Combining ability for yield related traits, earliness and yield in Bitter gourd (*Momordica charantia)*

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Abstract

Combining ability analysis using eight parents and their 28 F_1 crosses of bitter gourd obtained from diallel mating design (excluding reciprocals) for yield and earliness indicated that non-additive gene action played major role than additive gene action in inheritance of the traits. Among the parents, IC-04448, IC-470560, IC-470558 and IC-085622 were found good general combiner for yield attributing characters and earliness hence, these parents can be exploited for hybridization for producing desirable recombinants in the segregating generations. High *sca* effects for yield and related characters were exhibited by IC-044438 × IC- 045339 followed by IC-044417 × IC-470558 and IC-045339 × IC-085622. For earliness the crosses *viz*., IC-044438 × IC-045339, IC-045339 × IC-470550 and IC-045339 × IC-470558 were identified as promising ones. Most good specific cross combinations involved High × Low and Low × Low general combiners. Five crosses were identified for developing high yielding genotypes of bitter gourd.

Key words: bitter gourd, combining ability, yield, yield components, earliness

Introduction

Bitter gourd (*Momordica charantia* L.) is one of the most important vegetable crops extensively grown throughout the country for its nutritive value and therapeutic properties. It is rich source of minerals (iron, calcium and phosphorous) and vitamins (A and C). Consumption of its fruit juice is very useful for diabetic patients due to its potent oxygen free radical scavenging activity (Sreejayan and Rao (1991). In breeding of high yielding varieties of crop plants, the breeder often faces with the problem of selecting parents and crosses. Combining ability analysis is one of the powerful tools available which estimates combining ability effects and aids in selecting desirable parents and crosses for further exploitation. Additive and non-additive gene action estimated through combining ability analysis in the parents may be useful for commercial exploitation of heterosis and isolation of pure lines among the progenies of heterotic F_1s. Further, the diallel mating design provides an opportunity to mate the given set of parents in all possible combinations (Griffing 1956) and it provides information on combining ability and thus helps in the selection of desirable parents for utilization in the hybridization programme, as well as in the choice of appropriate breeding procedure for the genetic improvement of various quantitative traits in the crop species. The present investigation was therefore, undertaken to obtain information regarding estimates of general and specific combining ability.

Material and Methods

Eight genetically diverse parents *viz*., IC-033227, IC-044417, IC-044438, IC-045339, IC-085622, IC-470550, IC-470558 and IC-470560 were crossed in diallel fashion without reciprocals during summer season 2010. The twenty eight hybrids along with parents were evaluated at model orchard, College of Horticulture, Rajendranagar, Hyderabad in a randomized block design with three replications during summer 2011. Seeds were sown with a spacing of 2.0 m x 0.5 m. All recommended agronomic package of practices were followed during crop growth period to get healthy crop. Observations were recorded on five randomly selected vines in each genotype from each replication for fifteen characters *viz*., vine length (m), number of laterals/vine, internodal length (cm), days to 1^{st} male flower appeared, days to 1^{st} female flower appeared, node number at which 1^{st} male flower appeared, node number at which 1^{st} female flower appeared, sex ratio (male to female), number of fruits/vine, average fruit weight (g), fruit length (cm), fruit girth (cm), pulp thickness (cm), number of seeds/fruit and yield/vine (kg). The combining ability for 8 × 8 diallel analysis (excluding reciprocals) was carried out by Method II and Model I of Griffing (1956).

Results and Discussion

The analysis of variance for combining ability for fifteen yield and yield attributing characters indicated that mean squares of general combining ability (GCA) and specific combining ability (SCA) were highly significant for all traits (Table 1). This indicates variation in parents and crosses and thus significant combination of additive and non-additive gene effects in expression of the characters. It was observed that variance due to *gca* was lower than that of *sca* for all the traits, which indicated that non-additive gene action played major role than additive gene action in inheritance of these traits. The ratio of *gca* and *sca* variance (σ^2gca/σ^2sca) was less than one (<1) further confirming the non-additive gene action in inheritance of the traits. Similar results were reported by Jadhav *et al.* (2010) and Dey *et al.* (2010) in bitter gourd.

The estimates of general combining ability of eight parents for fifteen characters are presented in Table 2. Among the parents, IC-044438 was good general combiner for all the traits except internodal length and node number at 1st female flower followed by IC-470560. Parents, IC-033327 (for yield/vine, number of fruits/vine, days to first male flower appeared and vine length) and IC-470550 (for internodal length and number of seeds/fruit) were found good general combiners. Similarly IC-085622 was good combiner for fruit girth. It was observed that the parental lines which were high performing were also good general combiners for the respective characters. It can be inferred that the potential parents for utilization in breeding programmes to improve yield and its related traits in bitter gourd may be judged on the basis of their *per se* performance. Sundaram (2008), Dey *et al.* (2010) and Jadhav *et al.* (2010) also reported good general combiners for yield and its contributing traits in bitter gourd.

Specific combining ability is the result of non-additive gene action and is not fixable in segregating generations. Specific combining ability effects for superior crosses for different characters were presented in Table 3. Combiners were mentioned as low (Low), medium (Medium) and high (High) according to their *gca* effects. For vine length, the cross combinations, IC-044438 × IC-045339, IC-044417 × IC-470558, IC-045339 × IC-470550, IC-45339 × IC-470560 and IC-044417 × IC-470560 were found to be best specific crosses. These specific crosses had *per se* performance for vine length ranging from 2.32 to 2.77 m and also exhibited heterosis of 31.47 to 41.34 per cent (Table 3). The high × low and low × low *gca* combination in these crosses indicated the importance of dominant gene and the complimentary gene effects. Venkateshwarlu and Singh (1982) suggested that high × low *gca* combination could produce transgressive segregants if the additive genetic system present in the good combiner and complementary epistatic effect act in the same direction to maximize the desirable plant attributes. The cross combinations with significant positive *sca* effects for number of laterals/vine were IC-044438 × IC-045339 (H×M), IC-044417 × IC-470558 (M × M), IC-03227 × IC-085622 (M × H) and IC-045339 × IC-085622 (M × H). These crosses had high *per se* performance (> six laterals/vine) and also exhibited maximum heterosis of 21.21 per cent. Three of these crosses involved at least one parent with high *gca*, suggesting that one parent must be a good combiner to bring about desired improvement in this trait. These results are in conformity with the findings of and Khattra *et al.* (2000). High sca effects in desired direction for internodal length were observed in IC-045339 × IC-085622, IC-044417 × IC-045339, IC-033227 × IC-470560, IC-044417 × IC-085622 and IC-033227 × IC-470550 in which mostly the parents with M × M, M × L and L × L general combiners were involved. This indicated, specific interaction effects, most likely of complementary nature performing the best (Ram *et al*., 1999).

For days to flowering (both male and female), highly significant negative *sca* effects were observed in IC-045339 × IC-470550 (L × L), IC-044438 × IC-045339 (H × L), IC-045339 × IC-085622 (L × M) and IC-470550 × IC-470558 (L × L) which also had high *per se* performance ranging from 39 to 42 days for male flower and 46 to 53 days for female flower besides high heterosis in desired direction (Table 3). Thus, it indicated the possibility of exploitation of hybrid vigour for these characters. Significant negative *sca* effects for days to male and female flower anthesis were reported by Khattra *et al.* (2000).

For node at which first male and female flower appeared, significant negative *sca* effects were noticed in IC-044438 × IC-045339, IC-045339 × IC-470558, IC-045339 × IC-470560 and IC-044417 × IC-470560. These specific crosses had one of the parents with high *gca* effect. These results are in consonance with that of Dey *et al.* (2010) for node to 1st female flower. Regarding sex ratio, significantly negative *sca* effects were found in IC-044438 × IC-045339, IC-045339 × IC-470560, IC-045339 × IC-470550, IC-045339 × IC-085622 and IC-044438 × IC-470550 in which M × H general combiners were involved. Hence, for such traits, population improvement with recurrent or reciprocal recurrent selection would appear to be highly rewarding. Similar results were reported by Sundaram (2008) and Rajeshwari and Natarajan (2002).

The specific cross combinations identified for number of fruits/vine were IC-044417 × IC-470558 (M × M), IC-044438 × IC-045339 (H × H), IC-033227 × IC-085622 (H × L) and IC-045339 × IC-470550 (H × L). Interestingly these crosses exhibited heterosis as well as high *per se* performance (Table 3). 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 Dey *et al.* (2010). The desirable cross combinations *viz.,* IC-044438 × IC-045339, IC-045339 × IC-085622, IC-044417 × IC-085622 and IC-044417 × IC-470558 were identified with H × M, M × M general combiners for average fruit weight. These specific crosses also showed high *per se* performance and heterotic values. The superiority of M × M and H × H combination may be due to presence of genetic diversity among the parents and there could be some complementary effects indicating the importance of non-additive gene effects. These specific crosses also can be exploited for development of hybrids. These results are in conformity with the results of Ranpise *et al.* (2001) and Jadhav *et al.* (2010).

Significant positive *sca* effects for fruit length were observed in IC-044438 × IC-045339, IC-044417 × IC-470558 and IC-044417 × IC-085622 in which parents with H × H and H × L *gca* were involved. As these crosses had high *per se* value up to 21.00 cm and exhibited heterosis of 40.00 per cent, they can be profitably used in spotting good desirable segregants. Similar results were also reported by Chowdhury and Sikdar (2005) and Yadav *et al.* (2008) in bitter gourd. The crosses, *viz.,* IC-045339 × IC-470560, IC-045339 × IC-085622, IC-045339 × IC-470550, IC-044438 × IC-045339 and IC-045339 × IC-470550 showed highest significant positive *sca* effects for fruit girth. These crosses mostly involved the parents with L × H, L × M and L × L *gca* effects and exhibited high *per se* performance and heterosis 13.73 cm and 24.36 per cent respectively. Superiority of L × L combination might be due to interaction between favourable gene combinations of the parents as reported by Ram *et al.* (1999). For pulp thickness, IC-044438 × IC-470550 (H × L), IC-044438 × IC-045339 (H × L), IC-045339 IC-470560 (L × M) and IC-044417 × IC-470558 (M × M) were superior specific crosses and the significant *sca* effects in desired direction in these promising crosses were due to interaction of positive alleles from good combiner and negative alleles from poor combiner. Thus, it indicates, a better scope for exploitation of hybrid vigour for this character (Dubey and Maurya, 2006 and Jadhav *et al.*, 2010). Significant *sca* effects in desired direction for number of seeds/fruit were recorded in crosses IC-033227 × IC-470550, IC-044438 × IC-470558 and IC-045339 × IC-470560. Khattra *et al.* (2000) also reported few promising crosses with H × L, M × M *gca* parents for this trait.

The cross combinations, *viz.,* IC-0444438 × IC-045339 (H × H), IC-044417 × IC-470558 (M × H), IC-045339 × IC-085622 (H × M), IC-045339 × IC-470550 (H × L) and IC-045339 × IC-470558 (H × H) were identified as superior specific crosses for yield/vine. All these specific crosses exhibited high *per se* value and high heterosis ranging from 50 to 96 per cent (Table 3). Shafiullah and Sikdar (2007) and Rajeshwari and Natarajan (2002) also reported similar type of results. The cross combinations which involved H × M and H × L having higher heterotic values besides higher *per se* performance suggested the possibility of exploiting these crosses for yield improvement though heterosis breeding. However with respect to crosses with H × H and H × M general combiners, pedigree selection could be more profitable.

From all these results it can be concluded that IC-044438, IC-470560, IC-470558 and IC-085622 for yield and yield attributing characters and IC-044438 and IC-470560 for earliness, were found to be good general combiners. With respect to crosses, IC-044438 × IC- 045339 followed by IC-044417 × IC-470558 and IC-045339 × IC-085622 were found to be highly promising due to expressing heterosis (relative heterosis, heterobeltiosis and standard heterosis) and *sca* effects in desirable direction for yield and most of the yield contributing characters. For earliness, the crosses, IC-044438 × IC-045339, IC-045339 × IC-470550 and IC-045339 × IC-470558 were identified as promising ones.

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Table 1: Analysis of variance for combining ability and proportionate gene action in bitter gourd

Source of variation	d.f	Vine length (m)	Number of laterals/ vine	Internodal length (cm)	Days to 1st male flower	Days to 1st female flower	Node number at 1st male flower	Node number at 1st female flower	Sex ratio
GCA	7	0.15**	0.84**	0.41**	11.91**	30.20**	1.34**	5.53**	1.00**
SCA	28	0.07**	0.22**	0.32**	1.91**	4.50**	0.82**	1.56**	0.32**
Error	70	0.00	0.02	0.05	0.57	0.60	0.14	0.25	0.09
σ^2gca		0.01	0.08	0.04	1.13	2.96	0.12	0.53	0.09
σ^2sca		0.07	0.21	0.27	1.34	3.90	0.68	1.31	0.23
σ^2gca/σ^2sca		0.14	0.38	0.15	0.84	0.76	0.18	0.40	0.39

*Significant at 0.05% probability ** Significant at 0.01% probability

Table 1: Contd…..

Source of variation	d.f	No. of fruits/vine	Average fruit weight (g)	Fruit length (cm)	Fruit girth (cm)	Pulp thickness (cm)	Number of seeds/fruit	Yield/ vine (kg)
GCA	7	34.31**	102.51**	4.90**	1.03**	0.05**	2.34*	0.28**
SCA	28	3.99**	49.21**	2.15**	0.75**	0.06**	1.43*	0.07**
Error	70	0.25	4.92	0.05	0.05	0.00	0.81	0.00
σ^2gca		3.41	9.76	0.49	0.10	0.00	0.15	0.03
σ^2sca		3.74	44.29	2.11	0.70	0.06	0.62	0.07
σ^2gca/σ^2sca		0.91	0.22	0.23	0.47	0.07	0.24	0.43

*Significant at 0.05% probability ** Significant at 0.01% probability

Table 2: Estimates of general combining ability (gca) effects in bitter gourd

Sl. No.	Parent	Vine length (m)	Number of laterals/ vine	Internodal length (cm)	Days to 1st male flower	Days to 1st female flower	Node number at 1st male flower	Node number at 1st female flower	Sex ratio
1.	IC-033227	0.06 **	-0.01	-0.10	-0.93 **	-0.34	0.10	-0.20	0.08
2.	IC-044417	-0.04 *	0.02	0.08	1.04 **	-0.36	0.05	0.21	0.25 **
3.	IC-044438	0.13 **	0.23 **	0.08	-1.14 **	-2.12 **	-0.27 *	-0.28	-0.39 **
4.	IC-045339	-0.04 *	0.07	0.15 *	0.68 **	-0.03	0.43 **	0.03	0.13
5.	IC-085622	0.02	0.15 **	0.22 **	0.22	0.64 **	-0.22	0.56 **	-0.21 *
6.	IC-470550	-0.26 **	-0.69 **	-0.37 **	1.33 **	3.40 **	0.53 **	1.29 **	0.54 **
7.	IC-470558	0.05 **	0.04	-0.19 **	0.42	0.78 **	-0.05	-0.35 *	-0.05
8.	IC-470560	0.08 **	0.19 **	0.13	-1.62 **	-1.96 **	-0.58 **	-1.27 **	-0.34 **
	SE(gi) ±	0.02	0.04	0.07	0.22	0.23	0.11	0.15	0.09

*Significant at 0.05% probability ** Significant at 0.01% probability

Table 2: Contd……

Sl. No.	Parent	Number of fruits/vine	Average fruit weight (g)	Fruit length (cm)	Fruit girth (cm)	Pulp thickness (cm)	Number of seeds/ fruit	Yield/ vine (kg)
1.	IC-033227	0.81 **	0.40	0.05	-0.20 **	0.02	-0.12	0.06**
2.	IC-044417	0.30	0.35	0.55 **	0.02	0.03	0.22	0.02
3.	IC-044438	1.40 **	5.79 **	0.83 **	0.33 **	0.12**	0.26	0.22**
4.	IC-045339	0.37 *	-0.38	-0.51 **	-0.51 **	-0.09**	0.00	0.03**
5.	IC-085622	-0.48 **	0.99	0.40 **	0.41 **	0.03*	0.25	-0.02
6.	IC-470550	-4.22 **	-4.47 **	-1.39 **	-0.33 **	-0.09**	-1.14**	-0.37**
7.	IC-470558	0.07	1.25	0.23 **	0.18 **	-0.01	0.29	0.03*
8.	IC-470560	1.76 **	-3.92 **	-0.16 *	0.10	-0.02	0.23	0.03*
	SE(gi) ±	0.15	0.66	0.06	0.07	0.02	0.27	0.01

*Significant at 0.05% probability ** Significant at 0.01% probability

Table 3: Best specific combiner on the basis of significant and desirable directions

Sl. No.	Character	Cross combinations	*Per se* performance	*sca* value	*gca* effect	Heterosis percentage		
						H_1	H_2	H_3
1.	Vine length (m)	IC-044438 × IC-045339	2.77	0.35	H × L	41.34	21.43	10.52
		IC-044417 × IC-470558	2.68	0.33	L × H	34.22	24.66	6.94
		IC-045339 × IC-470550	2.32	0.28	L × L	36.49	31.95	-
		IC-045339 × IC-470560	2.64	0.27	L × H	35.34	16.61	5.39
		IC-044417 × IC-085622	2.52	0.21	L × M	31.47	26.65	0.53
2.	Number of laterals/vine	IC-044438 × IC-045339	7.00	0.74	H × M	18.64	16.67	11.70
		IC-044417 × IC-470558	6.67	0.65	M × M	21.21	17.65	6.38
		IC-033227 × IC-085622	6.60	0.50	L × H	14.45	8.79	5.32
		IC-045339 × IC-085622	6.67	0.48	M × H	12.36	9.89	6.38
		IC-044417 × IC-470550	5.73	0.44	M × L	14.67	7.50	-
3.	Internodal length (cm)	IC-045339 × IC-085622	5.81	-0.81	L × L	-17.31	-16.40	-12.36
		IC-044417 × IC-045339	5.75	-0.74	M × M	-23.28	-19.13	-13.37
		IC-033227 × IC-470560	5.67	-0.62	M × M	-17.26	-16.98	-14.47
		IC-033227 × IC-470550	5.19	-0.59	M × H	-21.79	-19.53	-21.71
		IC-044417 × IC-085622	5.97	-0.59	M × L	-19.51	-14.10	-10.05
4.	Days to 1st male flower	IC-044438 × IC-045339	38.87	-2.42	H × L	-9.33	-0.66	-9.33
		IC-033227 × IC-044417	39.73	-2.13	H × L	-7.31	-2.46	-7.31
		IC-045339 × IC-085622	40.73	-1.91	L × M	-4.98	-3.48	-4.98
		IC-045339 × IC-470550	42.20	-1.56	L × L	-1.56	-6.64	-1.56
		IC-033227 × IC-470550	40.67	-1.49	H× L	-5.13	-0.15	-5.13
5.	Days to 1st female flower	IC-045339 × IC-470550	50.73	-4.29	M × H	-9.57	-7.65	0.52
		IC-044438 × IC-045339	46.27	-3.24	H × M	-7.53	-	-9.28
		IC-470550 × IC-470558	53.40	-2.43	L × L	-3.55	-0.13	-
		IC-045339 × IC-085622	50.07	-2.20	M × L	-6.24	-	-1.83
		IC-044417 × IC-470560	47.40	-1.93	M × H	-1.59	-	-
6.	Node number at 1st male flower	IC-045339 × IC-470558	7.07	-1.76	L× M	-27.15	-16.53	-19.70
		IC-044438 × IC-045339	7.27	-1.34	H × L	-24.04	-11.34	-17.42
		IC-044417 × IC-470560	8.93	-0.99	H × H	-	-	-
		IC-045339 × IC-470560	7.27	-1.04	L × L	-17.74	-	-17.42
		IC-033227 × IC-470560	6.93	-1.04	M × H	-12.97	-	-21.21
7.	Node number at 1st female flower	IC-044438 × IC-045339	12.67	-2.12	H × M	-20.34	-15.14	-12.84
		IC-044417 × IC-470560	12.00	-1.96	M × H	-15.69	-0.58	-17.43
		IC-033227 × IC-470550	14.40	-1.72	M × L	-11.48	-4.82	-0.92
		IC-033227 × IC-044417	13.67	-1.37	M × M	-13.32	-9.65	-5.96
		IC-045339 × IC-085622	14.53	1.09	M × L	-13.66	-13.51	-
8.	Sex ratio	IC-044438 × IC-045339	6.54	-0.82	H × M	-21.93	-11.38	-12.34
		IC-045339 × IC-470560	6.62	-0.80	M × H	-19.92	-7.54	-11.29
		IC-045339 × IC-470550	7.58	-0.72	M × L	-15.59	-10.72	-
		IC-045339 × IC-085622	6.90	-0.65	M × H	-17.62	-6.38	-7.56
		IC-044438 × IC-470550	7.15	-0.62	H × L	-9.86	-3.12	-4.16

Table 4: Contd……..,

Sl. No	Character	Cross combinations	*Per se* Performance	sca effects	gca effects	Heterosis percentage		
						H_1	H_2	H_3
9.	Number of fruits/ Vine	IC-044417 × IC-470558	25.40	4.59	M × M	37.55	31.83	5.25
		IC-044438 × IC-045339	25.40	3.19	H × H	30.70	17.59	5.25
		IC-033227 × IC-085622	23.47	2.70	H × L	21.38	17.33	-
		IC-045339 × IC-470550	18.73	2.15	H × L	22.98	8.49	-
		IC-045339 × IC-085622	22.13	1.81	H × L	23.19	18.57	-
10.	Average fruit weight (g)	IC-044438 × IC-045339	98.57	22.82	H × M	51.41	34.43	32.36
		IC-045339 × IC-085622	79.42	8.47	M × M	24.28	11.97	6.64
		IC-044417 × IC-470558	67.36	8.35	M × M	16.20	16.09	7.81
		IC-044417 × IC-085622	78.59	6.91	M × M	12.19	10.80	5.52
		IC-044438 × IC-470550	78.26	6.60	H × L	19.79	6.73	5.08
11.	Fruit length (cm)	IC-044438 × IC-045339	20.99	4.49	H × L	40.00	20.94	19.92
		IC-044417 × IC-470558	19.61	2.65	H × H	25.11	20.43	12.08
		IC-044417 × IC-085622	19.37	2.24	H × H	25.75	23.03	10.70
		IC-033227 × IC-085622	17.61	0.98	M × H	11.16	10.46	0.66
		IC-033227 × IC-044438	17.90	0.88	M × H	7.75	3.38	2.51
12.	Fruit girth (cm)	IC-045339 × IC-470560	12.43	1.61	L × M	24.36	10.68	7.10
		IC-045339 × IC-085622	13.73	1.15	L × H	23.61	10.46	5.91
		IC-045339 × IC-470550	13.45	1.08	L× L	24.28	17.29	-
		IC-044438 × IC-045339	13.53	1.03	H × L	22.25	9.55	4.37
		IC-045339 × IC-470558	13.37	1.01	L× H	20.46	7.74	3.08
13.	Pulp thickness (cm)	IC-044438 × IC-470550	4.33	0.66	H × L	26.34	22.64	17.75
		IC-044438 × IC-045339	4.06	0.39	H × L	22.66	14.91	10.33
		IC-045339 × IC-470560	3.87	0.34	L × M	17.97	11.30	5.25
		IC-044417 × IC-470558	3.97	0.32	M × M	11.30	8.36	7.97
		IC-045339 × IC-085622	3.83	0.26	L × H	16.63	9.94	4.17
14.	Number of seeds/fruit	IC-033227 × IC-470550	15.00	-3.34	M × H	-20.49	-11.76	-23.99
		IC-044438 × IC-470558	18.20	-1.96	M × M	-8.85	-6.52	-7.77
		IC-045339 × IC-470560	18.13	-1.70	M × M	-12.12	-11.69	-8.11
15.	Yield/vine (kg)	IC-044438 × IC-045339	2.50	0.81	H × H	96.03	58.48	39.32
		IC-044417 × IC-470558	2.03	0.54	M × H	60.24	54.01	13.17
		IC-045339 × IC-085622	1.76	0.29	H × M	52.64	32.44	-
		IC-045339 × IC-470558	1.69	0.18	H × H	54.09	38.70	-
		IC-045339 × IC-470550	1.28	0.18	H × L	48.31	31.67	-