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Effect of general and specific combining ability in yield contributing characteristics of bitter gourd (*Momordica charantia* L.)

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Abstract
Length of fruit (cm), among the all parents significantly positive GCA effects recorded in the parents RHRBG-29 (P_7) (2.519 and 3.053), RHRBG-31 (P_8) (0.679 and0.563), RHRBG-26 (P_1) (0.639 and 0.668) and RHRBG-10 (P_3) (0.779 and 0.678) in both summer and *kharif* seasons respectively. Number of fruits per vine, among the eight parents significantly highest and positive GCA effects exhibited by the parentRHRBG-29 (P_7) (7.215 and 5.492) respectively during both summer and *kharif* seasons. The parents RHRBG-26 (P_1) (2.065) and RHRBG-10 (P_3) (1.620) displayed significantly positive GCA effect in *kharif* season. Weight of fruit (g), the parent RHRBG-29 (P_7) (9.590 and 8.395) expressed significantly highest and positive GCA effects during both summer and *kharif* seasons respectively. The parents RHRBG-31 (P_8) (1.322) in summer season and P_1 (1.844) displayed significantly positive GCA effect in *kharif* season. Fruit yield (q/ha), among the eight parents, RHRBG-29 (P_7) (40.204), RHRBG-31 (P_8) (4.912) and RHRBG-10 (P_3) (4.358) showed significantly positive GCA effects during summer season and RHRBG-29 (P_7) (33.641), RHRBG-26 (P_1) (10.475) and RHRBG-31 (P_8) (5.309) during *kharif* season.

Keywords: Fruit, general combining ability, kharif, parents, bitter gourd

Introduction

Bitter gourd (*Momordica charantia* L.) is one of the major cucurbitaceous vegetables grown throughout India belonging to the family Cucurbitaceae, genus *Momordica*. It is a large genus with many species of annual and perennial climbers of which *Momordica charantia* L. is widely cultivated. It has been identified as one of the promising vegetables for export by Agricultural Processed products for Export and Development Authority (APEDA). Bitter gourd shows a lot of variability in yield and yield contributing components. For developing a suitable and efficient breeding programme, information regarding the nature and magnitude of genetic variation that exist in the breeding population is necessary. Although, bitter gourd is becoming a commercial crop but relatively less attention has been paid towards the improvement of existing germplasm available in different parts of the country. Information about combining ability of parents is imperative to a breeding programme aiming to develop hybrids and composite varieties having high yield and quality. The yield potential of bitter gourd in India is very low due to poor yielding varieties and their susceptibility to pests and diseases. One of the method to improve yield and quality is heterosis breeding. The importance of heterosis breeding has been recognized widely in many vegetable crops. The exploitation of heterosis is much easier in cross pollinated crops and bitter gourd being monoecious, provides ample scope for the utilization of hybrid vigour on commercial scale. On combining ability and heterosis breeding in bitter gourd Sirohi and Choudhury, 1977; Abdul Vahab, 1989 [1]; Lawande and Patil, 1990 a/b [11, 12]; Choudhary and Kale, 1991a/b [3, 4] reported.

Materials and Methods

Production of F_1 hybrid seeds: The parents were sown during *Kharif*-2019 to constitute a crossing block. The crossing among the parents was followed in diallel fashion without reciprocals, to obtain cross seed to raise the F_1s. The female and male flowers, which were open during morning, were bagged separately in the evening, one day before crossing. In the morning after anthesis, the respective female flower was hand pollinated with pollens collected from the bagged desired male flowers. Similarly, the parents were covered with butter paper bags to collect selfed seeds. Sufficient selfed and crossed seeds were obtained at the end of *Kharif*-2019.

The experimental material consists of eight parents, 28 F_1 hybrids and one standard check. The complete sets of 37 genotypes were evaluated in Randomized Block Design replicated twice during Summer-2020 and *Kharif* 2020. There were 10 vines per replication. Row-to-row and plant-to-plant spacing were maintained at 1.5m and 1m, respectively. All the recommended agronomical package of practices was followed to grow a healthy crop. Combining ability effects and variances were worked out as per Griffing's Method-II and Model-I (1956).

Observations recorded

Five plants per genotype in each replication were randomly selected for recording following observations.

Length of fruit (cm)

Five fruits from individual observational plant were selected during peak period of harvesting for recording the length of fruit. The fruits were harvested at edible maturity and the length in centimeter was recorded from peduncle end to blossom end of the fruit and the mean value length of fruit was worked out.

Number of fruits per vine

The number of fruits of all pickings, harvested from the individual observational plants, were summed up to workout mean number of fruits per vine.

Weight of fruit (g)

The mean weight of fruit was calculated by dividing total weight of all harvested fruits per vine by number of fruits per vine in gram.

Yield per hectare

The total yield of fruits per vine was summed up then multiplied by hectare factor.

Result and Discussion

Combining ability

It is the ability of parent or cultivar to combine with each other during hybridization process such that desirable genes or characters are transmitted to their progenies. It is a considerable analysis tool; it is not only useful for selecting favorable parents but also for provides information about the nature of gene action influencing the expression of various quantitative characters and thus helps to deciding the breeding procedure for genetic improvement (Fasahat *et al.* 2016) [6]. It divided into two types *viz.*, general combining ability (GCA) and specific combining ability (SCA) in plant breeding. GCA is the average performance of a genotype in a series of hybrid combinations and SCA is the performance of a parent in a specific cross. The parents showing a high and desirable average combining ability are considered to be a good general combiner however if their potential to combine well in a particular cross then considered to have good SCA. GCA is owing to the activity of gene which are largely additive in nature but if the epistasis is present GCA will also include additive x additive type of non-allelic interaction. It has positively related with narrow sense heritability. GCA helps for selection of suitable parents for hybridization. SCA is regarded mainly as a function of dominance variance (non-additive), but if epistasis is present, it would include all the three types of epistasis (non-allelic) interaction components *viz.*, additive x additive, additive x dominance and dominance x dominance.

It has positive association with heterosis. It also helps in identification of superior cross combination for commercial exploitation of heterosis.

Analysis of variance for combining ability

The analysis of variance for general and specific combining ability of 8 genetically diverse parents and their 28 F_1.

General combining ability effects

General combining ability effects of all eight parents for different fifteen characters are presented in table. The character wise description of GCA effects is elucidated and discussed below.

Length of fruit (cm)

Among the all parents significantly positive GCA effects recorded in the parents RHRBG-29 (P_7) (2.519 and 3.053), RHRBG-31 (P_8) (0.679 and0.563), RHRBG-26 (P_1) (0.639 and 0.668) and RHRBG-10 (P_3) (0.779 and 0.678) in both summer and *kharif* seasons respectively. Similar findings recorded by Singh *et al.* (2004) [19], Naliyadhara *et al.* (2010) [14] and Podder *et al.* (2010) [17] Mallikarjunarao *et al.* (2018) [13].

Number of fruits per vine

Among the eight parents significantly highest and positive GCA effects exhibited by the parentRHRBG-29 (P_7) (7.215 and 5.492) respectively during both summer and *kharif* seasons. The parents RHRBG-26 (P_1) (2.065) and RHRBG-10 (P_3) (1.620) displayed significantly positive GCA effect in *kharif* season. These findings were in consonance with Lawande and Patil (1989) [10], Khattra *et al.* (2000) [8], Tewari *et al.* (2001) [21], Singh *et al.* (2004) [19], Bhave *et al.* (2004) [2], Panday *et al.* (2005) [16] and Yadav *et al.* (2008) [23].

Table 1: Analysis of variance for combining ability in 8 x 8 diallel of Bitter gourd

Sr. No.	Replication	Season	GCA		SCA		Error	
			D.F	M.S.S.	D.F	M.S.S.	D.F	M.S.S.
1.	Length of vine (m)	S	7	3.27	28	0.88	35	0.25
		K	7	3.82	28	0.54	35	0.84
2.	Days to 1st female flower	S	7	22.35	28	7.29	35	4.57
		K	7	17.55	28	5.53	35	1.97
3.	Days to male flower	S	7	14.77	28	4.70	35	3.72
		K	7	11.89	28	3.92	35	2.00
4.	Days to 50 per cent flowering	S	7	25.59	28	4.34	35	0.67
		K	7	10.16	28	2.33	35	0.85
5.	Number of female flowers	S	7	124.24	28	17.95	35	3.51

		K	7	116.32	28	15.21	35	2.23
6.	Days required for first harvest	S	7	25.59	28	4.34	35	0.67
		K	7	10.16	28	2.33	35	0.85
7.	Length of pedicel (cm)	S	7	0.96	28	0.64	35	0.01
		K	7	0.83	28	0.65	35	0.06
8.	Length of fruit (cm)	S	7	20.99	28	3.03	35	0.55
		K	7	26.20	28	2.94	35	0.54
9.	Girth of fruit (cm)	S	7	10.18	28	1.79	35	1.39
		K	7	5.35	28	1.37	35	0.89
10.	Number of fruits per vine	S	7	125.70	28	17.76	35	3.79
		K	7	100.79	28	20.80	35	7.01
11.	Number of seeds/fruit	S	7	83.67	28	7.34	35	0.77
		K	7	78.99	28	8.46	35	0.50
12.	Weight of fruit (g)	S	7	200.65	28	38.31	35	3.61
		K	7	172.83	28	29.45	35	4.53
13.	Yield per vine (kg)	S	7	0.80	28	0.09	35	0.00
		K	7	0.67	28	0.08	35	0.00
14.	Yield per plot (kg)	S	7	20.06	28	2.27	35	0.22
		K	7	16.92	28	2.15	35	0.19
15	Yield per hector (Q)	S	7	3566.95	28	403.94	35	39.71
		K	7	3007.98	28	382.57	35	34.67

Weight of fruit (g)

The parent RHRBG-29 (P_7) (9.590 and 8.395) expressed significantly highest and positive GCA effects during both summer and *kharif* seasons respectively. The parents RHRBG-31 (P_8) (1.322) in summer season and P_1 (1.844) displayed significantly positive GCA effect in *kharif* season. Similar result of positively significant GCA effects for average weight of fruit was reported earlier by Khattra *et al.* (2000) [8], Sharma and Bhutani (2000) [18], Jha *et al.* (2009) [7], Day *et al.* (2010) [5], Kumara *et al.* (2011) [9] and Nisha and Veeraragvathatham (2014) [15].

Table 2: Significantly positive GCA effect in *kharif* season

Source	Length of fruit (cm)		Number of fruits per vine		Weight of fruit (g)		Yield per hector (Q)	
	Summer	*Kharif*	Summer	*Kharif*	Summer	*Kharif*	Summer	*Kharif*
P_1	0.639**	0.668**	0.845	2.065*	-0.640	1.844**	3.552	10.475**
P_2	-0.116	-0.218	-0.185	0.300	-1.532**	-0.489	-3.788*	-2.058
P_3	0.779**	0.678**	0.905	1.620*	0.694	0.711	4.358*	2.375
P_4	-1.251**	-1.383**	-3.885**	-4.121**	-6.058**	-5.076**	-15.388**	-17.351**
P_5	-1.731**	-1.363**	-2.835**	-1.816*	-0.948	-3.726**	-17.515**	-15.732**
P_6	-1.516**	-1.998**	-3.165**	-3.626**	-2.430**	-2.463**	-16.335**	-16.659**
P_7	2.519**	3.053**	7.215**	5.492**	9.590**	8.395**	40.204**	33.641**
P_8	0.679**	0.563*	1.105	0.087	1.322*	0.806	4.912*	5.309**
S.E.±	0.33	0.32	0.87	1.18	0.85	0.95	2.81	2.63
C.D.5%	0.67	0.66	1.76	2.40	1.72	1.93	5.72	5.34
C.D.1%	0.91	0.89	2.37	3.22	2.31	2.59	7.67	7.17

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

Fruit yield (q/ha)

Among the eight parents, RHRBG-29 (P_7) (40.204), RHRBG-31 (P_8) (4.912) and RHRBG-10 (P_3) (4.358) showed significantly positive GCA effects during summer season and RHRBG-29 (P_7) (33.641), RHRBG-26 (P_1) (10.475) and RHRBG-31 (P_8) (5.309) during *kharif* season. The results were hypothesized by Lawande and Patil (1989) [10], Khattra *et al.* (2000) [8], Tewari *et al.* (2001) [21], Singh *et al.* (2004) [19], Verma *et al.* (2013) [22] and Mallikarjunarao *et al.* (2018) [13].

Specific combining ability effects

The specific combining ability effects of twenty-eight F_1 hybrids studied for different fifteen characters investigated during summer and *kharif* seasons are presented in table and described below in details.

Table 3: The specific combining ability effects of twenty-eight F_1 hybrids studied for different fifteen characters investigated during summer and *kharif* seasons

Crosses	Length of fruit (cm)		Number of fruits per vine		Weight of fruit (g)		Yield per hector (Q)	
	Summer	*Kharif*	Summer	*Kharif*	Summer	*Kharif*	Summer	*Kharif*
1×2	2.743**	1.403*	6.723**	6.963**	7.370**	8.847**	26.871**	49.223**
1×3	0.898	0.858	3.533	2.443	5.394**	7.757**	13.725*	25.455**
1×4	-0.972	-0.182	-4.877**	-3.117	-1.144	-6.656**	-8.729	-12.818*
1×5	-0.192	0.798	-2.427	-2.722	-2.744	-4.226*	-0.402	-11.438*
1×6	-1.557*	-0.467	-1.297	-3.512	-4.022*	-4.519*	-7.582	-20.511**
1×7	-0.942	-0.717	-0.777	3.871	5.738**	3.053	0.544	-3.146
1×8	1.148	-0.427	2.933	2.676	1.016	4.292*	11.171	8.522
2×3	-1.847**	-0.407	-0.737	-2.342	-4.514*	-5.360**	-15.935**	-10.012
2×4	1.433*	0.153	0.153	0.348	3.748*	3.167	1.146	-0.950
2×5	-1.787*	0.983	1.603	-2.957	-4.452*	-2.453	-3.062	-7.905
2×6	-0.902	-0.982	-4.467*	-3.047	-4.540*	-1.296	-7.442	-6.978
2×7	-0.037	1.418*	1.153	4.536	8.940**	3.246	17.554**	14.387*
2×8	-0.297	-2.142**	-5.737**	-1.759	-7.052**	-4.475*	-20.224**	-23.280**
3×4	-2.262**	-0.142	-2.937	-2.472	1.772	-1.273	-9.670	-7.053
3×5	-0.582	-0.862	-2.887	-0.977	-4.048*	-1.253	-9.878	-6.003
3×6	1.953**	-1.177	-4.857**	-1.867	-2.416	-6.366**	-1.523	-8.411
3×7	1.068	2.173**	2.663	4.116	5.764**	5.236*	23.408**	2.619
3×8	-0.242	1.963**	5.473**	5.721*	5.452**	7.255**	22.035**	22.292**
4×5	0.398	-2.452**	-0.397	-2.637	3.164	-0.356	-10.792	-1.676
4×6	-1.167	-2.817**	-1.967	-0.627	2.726	-1.999	-15.372*	-6.619
4×7	4.448**	3.683**	7.953**	5.406*	8.476**	7.393**	37.154**	29.351**
4×8	-1.212	0.523	-1.237	-0.439	-0.806	-3.368	-9.889	-7.982
5×6	-0.287	-0.287	0.983	-0.932	2.656	0.401	-5.850	1.696
5×7	2.628**	0.363	5.103**	3.451	3.056	4.073*	27.945**	18.061**
5×8	0.368	0.903	-3.687*	7.256**	-3.416	-0.918	-4.627	12.394*
6×7	0.213	2.298**	3.833*	4.661	2.898	4.270*	16.431**	24.323**
6×8	2.653**	2.038**	6.143**	4.966*	5.126**	6.869**	26.058**	20.321**
7×8	-0.532	-1.412*	-0.837	-11.731**	2.096	-1.539	-2.816	3.026
S.E.±	1.00	0.98	2.61	3.55	2.55	2.85	8.45	7.90
C.D.at5%	2.036	2.009	5.303	7.216	5.177	5.803	17.164	16.039
C.D.1%	2.732	2.695	7.115	9.681	6.946	7.786	23.030	21.520

Length of fruit (cm)

The length of fruit revealed that, 6 crosses in summer and 7 crosses in *kharif* season expressed significantly positive SCA effects. Among these cross combinations 4x7 (4.448 and 3.683), 1x2 (2.743 and 1.403) and 6x8 (2.653 and 2.038) respectively displayed positive and significant SCA effects during summer and *kharif* seasons. While, the cross 5x7, 3x6 and 2x4 exhibited significant positive SCA effect during summer season and 6x7, 3x7, 3x8 and 2x7 in *kharif* season. Similar findings recorded by Singh *et al.* (2004) [19], Naliyadhara *et al.* (2010) [14] and Podder *et al.* (2010) [17] Mallikarjunarao *et al.* (2018) [13].

Number of fruits per vine

Among all 28 F_1 hybrids, 6 crosses in summer and 5 crosses in *kharif* season indicated highest positive value and significant SCA effects. The cross combinations 4x7 (7.953 and 5.406), 1x2 (6.723 and6.963), 6x8 (6.143 and 4.966) and 3x8 (5.473 and 5.721) respectively displayed significantly positive SCA effects during both summer and *kharif* seasons. While crosses 5x7 and 6x7 in summer and 5x8 in *kharif* season display significantly positive effect. These findings were in consonance with Lawande and Patil (1989) [10], Khatra *et al.* (2000) [8], Tewari *et al.* (2001) [21], Singh *et al.* (2004) [19], Bhave *et al.* (2004) [2], Panday *et al.* (2005) [16] and Yadav *et al.* (2008) [23].

Weight of fruit (g)

The average weight of fruit represented, 9 crosses in both summer and *kharif* season expressed significant and highest positive SCA effects. Among all 28 crosses, the cross combinations 4x7 (8.476 and 7.393), 1x2 (7.370 and 8.847), 3x7 (5.764 and 5.236), 3x8 (5.452 and 7.255), 1x3 (5.394 and 7.757) and 6x8 (5.126 and 6.869) respectively exhibited significantly positive SCA effects during both summer and *kharif* seasons. Cross combination 2x7 (8.940), 2x4 (3.748) in summer and 1x8 (4.292), 6x7 (4.270), 5x7 (4.073) exhibited significant positive SCA effect in *kharif* season. Similar result of positively significant GCA effects for average weight of fruit was reported earlier by Khatra *et al.* (2000) [8], Sharma and Bhutani (2000) [18], Jha *et al.* (2009) [7], Day *et al.* (2010) [5], Kumara *et al.* (2011) [9] and Nisha and Veerara gvathatham (2014) [15].

Fruit yield (q/ha)

According to the presented data it was revealed that, the positively significant of SCA effects were expressed in the 9 crosses in both *kharif* and summer seasons. The cross combinations 4x7 (37.154 and 29.351), 5x7 (27.945 and 18.061), 1x2 (26.871 and 49.223), 6x8 (26.058 and 20.321), 3x8 (22.035 and 22.292), 2x7 (17.554 and14.387), 6x7 (16.431 and 24.323) and 1x3 (13.725 and 25.455) exhibited significant and positive SCA effect in both summer and *kharif* seasons respectively. In summer season the cross 3x7 (23.408) and in *kharif* season the cross combination 5x8 (12.394) exhibited significantly positive SCA effects. The results were hypothesized by Lawande and Patil (1989) [10], Khattra *et al.* (2000) [8], Tewari *et al.* (2001) [21], Singh *et al.* (2004) [19], Verma *et al.* (2013) [22] and Mallikarjunarao *et al.* (2018) [13].

Components of genetic variance

The estimates of variance due to general combining ability (σ^2gca) and specific combining ability (σ^2sca) manifested that, the variances due to specific combining ability (σ^2sca) were greater than general combining ability variances (σ^2gca) for all the estimated characters in summer as well as *kharif* seasons.

The data presented in Table 4x8 revealed genetic variance due to general and specific combining ability for all studied characters. For length of vine estimated σ^2gca was 0.302, 0.297 during summer and *kharif* seasons respectively, while σ^2sca was 0.630, -0.302 respectively in summer and *kharif* seasons. For all flowering characters *viz*., estimated σ^2gca (1.777, 1.557) and σ^2sca (2.725, 3.553) for days to 1st female flower and (1.105, 0.998) and (0.981, 1.920) for days to male flower in summer and *kharif* seasons, respectively. Days to 50% flowering σ^2gca (2.491, 0.930) and σ^2sca (3.670, 1.477), number of female flowers σ^2gca (12.073, 11.408) and σ^2sca (14.444, 12.982), days required for first harvest σ^2gca (2.491, 0.930) and σ^2sca (3.670, 1.477) respectively in summer and *kharif* seasons. Calculated GCA variance and SCA variance for all yield, quantitative traits during summer and *kharif* seasons was listed one by one likewise, length of pedicel (0.095, 0.076) and (0.634, 0.591), length of fruit (2.043, 2.566) and (2.473, 2.404), girth of fruit (0.879, 0.445) and (0.933, 0.482). For yield contributing characters *viz*., number of fruits per vine (12.191, 9.377) and (13.972, 13.781). number of seeds/fruit σ^2gca (8.290, 7.848) and σ^2sca (6.571, 7.961), weight of fruit σ^2gca (19.704, 16.829) and σ^2sca (34.707, 24.918), yield per vine (kg) σ^2gca (0.079, 0.067) and σ^2sca (0.081, 0.078), yield per plot (kg) σ^2gca (1.984, 1.672) and σ^2sca (2.048, 1.956), yield per hector (q/ha) σ^2gca (352.724, 297.331) and σ^2sca (364.231, 347.901) respectively in summer and *kharif* seasons.

Table 4: Estimation of general combining ability and specific combiningability variance

Sr. No.	Characters	Season	σ²gca	σ²sca
1.	Length of vine (m)	Summer	0.302	0.630
		Kharif	0.297	-0.302
2.	Days to 1st female flower	Summer	1.777	2.725
		Kharif	1.557	3.553
3.	Days to male flower	Summer	1.105	0.981
		Kharif	0.988	1.920
4.	Days to 50 per cent flowering	Summer	2.491	3.670
		Kharif	0.930	1.477
5.	Number of female flowers	Summer	12.073	14.444
		Kharif	11.408	12.982
6.	Days required for first harvest	Summer	2.491	3.670
		Kharif	0.930	1.477
7.	Length of pedicel (cm)	Summer	0.095	0.634
		Kharif	0.076	0.591
8.	Length of fruit (cm)	Summer	2.043	2.473
		Kharif	2.566	2.404
9.	Girth of fruit (cm)	Summer	0.879	0.933
		Kharif	0.445	0.482
10.	Number of fruits per vine	Summer	12.191	13.972
		Kharif	9.377	13.781
11.	Number of seeds/fruit	Summer	8.290	6.571
		Kharif	7.848	7.961
12.	Weight of fruit (g)	Summer	19.704	34.707
		Kharif	16.829	24.918
13.	Yield per vine (kg)	Summer	0.079	0.081
		Kharif	0.067	0.078
14.	Yield per plot (kg)	Summer	1.984	2.048
		Kharif	1.672	1.956
15.	Yield per hector (Q)	Summer	352.724	364.231
		Kharif	297.331	347.901

Conclusion

The parents RHRBG-24 (P_2), RHRBG-10 (P_3) and RHRBG-29 (P_7) were observed the good general combiners as they displayed significant GCA effects in desirable direction for most of characters like earliness and yield attributing characters during both the summer and *kharif* seasons. The estimates of components of specific combining ability variance were higher than components of general combining ability variance which indicated that the preponderance of non-additive gene action for all the traits under study and hence heterosis breeding is rewarding. From the present study, it is concluded that, parents RHRBG-24 (P_2), RHRBG-10 (P_3) and RHRBG-29 (P_7) are the good general combiner for most of the traits.

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