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Combining ability studies in bitter gourd (*Momordica charantia* L.) for yield and yield related characters

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Abstract
Ten lines of bitter gourd (*Momordica charantia* L.) were crossed each with four testers in line x tester mating design. The resultant 40 hybrids along with the parents were evaluated in randomized block design with two replications at Vegetable Science unit, College of Horticulture, Bagalkot. Combining ability analysis revealed importance of both additive and non-additive gene action. On the basis of overall performance the line L10 was found good combiner for majority of the characters (number of nodes up to first female flowering, days to first harvest, number of fruits per vine, average fruit weight, fruit length, fruit girth and fruit yield per vine). L10 x T1 exhibited high sca effects for nodes up to first female flowering, fruit maturity to fruit set and fruit yield per vine. The cross L3 x T2 exhibited high sca effects for fruit length, fruit yield per vine and days to last harvest. These crosses were also found to show significant heterosis in the desired direction for most of the yield characters. Hence they can be exploited as desirable hybrids.

Keywords: Bitter gourd, general combining ability and specific combining ability

Introduction
Bitter gourd (*Momordica charantia* L.) is one of the important commercial cucurbit vegetable belongs to family cucurbitaceae. The fruits of bitter gourd are bitter in taste. The bitter principle is due to 'momordicine' an alkaloid, which is different from cucurbitacins present in other cucurbits (Jeffery, 1967) [2]. It ranks first among the cucurbits for its nutritive value. It is monoecious in sex expression and can be profitably utilized through commercial exploitation of hybrid vigour for the production of F_1 hybrids. In spite of wide range of diversity in bitter gourd, very little work had been done to exploit this naturally endowed diversity to breed hybrid varieties. To make heterosis breeding a successful endeavour, identification of good combiners with substantial diversity is the prerequisite. Selection of better parent is based on genetic information, combining ability analysis is one of the potent tool available which estimates combining additive and non- additive gene action for parents and helps in selecting desirable parents and crosses for further exploitation of hybrids (Sirohi and Choudhury, 1978) [10]. The knowledge of the relative importance of general and specific combining ability for yield and its component traits is very useful in selecting parents for production of superior hybrids. Main purpose of crop improvement is to enhance yield potentiality.

Material and Methods
The present investigation undertaken involving 10 lines namely, L_1 (Dharwad local), L_2 (Budihal local), L_3 (Dharwad local), L_4 (Bagalkot local), L_5 (Gadag local), L_6 (Guledgudd local), L_7 (DVBTG-5-6), L_8 (Bagalkot local), L_9 (Laxmeshwar local) and L_{10} (VRBTG-1-1) and four testers namely T_1 (CO -1), T_2 (Pusa Rasdar),T_3 (Preethi) and T_4 (Pusa Aushadhi) and their 40 hybrids of bitter gourd. The material was evaluated in a Randomized Block Design with two replications at Vegetable Science unit, College of Horticulture Bagalkot. Observation were recorded on five randomly selected tagged plants from each treatment for days to first male and female flowering, nodes up to first female flowering, days to first and last harvest, sex ratio, days taken from fruit set to maturity, number of fruits per vine, fruit girth, fruit length, average fruit weight and fruit yield per vine. The combining ability estimation for different traits was calculated according to model suggested by Kempthrone, 1957 [4].

Result and Discussion
Significance of parents can be judged through Its *per se* performance and general combining ability (gca) of parents to obtain a desirable recombinant.

Estimates of general combining ability are given in the table 1. In the present study, estimates of gca revealed that inbred line L3 and L10 exhibited positive significant gca effects indicating their good general combining ability for yield per vine. These are in conformity with the results from Venkatesh (2007) and Yadav *et al.* (2008) [14]. Among testers T1 was good general combiner for days to first male flowering and fruit girth. Tester T4 considered better combiner for number of nodes up to first female flowering and days from fruit set to maturity. Whereas, tester T3 was good combiner for sex ratio and average fruit weight. Tester T2 for number of fruits per vine and fruit yield per vine were found better general combiner. Similar findings were obtained from Tiwari *et al.* (2015) and Bhatt *et al.* (2017) [13, 1]. This high gca effects are due to additive gene action and additive x additive gene action. Line L4 was good general combiner for days to first female flowering, number of nodes up to first female flowering and days to first harvest. Negative significant results were recorded from the studies of Kaniti (2015) and Mahaboob *et al.* (2015) [3, 7]. Line L6 for days to first male flowering and days from fruit set to maturity was found better combiner. Similar consonance also obtained from Yadav *et al.* (2008) [14] and Thangamani *et al.* (2011) [12]. For sex ratio L7, for number of fruits per vine L5, for fruit length L9, for fruit girth and average fruit weight L10 were recorded as better general combiner. The genotypic difference for GCA effects were also reported earlier in bitter gourd by Bhatt *et al.* (2017) [1] and Khan *et al.* (2017) [5]. It was observed that the parents which were high performing were also found better general combiners for the respective characters. It can be concluded that the potential parents for utilization in breeding programme to improve yield and its related traits in bitter gourd may be judged on the basis of their *per se* performance and combining ability.

Estimates of specific combining ability are given in the table 2. High sca effects were observed in L7 x T4 and L8 x T2 for days to first female flowering. The results are in agreement with those of Maurya *et al.* (1993) [8] who reported in bottle gourd that for the crosses having highest sca effects are not necessarily the product of parents having high gca effects and there is no direct relationship between *per se* performance of parents and their resultant crosses. Similar consonance also obtained from Yadav *et al.* (2008) [14], Thangamani *et al.* (2011) [12], Mahaboob *et al.* (2015) [7] and Bhatt *et al.* (2017) [1] in bitter gourd.

Out of 40 hybrids, 12 hybrids showed significantly negative sca effects, among them hybrids L4 x T4 and L1 x T1 showed high sca effect for number of nodes up to first female flowering. Similar results obtained from Mahaboob *et al.* (2015) [7] and Bhatt *et al.* (2017) [1].

The crosses L3 x T1and L4 x T4 were good specific combiner for days to first harvest. As this cross exhibited maximum heterosis of -42.77 per cent, it can be profitably used in spotting good desirable segregants. L3 x T2 and L8 x T4 were only two good combiners for days to last harvest. Similar results were revealed from Yadav *et al.* (2008) [14] and Thangamani *et al.* (2011) [12]

Hybrids L8 x T3 and L4 x T2 exhibited high sca effects for days from fruit set to maturity. Tamilselvi *et al.* (2015) reported that sca effect of hybrid is the deviation from the performance predicted based on the gca of parents. The sca effect is due to dominance, epistasis and environmental influence. Under certain favorable condition, all the non additive gene functions may be triggered and result in high sca effect. Six crosses showed negative sca effects for sex ratio, among them L5 xT3 found highest sca effect. Similar findings were reported by Mahaboob *et al.* (2015) [7] and Bhatt *et al.* (2017) [1]. Crosses L10 x T1 and L8 x T2 showed highest sca effect for number of fruits per vine. The superior performance of these cross combinations might be due to presence of fixable and non-fixable genes indicating high success through adoption of suitable breeding methods which utilizes both additive and non-additive genetic variation. These results are in collaboration with the results of Khattra *et al.* (2000) and Thangamani *et al.* (2011) [6, 12].

Table 1: General combining ability effects for yield and yield related parameters in bitter gourd

Sl. No.	Genotypes	Days to first male flowering	Days to first female flowering	Nodes up to female flowering	Days to first harvest	Days to last harvest	DFFFM
1	L1	0.663	0.201	2.900**	-0.368	2.077	-0.025
2	L2	-1.132	-1.124	-1.925**	-0.385	2.828	-0.125
3	L3	0.005	0.314	0.163	0.207	1.540	0.437
4	L4	-0.694	-3.786**	-3.075**	-2.323*	-0.148	-0.430
5	L5	-1.020	-2.811**	3.413**	-1.460	0.715	1.146**
6	L6	-2.170**	-0.986	-0.012	-1.085	0.090	-0.992*
7	L7	0.418	1.901*	0.162	1.244	-3.085	0.478
8	L8	0.768	0.564	0.137	-0.015	-5.497**	-0.034
9	L9	1.493*	0.551	-0.675	0.003	-0.672	-0.004
10	L10	1.668*	5.176**	-1.088**	4.182**	2.152	-0.450
	C.D.@1%	1.981	2.157	0.906	2.535	4.558	1.007
	C.D.@5%	1.480	1.611	0.676	1.894	3.405	0.752
	S.E.(m)±	0.732	0.796	0.334	0.936	1.683	0.372
	Tester						
1	T1	-11.103*	1.289*	0.528*	1.432*	1.705	0.844**
2	T2	1.171*	-0.971	1.453**	-1.130	-2.595*	-0.653*
3	T3	-2.527**	-0.836	0.027	-0.174	-1.060	0.907**
4	T4	0.253	0.519	-2.008**	-0.128	1.950	-1.097**
	C.D.@1%	1.253	1.364	0.573	1.603	2.883	0.637
	C.D.@5%	0.936	1.019	0.428	1.894	2.153	0.475
	S.E.(m)±	0.463	0.504	0.212	0.592	1.065	0.235

* and ** indicate significance of values at p=0.05 and p= 0.01, respectively.

Table 1: Contd….

Sl. No.	Genotypes	Sex ratio	Number of fruits per vine	Average fruit weight	Fruit length	Fruit girth	Fruit yield per vine
1	L1	-2.619**	0.478	1.108	0.672*	0.998	-0.048
2	L2	-0.835	-1.448**	-1.418	-0.408	0.463	-0.138**
3	L3	2.015**	-0.998**	3.170**	0.838**	-3.549*	0.461**
4	L4	0.431	-2.060**	4.983**	-3.781**	0.630	-0.126**
5	L5	2.356**	2.853**	-5.143**	-2.116**	-0.637	0.029
6	L6	1.115	-1.835**	-0.393	-1.224**	-0.949	-0.098**
7	L7	-4.397**	-0.185	-6.868**	1.082**	-2.874**	-0.173**
8	L8	-0.272	-0.785*	-4.568**	0.877**	2.821**	-0.177**
9	L9	-0.310	3.128**	2.408*	2.158**	-1.212*	0.060
10	L10	2.515**	0.853*	6.720**	1.901**	4.308**	0.211**
	C.D.@1%	1.910	0.876	2.591	0.732	1.466	0.082
	C.D.@5%	1.427	0.654	1.935	0.547	1.095	0.061
	S.E.(m)±	0.705	0.324	0.957	0.270	0.542	0.030
	Tester						
1	T1	3.803**	-0.540*	-1.183	-0.847**	3.323**	-0.053**
2	T2	-0.804	2.690**	0.122	0.206	2.570**	0.304**
3	T3	-3.007**	-1.665**	2.003**	-0.960**	-0.121	-0.115**
4	T4	0.009	-0.485*	-0.943	1.600**	-5.772**	-0.136**
	C.D.@1%	1.208	0.554	1.639	0.463	0.927	0.052
	C.D.@5%	0.902	0.414	1.224	0.346	0.693	0.039
	S.E.(m)±	0.446	0.205	0.605	0.171	0.343	0.019

* and ** indicate significance of values at p=0.05 and p= 0.01, respectively.

Table 2: Specific combing ability effects for yield and yield related parameters in bitter gourd

Sl. No.	Genotypes	Days to first male flowering	Days to first female male flowering	Nodes up to first female flower	Days to first harvest	Sex ratio
1	L1 x T1	-1.198	-1.876	-3.690**	-2.085	0.394
2	L1 x T2	-0.286	-1.266	4.285**	0.548	-0.034
3	L1 x T3	1.282	1.349	-1.690*	0.941	-1.796
4	L1 x T4	0.202	1.794	1.095	0.595	1.437
5	L2 x T1	1.797	0.549	-3.165**	-0.148	2.710
6	L2 x T2	-0.771	-1.841	4.060**	1.164	1.917
7	L2 x T3	1.277	-0.326	0.035	-0.177	-2.780
8	L2 x T4	-2.303	1.619	-0.930	-0.838	-1.846
9	L3 x T1	2.210	-1.089	-1.753*	1.21	-0.040
10	L3 x T2	-1.009	-0.229	1.023	-1.447	-2.833
11	L3 x T3	-2.361	1.836	-0.602	2.266	5.770**
12	L3 x T4	1.160	-0.519	1.333	-2.03	-2.896*
13	L4 x T1	-0.590	1.011	1.385*	1.59	-1.756
14	L4 x T2	-0.758	1.821	-0.340	0.518	-0.349
15	L4 x T3	0.089	-0.014	3.935**	-0.524	-2.846
16	L4 x T4	1.259	-2.819	-4.980**	-1.585	4.951**
17	L5 x T1	-0.266	0.136	2.298**	0.377	1.169
18	L5 x T2	2.367	1.796	-2.678**	0.039	1.491
19	L5 x T3	-2.536	-3.939 *	-1.953**	-0.667	-8.171 **
20	L5 x T4	0.435	2.006	2.333**	0.252	5.512**
21	L6 x T1	-0.866	-0.989	1.523*	-2.948	-3.840**
22	L6 x T2	1.267	4.871**	-2.403**	2.764	3.267*
23	L6 x T3	-2.885	0.036	-1.378*	-0.577	0.820
24	L6 X T4	2.484	-3.919*	2.258**	0.762	-0.246
25	L7 X T1	-0.703	6.424**	0.348	4.523 *	-0.528
26	L7 X T2	0.579	1.084	-1.428*	3.085	1.229
27	L7 X T3	0.527	-1.601	2.497**	-3.191	0.782
28	L7 X T4	-0.403	-5.906**	-1.418*	-4.417*	-1.484
29	L8 X T1	0.097	-0.039	1.573*	2.132	3.447*
30	L8 X T2	-2.321	-5.079**	0.747	-4.526*	-2.946*
31	L8 X T3	3.727*	2.686	-1.328	-0.647	-0.493
32	L8 X T4	-1.503	2.431	-0.992	3.042	-0.009
33	L9 X T1	0.572	0.424	2.385**	0.814	-2.015
34	L9 X T2	0.454	0.034	-1.940**	0.277	-3.008*
35	L9 X T3	-0.498	1.299	-0.415	1.835	8.595**
36	L9 X T4	-0.528	-1.756	-0.030	-2.926	-3.571*
37	L10 X T1	-1.053	-4.551**	-0.903	-5.465**	0.460
38	L10 X T2	0.479	-1.191	-1.328	-2.422	1.267
39	L10 X T3	1.377	-1.326	0.898	0.741	0.120

40	L10 X T4	-0.803	7.069**	1.333	7.145**	-1.846
	C.D.@1%	3.961	4.313	1.811	5.071	3.820
	C.D.@5%	2.959	3.222	1.353	3.788	2.853
	S.E.(m)	1.463	1.593	0.669	1.872	1.411

Table 2: Contd….

Sl. No.	Genotypes	Days from fruit set to maturity	Days to last harvest	Number of fruits per vine	Fruit length	Fruit girth	Average fruit weight	Fruit yield per vine
1	L1 x T1	-0.909	-1.743	5.053**	0.863	-5.058**	3.958*	0.354**
2	L1 x T2	2.308 **	4.108	2.873**	-0.725	1.895	1.753	-0.102
3	L1 x T3	-0.652	-4.227	-2.873**	0.976	5.076**	-6.078**	-0.124*
4	L1 x T4	-0.748	1.862	-5.053**	-1.114*	-1.913	0.368	-0.128*
5	L2 x T1	0.011	-1.543	5.628**	1.353*	-1.573	9.583**	0.479**
6	L2 x T2	-0.727	-1.042	-6.353**	1.160*	-3.220**	-5.923**	-0.582**
7	L2 x T3	1.313	5.023	-0.098	-2.689**	7.071**	-1.603	0.036
8	L2 x T4	-0.598	-2.438	0.823	0.176	-2.278*	-2.058	0.067
9	L3 x T1	1.598 *	1.945	-0.773	1.327*	6.040**	5.495**	-0.465**
10	L3 x T2	-0.724	8.345*	-3.553**	3.554**	-3.857**	-14.860**	0.616**
11	L3 x T3	0.186	4.910	1.503*	-4.610**	-5.816**	12.110**	-0.238**
12	L3 x T4	-1.06	-15.200**	2.823**	-0.270	3.634**	-2.745	-0.292**
13	L4 x T1	2.316 **	4.083	-2.160**	-0.305	6.161**	-15.118**	-0.243**
14	L4 x T2	-3.122 ***	-1.118	-2.190**	0.512	5.914**	13.328**	-0.070
15	L4 x T3	1.683 *	1.998	0.915	-0.852	-7.330**	10.548**	0.139*
16	L4 x T4	-0.878	-4.963	3.435**	0.644	-4.745**	-8.758**	0.174**
17	L5 x T1	0.29	-2.930	0.627	-1.400*	1.127	-12.993**	-0.038
18	L5 x T2	-0.513	0.120	-1.253	-1.133*	-2.820*	13.203**	0.125*
19	L5 x T3	0.777	-0.415	1.403*	-1.257*	-4.229**	-7.178**	-0.156*
20	L5 x T4	-0.554	3.225	-0.777	3.789**	5.922**	6.968**	0.069
21	L6 x T1	-2.023 **	-3.005	-3.685**	0.049	2.140	6.108**	-0.171**
22	L6 x T2	-0.175	1.995	6.285**	-4.614**	3.243**	2.553	0.463**
23	L6 x T3	0.58	0.260	0.540	2.552**	-6.366 **	-8.478**	-0.114
24	L6 X T4	1.619 *	0.750	-3.140**	2.012**	0.984	-0.183	-0.178**
25	L7 X T1	-0.828	4.020	-3.285**	-0.567	-3.585**	-9.168**	-0.256**
26	L7 X T2	1.905 *	-1.580	1.285	1.480**	5.718**	4.128*	-0.037
27	L7 X T3	-2.425 **	-6.065	-2.460**	1.531**	-1.491	4.148*	-0.009
28	L7 X T4	1.349	3.625	4.460**	-2.444**	-0.641	0.892	0.302**
29	L8 X T1	1.47	-0.967	-3.435**	-2.512**	-4.665	8.033**	-0.072
30	L8 X T2	1.047	-1.818	6.885**	0.110	2.088	1.827	0.152*
31	L8 X T3	-3.578 **	-5.453	-2.210**	1.111*	5.614**	-8.453**	-0.110
32	L8 X T4	1.061	8.238*	-1.240	1.291*	-3.036**	-1.408	0.030
33	L9 X T1	-0.31	3.607	-5.648**	0.457	-1.398	3.858	-0.205**
34	L9 X T2	0.737	-7.292*	4.773**	2.824**	-7.645**	-7.348**	-0.081
35	L9 X T3	0.292	0.522	3.678**	0.390	7.046**	6.172**	0.308**
36	L9 X T4	-0.719	3.163	-2.803**	-3.670**	1.997	-2.682	-0.022
37	L10 X T1	-1.614 *	-3.468	7.678**	0.734	0.812	0.245	0.994
38	L10 X T2	-0.737	-1.718	-8.753**	-3.169**	-1.315	-8.660**	-0.861**
39	L10 X T3	1.823 *	3.448	-0.398	2.847**	0.426	-1.190	0.268**
40	L10 X T4	0.527	1.738	1.473*	-0.413	0.077	9.605**	-0.022
	C.D.@1%	2.015	9.116	1.752	1.464	2.933	5.182	0.163
	C.D.@5%	1.504	6.809	1.309	1.094	2.190	3.871	0.122
	S.E.(m)	0.744	3.366	0.647	0.540	1.083	1.914	0.060

* and ** indicate significance of values at p=0.05 and p= 0.01, respectively.

Conclusion

The cross combinations L5 x T4 and L3 x T2 for fruit length, L2 x T3 and L9 x T3 for fruit girth, L4 x T2 and L5 x T2 for average fruit weight exhibited high sca effects. These were considered as good specific combiner for respective traits. Crosses L10 x T1and L3 x T2 exhibited high significant SCA effect in desirable direction for fruit yield per vine. Interestingly these crosses exhibited high heterosis as well as *per se* performance was identified as good, possessing high sca effect. The superiority of H x H combination might be due to presence of genetic variability among the parents and there could be complementary effects representing the consequence of non-additive gene action. These specific crosses can be exploited for hybrid development. These results are in consonance with the findings of Thangamani *et al.* (2011) [12] and Singh *et al.* (2013) [9],

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