aruna	Aruna	P_1 x P_2	P_2 x P_8	P_2 x P_8	P_2 x P_8	0.935^{**}	0.776^{*}	0.786^{**}	0.904^{**}
		Pusa Naveen	Pusa Naveen	Pusa Naveen	P_3 x P_4	P_2 x P_6	P_3 x P_4	P_1 x P_9				
		Arka Bahar	Arka Bahar	Arka Bahar	P_3 x P_5	P_1 x P_9	P_3 x P_5	P_2 x P_6				
		Santosh	-	JBOGL-01-42	P_1 x P_9	P_1 x P_3	P_1 x P_2	P_4 x P_7				
		NDBG-15	-	-	P_2 x P_8	P_4 x P_7	P_4 x P_7	P_5 x P_7				
2	Vine length (m)	Pusa Naveen	Aruna	JBOGL-01-42	P_1 x P_2	P_6 x P_7	P_2 x P_8	P_2 x P_8	0.927^{**}	0.816^{**}	0.737^{**}	0.878^{**}
		Arka Bahar	Pusa Naveen	Pusa Naveen	P_3 x P_4	P_1 x P_3	P_3 x P_4	P_6 x P_7				
		Aruna	Arka Bahar	-	P_2 x P_3	P_2 x P_8	P_1 x P_9	P_3 x P_6				
		JBOGL-01-42	-	-	P_1 x P_3	P_4 x P_7	P_3 x P_5	P_2 x P_6				
		Punjab Long	-	-	P_2 x P_8	P_7 x P_9	P_1 x P_2	P_1 x P_3				
3	Number of fruits per plant	Santosh	Santosh	Santosh	P_1 x P_6	P_1 x P_9	P_2 x P_7	P_2 x P_8	0.930^{**}	0.824^{**}	0.695^{**}	0.906^{**}
		NDBG-15	Pusa Naveen	Pusa Naveen	P_2 x P_6	P_3 x P_6	P_4 x P_6	P_5 x P_9				
		Pusa Naveen	NDBG-15	-	P_4 x P_6	P_2 x P_6	P_1 x P_6	P_3 x P_6				
		JBGL-43	-	-	P_6 x P_9	P_1 x P_8	P_5 x P_9	P_1 x P_9				
		PBOG-88	-	-	P_5 x P_9	P_5 x P_9	P_4 x P_7	P_1 x P_7				
4	Fruit length (cm)	Punjab Long	Punjab Long	Punjab Long	P_6 x P_7	P_6 x P_7	P_6 x P_7	P_6 x P_7	0.902^{**}	0.775^{*}	0.698^{**}	0.780^{**}
		Pusa Naveen	JBOGL-01-42	JBOGL-01-42	P_4 x P_5	P_4 x P_7	P_4 x P_5	P_2 x P_6				
		JBOGL-01-42	Pusa Naveen	Pusa Naveen	P_1 x P_4	P_2 x P_6	P_2 x P_6	P_1 x P_3				
		Arka Bahar	Santosh	Santosh	P_4 x P_7	P_4 x P_6	P_8 x P_9	P_7 x P_9				
		PBOG-88	-	-	P_1 x P_7	P_7 x P_9	P_6 x P_8	P_4 x P_7				

P_1	=	Pusa Naveen	P_4	=	Punjab Long	P_7	=	JBOGL-01-42
P_2	=	Arka Bahar	P_5	=	NDBG-15	P_8	=	JBGL-43
P_3	=	Aruna	P_6	=	Santosh	P_9	=	PBOG-88

Table 7: Contd…

Sr. No.	Characters	Best parents			Best cross combinations				*per se* performance and gca effects		*per se* performance and sca effects	
		per se	GCA		*per se*		SCA					
			F_1	F_2	F_1	F_2	F_1	F_2	F_1	F_2	F_1	F_2
5	Fruit girth (cm)	Punjab Long Pusa Naveen JBOGL-01-42 Santosh JBGL-43	Punjab Long Santosh JBOGL-01-42 - -	Punjab Long JBOGL-01-42 Santosh Pusa Naveen -	P_4 x P_8 P_5 x P_6 P_4 x P_5 P_6 x P_7 P_6 x P_8	P_4 x P_7 P_6 x P_7 P_4 x P_6 P_2 x P_6 P_1 x P_4	P_5 x P_6 P_4 x P_8 P_4 x P_5 P_7 x P_9 P_6 x P_7	P_6 x P_7 P_2 x P_6 P_1 x P_3 P_4 x P_7 P_4 x P_6	0.833^{**}	0.846^{**}	0.778^{**}	0.776^{**}
6	Average fruit weight (g)	Punjab Long Arka Bahar Pusa Naveen JBOGL-01-42 PBOG-88	Punjab Long JBOGL-01-42 - - -	Punjab Long JBOGL-01-42 Santosh Pusa Naveen -	P_6 x P_7 P_4 x P_5 P_4 x P_7 P_4 x P_8 P_2 x P_6	P_6 x P_7 P_4 x P_7 P_4 x P_6 P_2 x P_6 P_1 x P_4	P_6 x P_7 P_4 x P_5 P_5 x P_6 P_2 x P_6 P_1 x P_3	P_6 x P_7 P_1 x P_3 P_2 x P_6 P_4 x P_7 P_4 x P_6	0.730^{*}	0.570	0.860^{**}	0.865^{**}
7	Fruit yield (kg/plant)	Pusa Naveen Santosh JBGL-43 Punjab Long NDBG-15	Santosh Punjab Long - - -	Santosh Pusa Naveen JBOGL-01-42 - -	P_2 x P_6 P_4 x P_6 P_4 x P_5 P_5 x P_6 P_4 x P_8	P_2 x P_6 P_4 x P_6 P_6 x P_7 P_4 x P_7 P_3 x P_6	P_2 x P_6 P_4 x P_6 P_4 x P_7 P_4 x P_8 P_4 x P_5	P_2 x P_6 P_4 x P_6 P_4 x P_7 P_1 x P_3 P_1 x P_8	0.771^{*}	0.551	0.812^{**}	0.917^{**}
8	Total soluble solids (˚Brix)	JBGL-43 Arka Bahar Santosh PBOG-88 Pusa Naveen	JBGL-43 PBOG-88 Santosh - -	JBGL-43 PBOG-88 Santosh - -	P_6 x P_9 P_8 x P_9 P_1 x P_2 P_5 x P_6 P_5 x P_8	P_6 x P_9 P_4 x P_8 P_6 x P_8 P_3 x P_8 P_1 x P_9	P_4 x P_6 P_1 x P_2 P_4 x P_8 P_5 x P_6 P_2 x P_5	P_4 x P_8 P_6 x P_9 P_4 x P_7 P_1 x P_9 P_6 x P_8	0.829^{**}	0.685^{*}	0.830^{**}	0.852^{**}

P_1	=	Pusa Naveen	P_4	=	Punjab Long	P_7	=	JBOGL-01-42
P_2	=	Arka Bahar	P_5	=	NDBG-15	P_8	=	JBGL-43
P_3	=	Aruna	P_6	=	Santosh	P_9	=	PBOG-88

Significant sca effects (Table 6) were observed in 29 and 34 cross combinations in F_1 and F_2 generations, respectively. Of these, fourteen and nineteen crosses had positive sca effects in F_1 and F_2, respectively. The corresponding sca effects ranges observed were from -1.293 (Arka Bahar x Santosh) to 0.736 (Punjab Long x Santosh) in F_1 and -1.544 (Arka Bahar x Santosh) to 1.156 (Punjab Long x JBGL-43 in F_2 generation. Twelve crosses *viz.*, Pusa Naveen x Arka Bahar, Pusa Naveen x PBOG-88, Arka Bahar x NDBG-15, Aruna x Santosh, Aruna x JBGL-43, Punjab Long x Santosh, Punjab Long x JBOGL-01-42, Punjab Long x JBGL-43, NDBG-15 x Santosh, NDBG-15 x JBGL-43, NDBG-15 x PBOG-88 and Santosh x PBOG-88 exhibited significant positive and sca effects.

Two cross *viz.*, Pusa Naveen x Arka Bahar (P_1 x P_2) and NDBG-15 x Santosh (P_5 x P_6) in F_1 generation and four cross *viz.*, Santosh x PBOG-88 (P_6 x P_9), Punjab Long x JBGL-43 (P_4 x P_8), Santosh x JBGL-43 (P_6 x P_8) and Pusa Naveen x PBOG-88 (P_1 x P_9) in F_2 generation displayed high *per se* performance with significant sca effects (Table 7). The results are similar with that of Janaranjani *et al.* (2016) in bottle gourd.

A summarized account of the best parents, good general combiners, and best cross combinations for *per se* performance and sca effects for various traits are presented in Table 7. In Table 7, the relationship between *per se* performance and sca effects for F_1 generation is marked with Red color, while for F_2 generation it is marked with Green color. The study indicated that the parents showing good general combining ability also had high *per se* performance for almost all the traits studied (Table 7). However, they differed among sets in respect of magnitude. This suggested that while selecting parents for hybridization programme in bottle gourd, *per se* performance of the parents may be given due consideration as reported by Kumar (2011) and Janaranjani *et al.* (2016) in bottle gourd; Thangamani *et al.* (2011) in bitter gourd and Singh *et al.* (2018) in sponge gourd.

The three best hybrids for fruit yield per plant *viz.*, Arka Bahar x Santosh (P_2 x P_6), Punjab Long x Santosh (P_4 x P_6) and Punjab Long x JBOGL-01-42 (P_4 x P_7) both in F_1 and F_2 generations showed significant and desirable sca effects and good *per se* performance. These three crosses also showed significant sca effects for some component traits such as number of fruits per plant, fruit length, fruit girth and average fruit weight and these crosses should be exploited commercially after rigorous multi-location testing. These crosses *viz.*, Arka Bahar x Santosh (P_2 x P_6), Punjab Long x Santosh (P_4 x P_6) and Punjab Long x JBOGL-01-42 (P_4 x P_7) had the combinations of good x average, good x good and good x poor gca effects, respectively, in F_1 generation, while in F_2 generation, these crosses observed good x poor, good x average and good x average gca effects, respectively. The shifting of general combining ability in parents from F_1 to F_2 is due to the segregation and recombination event taken place in F_2 generation. The specific combining ability effects of crosses did not show any specific trend for good general combining ability effects of the parents involved in these combinations. However, in majority of crosses, good x poor combinations resulted in high sca effects in F_1 generation and in F_2 generation pooled over all the traits studied.

With regard to parental lines, significant and positive correlation was observed between *per se* performance and gca effects (Table 7) for the studied characters in F_1 generation, while in F_2 generation, significant and positive correlation was observed in all characters except average fruit weight and fruit yield. Thus, the association between *per se* performance of parents and their gca effects suggested that while selecting the parents for hybridization programme, *per se* performance of parents should be given due consideration. Thus, if a character is uni-directionally controlled by a set of alleles and additive effects are important, the choice of parents on the basis of *per se* performance may be more effective. On the other hand, if trait is controlled by set of polygenes and non-additive effects are important; under this circumstances the relationship between *per se* performance and gca effects lead to non-significant association as observed in the two traits *viz.*, average fruit weight and fruit yield per plant in F_2 generation.

A comparison of *per se* performance of crosses and their sca effects presented in Table 7 revealed that *per se* performance of crosses was correlated and showed high association with their sca effects in all the studied traits in both F_1 and F_2 generations. This indicated that either *per se* performance of hybrids or sca effects would be equally effective but former is more desirable. It is fact that *per se* performance is a realized value, whereas sca effect is an estimate value, measured as the deviation of F_1 over the parental performance. Therefore, for a given cross, performance of sca effect may or may not be high depending upon the performance of parental lines. If a cross combination showing high sca effects involving both the parents with good gca effects, the same is likely to be exploited rather more profitably in a varietal breeding programme.

CONCLUSION

The *per se* performance appeared to be a good indication of gca and sca effects for parents and crosses, respectively in both F_1 and F_2 generations. Hence, it could be utilized while selecting the parents and crosses for further breeding programme. The parents with high gca effects in F_1 also showed more or less similar trend in F_2 suggesting the feasibility of estimating gca effects from the data of F_2 generation. Accordingly, Santosh, Punjab Long, JBGL-43, JBOGL-01-42 and Pusa Naveen offer the best possibilities of exploitation for the development of improved inbred lines with enhanced fruit yielding ability. It is suggested that population involving these lines in a multiple crossing programme may be developed for isolating desirable recombinants. On the other hand, the crosses, Arka Bahar x Santosh and Punjab Long x Santosh were found to be the best specific combiners for fruit yield per plant and also showed best *per se* performance in both the generations. This indicated that genetic improvement in bottle gourd for fruit yield and its attributes may be expected either through heterosis breeding or population improvement by recurrent selection for sca.

Acknowledgement: The authors are thankful to Research Scientist, Vegetable Research Station, Junagadh Agricultural University, Junagadh, Gujarat for allowing conducting the research work. Authors are also thankful to Farm Manager, Instructional Farm, College of Agriculture, Junagadh Agricultural University, Junagadh, Gujarat for providing field for the evaluation work.

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How to cite this article: Patel, H.R. and Mehta, D.R. (2021). Determining Combining Ability for Fruit Yield and its Component Traits in Bottle Gourd [*Lagenaria siceraria* (Mol.) Standl.]. *Biological Forum – An International Journal*, *13*(2): 187-200.