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Combining Ability Studies in Bitter Gourd (*Momordica charantia* L.)

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An experiment was under taken to study the combining ability analysis using ten parental lines and their F_1 hybrids of bitter gourd through full diallel analysis for yield and its contributing characters. The mean squares due to GCA (General Combining ability) and SCA (Specific Combining Ability) were significant for all the characters. The ratio of $\sigma_2 g/\sigma_2 s$ was lesser than one for the characters viz., yield of fruits per vine, ascorbic acid content and iron content thereby indicating preponderance of non- additive (dominance) variance in expression of these traits. The parents CO-1 and Preethi were the best general combiners as it showed desirable GCA effects in favourable direction for most of the traits. The highest SCA effects observed in MC-105 x MC-10 for total fruit yield per plant and number of fruits per plant and for iron content, days to first female flower appearance and days to first harvest, Preethi x MC-30 showed desirable SCA effects in favourable direction. The best general combiners and desirable cross combinations may be further used in the breeding programme for bitter gourd crop improvement.

Key words: *Momordica charantia* L., yield, earliness and quality characters, GCA,SCA, RCA

Bitter gourd is an important cucurbitaceous vegetable and ranks all other cucurbits by its nutritive value and its curative nature against diabetics (Dey *et al*., 2010). Compared to other cucurbits bitter gourd is rich in ascorbic acid and iron content. The present study was under taken by using a new set of diverse parental combinations with the aim of obtaining hybrids have higher yield, earliness and fruit quality. Information on combining ability facilitates the choice of suitable parents for hybridization programme to develop promising F_1 hybrids. The diallel cross helps in determining both general and specific combining abilities of parents and hybrid combinations respectively. Further it helps in formulating the breeding methodology for crop improvement. Hence, the present study was carried out to identify the productive parents and potential hybrids of bitter gourd through combining ability analysis.

Materials and Methods

The experimental material are of ten parental lines viz., CO-1 and Green Long from Coimbatore, Tamil Nadu; Priyanka and Preethi from Kerala; Karala Rakshuse (KR), Uchha Small Long (USL) and Uchha Bolder (UB) from West Bengal; MC-30, MC-105 and MC-10 from Palur, Tamil Nadu were chosen from germplasm collection maintained at Research Farm, Department of Vegetable Crops, Horticultural College and Research Institute, Coimbatore.

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The parent Uchha Bolder (UB) is round and very small fruited type while all other are medium to long fruited type. Ten parental lines were crossed in all possible combinations, including reciprocals to produce F_1 seeds by hand pollination using the method Diallel cross (Method I, Model 1 Griffing (1956)).

During January - April, 2008 all the seeds of 90 cross combinations and 10 parents were sown in randomized block design with two replications. Five plants were selected and tagged for recording the observations on different characters *viz*., days to first female flower appearance, node of first female flower appearance, number of female flowers per vine, sex ratio, days to first harvest, fruit length, fruit girth, individual fruit weight, fruit flesh thickness, number of fruits per vine, yield of fruits per vine, ascorbic acid and iron content. All the cultural operations and plant protection measures were carried out as per the recommendations of crop production guide,TNAU (2004). The combining ability analysis was calculated by the method suggested by Griffing (1956).

Results and Discussion

In the present study, mean squares due to GCA and SCA were significant for all the characters, indicate variation in parents and crosses and thus significant combination of additive and non- additive gene effects in the expression of the characters. The ratio of $\sigma_2 g/\sigma_2 s$ was lesser than one for the

Table 1. Analysis of variance for combining ability

Character	Mean squares of			GCA/
	GCA	SCA	RCA	SCA
Days to first female flower appearance	24.42**	19.35**	14.89**	1.26
Node of first female flower appearance	36.39**	10.02**	9.67**	3.63
Number of female flowers per vine	1246.12**	49.05**	26.36**	25.40
Sex ratio	170.78 **	16.44 **	14.80 **	10.39
Days to first harvest	148.37**	40.27**	52.69**	3.68
Fruit length	158.03**	14.38**	16.80**	10.99
Fruit girth	12.01**	4.69**	6.47**	2.56
Individual fruit weight	3022.75**	135.62**	195.01**	22.29
Fruit flesh thickness	0.029**	0.013**	0.014**	2.23
Number of fruits per vine	1511.91**	60.48**	41.43**	24.99
Yield of fruits per vine	0.320**	0.356**	0.308**	0.898
Ascorbic acid content	74.28**	286.65**	323.25**	0.259
Iron content	0.112**	0.203**	0.145**	0.552

** Significant at 1 per cent level

characters viz., yield of fruits per vine, ascorbic acid content and iron content thereby indicating preponderance of non - additive (dominance) variance in expression of these traits. The variance due to reciprocal effects was also significant for all the characters studied (Table 1). The reciprocal variation might be due to cytoplasmic inheritance and its interaction with nuclear genes. Similar significant reciprocal effects were reported earlier in bitter gourd by Gopalakrishnan (1986) and Devadass (1993).

Estimates of general combining ability effects (Table 2) showed that the parent CO- 1 was good general combiner for most of the traits viz., days to first female flower appearance, days to first harvest, fruit length, fruit girth, individual fruit weight, fruit flesh thickness, yield of fruits per vine and ascorbic acid content. The parent Preethi was also found to be good general combiner for nine characters viz., days to first female flower appearance, node of first female flower appearance, sex ratio, fruit girth, individual fruit weight, fruit flesh thickness, yield of fruits per

Table 2. Estimates of *gca* values of parents for ancillary characters of bitter gourd

Parents	Days to first female flower appearance	Node of first female flower appearance	Number of female flowers per vine	Sex ratio	Days to first harvest	Fruit length	Fruit girth	Individual fruit weight	Fruit flesh thickness	Number of fruits per vine	Yield of fruits per vine	Ascorbic acid content	Iron content
CO -1	-2.55**	0.66**	-4.92**	2.33**	-3.11**	3.92**	0.32**	1.91**	0.06**	-2.55**	0.09**	2.51**	0.00
Green Long (GL)	0.43**	0.90**	-4.05**	3.23**	-3.22**	2.38**	-0.15**	5.27**	0.00	-3.82**	-0.07**	0.07	0.03**
Priyanka	0.28*	1.69**	-5.03**	2.37**	-0.17	0.53**	0.37**	6.36**	-0.00**	-4.08**	-0.12**	-4.17**	-0.06**
Preethi	-0.34**	-2.09**	-1.70**	-0.47**	1.74**	-2.09**	1.12**	7.73**	0.03**	-1.34**	0.12**	1.96**	0.14**
Karala Rakshuse (KR)	-0.19	0.75**	-3.04**	2.45**	-0.04	-0.03	0.27**	4.49**	0.03**	-3.72**	-0.08**	0.74**	0.04**
Uchha Small Long (USL)	1.04**	0.53**	-1.87**	-0.64**	2.77**	-1.22**	-1.17**	-7.55**	-0.07**	-2.45**	-0.10**	-1.46**	0.06**
Uchha Bolder (UB)	-0.29*	-2.16**	21.60**	-8.86**	-3.47**	-5.93**	-1.01**	-33.10**	-0.03**	23.44**	0.17**	1.01**	-0.03**
MC-30	-0.59**	1.04**	-0.81**	-1.38**	1.07**	2.60**	-0.66**	10.81**	-0.01**	-2.67**	0.10**	0.64**	-0.07**
MC- 105	1.80**	-0.76**	-0.12	-0.18**	2.16**	-0.51**	0.69**	2.88**	-0.02**	-2.51**	-0.10**	1.77**	-0.03**
MC-10	0.40**	-0.57**	-0.05	1.16**	2.27**	0.35**	0.20**	1.21**	0.01**	-0.32**	-0.01**	-3.07**	-0.07**
SE (g_i)	0.1117	0.04	0.08	0.04	0.13	0.04	0.02	0.18	0.001	0.06	0.003	0.16	0.03

* Significant at 5 per cent level, ** Significant at 1 per cent level

vine, ascorbic acid and iron content. The parents Uchha Bolder and MC-30 were good general combiners for eight and seven characters respectively. Parents Karala Rakshuse, MC-105 and MC -10 were good general combiners for varying set of five characters each, followed by Green Long for four characters, Priyanka for three characters and Uchha Small Long for two characters. In bitter gourd with different set of parents these types of results were reported by Lawande and Patil (1990).

From specific combining ability effects (Table 3 & 4), it was observed that out of 90 cross combinations, 26 for days to first female flower appearance, 43 for node of first female flower appearance, 45 for number of female flowers per vine, 52 for sex ratio, 26 for days to first harvest , 32 for fruit length, 40 for fruit girth, 38 for individual fruit weight, 26 for fruit flesh thickness, 40 for numbers of fruits per vine, 39 for yield of fruits per vine, 40 for ascorbic acid content and 29 for iron content exhibited significant SCA effects in desirable direction, indicating presence of non additive type of gene interaction. Thus it indicates the possibility of exploitation of hybrid vigour in these characters. Similar results of specific combining ability effects in the crosses of bitter gourd were also recorded by Sundaram (2006).

Earliness

In bitter gourd the flowering time measured as the days to opening of first female flower and nodal position of first female flower are considered as the indices of earliness. Earliness indicated by negative significant values of combining ability. Significant

Table 3. Estimates of *sca* values of hybrids for ancillary characters of bitter gourd

Hybrids	Days to first female flower appearance	Node of first femaleflower appearance	Number of female flowers per vine	Sex ratio	Days to first harvest	Fruit length	Fruit girth
CO -1 x GL	-4.41**	2.04**	-3.13**	1.69**	-0.57	1.50**	0.24**
CO -1 x Priyanka	-1.36**	1.41**	4.24**	2.99**	-0.74	2.28**	-0.25**
CO -1 x Preethi	0.83*	0.18	-2.10**	1.22**	1.39**	-0.23	0.29**
CO -1 x KR	4.17**	-1.92**	-1.26**	3.05**	-2.64**	0.31*	-1.31**
CO -1 x USL	1.88**	-2.39**	-1.20**	0.1	7.99**	-0.2	0.23**
CO -1 x UB	-0.74*	0	-1.88**	-3.48**	-4.04**	-6.07**	-0.44**
CO -1 x MC - 30	1.85**	2.96**	2.14**	-2.07**	3.35**	-1.51**	0.20*
CO -1 x MC - 105	0.76*	-4.94**	-0.16	1.63**	-2.80**	4.34**	0.96**
CO -1 x MC - 10	-2.55**	-1.99**	-0.94**	2.09**	-3.69**	-1.12**	-0.07
GL x CO -1	0.59	-0.61**	-2.40**	-0.06	0.05	-1.89**	-0.69**
GL x Priyanka	1.73**	-1.39**	-2.50**	3.27**	-2.11**	1.07**	1.63**
GL x Preethi	1.68**	-2.27**	3.55**	-4.19**	-2.55**	1.27**	0.37**
GL x KR	0.96**	-0.96**	-0.38	0.17	1.41**	0.81**	1.16**
GL x USL	1.87**	0.78**	-3.82**	2.14**	0.46	1.12**	-2.13**
GL x UB	-1.60**	-2.38**	0.25	-4.30**	3.67**	-2.68**	-0.95**
GL x MC - 30	-2.48**	-1.88**	1.13**	-1.39**	1.45**	-3.48**	-1.37**
GL x MC - 105	1.19**	0.06	3.98**	-3.75**	2.10**	-0.92**	-1.48**
GL x MC - 10	-4.30**	0.29*	3.43**	-2.30**	-4.45**	-0.94**	0.52**
Priyanka x CO -1	-0.67	1.47**	5.83**	-7.32**	-6.05**	-1.94**	0.62**
Priyanka x GL	2.39**	0.01	4.70**	-4.50**	-3.44**	1.02**	4.22**
Priyanka x Preethi	4.09**	1.60**	-2.95**	2.97**	0.91*	1.17**	0.72**
Priyanka x KR	-1.25**	2.60**	0.3	-1.79**	0.97*	-0.56**	-1.88**
Priyanka x USL	1.36**	1.98**	0.21	-1.55**	-0.63	-3.43**	-1.37**
Priyanka x UB	-1.19**	-2.81**	-0.43	-1.11**	-3.44**	-1.60**	0.37**
Priyanka x MC - 30	0.12	1.27**	4.76**	-3.05**	3.72**	-1.35**	0.29**
Priyanka x MC - 105	-1.75**	-0.60**	0.91**	-3.01**	1.78**	-1.20**	-0.74**
Priyanka x MC - 10	-3.24**	1.07**	0.33	-0.67**	1.59**	2.98**	0.79**
Preethi x CO -1	2.00**	-3.24**	7.16**	-6.71**	-8.10**	-0.35*	1.70**
Preethi x GL	0.93*	-1.35**	-5.41**	2.10**	4.98**	-6.11**	-0.38**
Preethi x Priyanka	2.68**	-6.00**	2.89**	-2.50**	2.43**	-4.50**	-1.77**
Preethi x KR	1.00**	0.02	-1.04**	-1.43**	5.01**	-0.73**	-0.15
Preethi x USL	-2.24**	-1.25**	0.90**	-0.64**	1.24**	-0.19	-0.16
Preethi x UB	-1.48**	-0.72**	4.23**	0.79**	-0.51	0.87**	0.37**
Preethi x MC - 30	-4.97**	0.35**	8.43**	-2.82**	-4.91**	-2.84**	0.43**
Preethi x MC - 105	-0.68*	-2.02**	-3.83**	1.98**	5.86**	-2.26**	-0.01
Preethi x MC - 10	5.20**	1.54**	0.93**	1.39**	6.67**	1.20**	-0.21*
KR x CO -1	6.48**	-2.40**	2.44**	-0.45**	2.98**	-1.36**	-2.46**
KR x GL	4.40**	-2.39**	2.67**	-3.51**	1.05*	-2.19**	-2.36**
KR x Priyanka	1.81**	-2.85**	5.82**	-5.19**	-5.39**	-6.16**	-1.10**
KR x Preethi	0.47	1.49**	0.01	0.39*	1.49**	-1.20**	0.58**
KR x USL	1.39**	-2.10**	5.53**	-4.66**	-1.00*	0.85**	0.81**
KR x UB	1.35**	2.05**	-0.92**	-2.06**	0.58	5.74**	0.23**
KR x MC - 30	-3.25**	-1.23**	-0.34	0.66**	1.24**	-1.23**	2.22**
KR x MC - 105	-2.34**	0.76**	1.12**	-1.42**	1.99**	-5.17**	-1.23**
KR x MC - 10	-1.36**	2.07**	1.95**	-1.73**	0.32	2.03**	-1.04**
USL x CO -1	4.53**	-2.90**	-0.28	0.61**	1.46**	-4.45**	-0.38**
USL x GL	3.52**	-1.01**	3.85**	-5.54**	10.99**	-2.67**	-0.12
USL x Priyanka	3.76**	-2.00**	1.01**	0.01	10.03**	0.66**	-0.33**
USL x Preethi	1.51**	2.00**	2.02**	-0.91**	6.54**	0.46**	1.70**
USL x KR	2.68**	1.02**	-1.50**	-0.77**	11.62**	0.03	-1.28**
USL x UB	0.63	2.52**	-1.71**	0.23	1.88**	1.95**	4.51**
USL x MC - 30	-2.66**	-1.91**	2.14**	0.81**	0.71	0.17	-1.69**
USL x MC - 105	1.60**	1.26**	2.55**	-0.09	-1.29**	-0.25*	-0.92**
USL x MC - 10	0.97**	-1.96**	-1.25**	2.51**	2.63**	1.53**	-0.38**
UB x CO -1	2.59**	-0.59**	-6.50**	0.24	-1.25**	-0.13	-1.54**
UB x GL	1.76**	-0.48**	0.5	-0.40*	-2.04**	0.75**	1.24**

Hybrids	Days to first female flower appearance	Node of first femaleflower appearance	Number of female flowers per vine	Sex ratio	Days to first harvest	Fruit length	Fruit girth
UB x Priyanka	-0.19	-2.48**	-2.18**	-1.98**	4.09**	-2.05**	0.24**
UB x Preethi	2.92**	2.97**	-1.08**	-0.90**	2.28**	0.74**	1.64**
UB x KR	-0.05	-1.44**	-0.83**	-1.51**	-0.91*	-3.68**	1.64**
B x USL	-3.42**	-0.68**	-0.28	-0.45**	-5.71**	-3.34**	-2.49**
UB x MC - 30	3.68**	1.83**	-7.47**	2.69**	2.08**	2.23**	1.90**
UB x MC - 105	0.70*	2.04**	-7.24**	2.45**	3.75**	2.92**	-1.53**
UB x MC - 10	1.34**	0.99**	-8.99**	2.59**	1.92**	-2.47**	-1.14**
MC - 30 x CO -1	-1.18**	-1.65**	6.99**	-5.39**	2.99**	-2.65**	-0.04
MC - 30 x GL	-0.35	-1.05**	3.13**	-2.99**	7.04**	-2.49**	-2.05**
MC - 30 x Priyanka	-0.08	0.90**	4.60**	-2.42**	0.81	2.03**	-1.88**
MC - 30 x Preethi	1.84**	1.82**	-6.52**	2.98**	8.57**	4.70**	1.04**
MC - 30 x KR	-1.98**	-3.53**	2.61**	-2.56**	3.27**	-3.45**	1.72**
MC - 30 x USL	-0.84*	-2.58**	4.76**	-1.59**	-0.38	-5.70**	1.06**
MC - 30 x UB	1.99**	1.40**	-0.09	0.98**	4.58**	1.79**	2.21**
MC - 30 x MC - 105	2.63**	0.81**	-4.49**	5.14**	2.41**	-0.13	0.54**
MC - 30 x MC - 10	4.65**	-1.37**	-0.18	-1.40**	0.65	-0.67**	-1.43**
MC - 105 x CO -1	4.94**	5.70**	2.49**	-2.60**	4.82**	-6.94**	-4.44**
MC - 105 x GL	2.62**	-0.99**	2.68**	-0.97**	1.04*	2.16**	0.09
MC - 105 x Priyanka	-0.41	-1.23**	0.65*	0.91**	1.81**	-2.13**	-0.84**
MC - 105 x Preethi	0.64	2.86**	2.22**	-0.78**	-6.73**	2.23**	-1.68**
MC - 105 x KR	5.45**	-0.44**	-0.57*	-0.16	-1.06*	-1.30**	-1.20**
MC - 105 x USL	-0.5	1.08**	4.26**	-2.19**	-2.36**	-5.03**	0.84**
MC - 105 x UB	1.52**	1.01**	-0.09	1.13**	7.14**	1.58**	-1.73**
MC - 105 x MC - 30	-2.00**	0.92**	0.04	0.36*	5.54**	-0.41**	-2.98**
MC - 105 x MC - 10	0.24	1.02**	9.48**	-3.96**	-3.53**	0.07	3.00**
MC - 10 x CO -1	0.64	0.01	2.69**	-2.79**	3.47**	-5.10**	1.98**
MC - 10 x GL	1.51**	-2.58**	2.01**	0.83**	-2.54**	1.20**	2.55**
MC - 10 x Priyanka	0.56	-0.99**	4.04**	-1.56**	1.69**	-2.09**	-1.37**
MC - 10 x Preethi	-0.24	2.67**	5.94**	-2.20**	-1.48**	0.49**	-0.02
MC - 10 x KR	-1.93**	-0.04	3.53**	-0.39*	-0.39	0.41**	0.01
MC - 10 x USL	-2.40**	0.1	2.09**	-0.35*	-2.27**	-0.65**	1.80**
MC - 10 x UB	2.57**	0.43**	0.15	1.51**	5.45**	-0.15	1.50**
MC - 10 x MC - 30	0.53	1.01**	-0.5	1.09**	1.96**	-2.71**	-0.57**
MC - 10 x MC - 105	2.61**	2.42**	1.05**	-0.30*	7.63**	-1.90**	-0.76**
SE (s_{ij})	0.34	0.12	0.23	0.13	0.39	0.12	0.08
SE (r_{ij})	0.37	0.14	0.26	0.15	0.43	0.13	0.09

** -Significant at 0.01 *- Significant at 0.05

SCA effects observed by the best cross combination Preethi × MC-30 for days to first female flower appearance (-4.97) and for days to first harvest (-4.91); for node of first female flower appearance CO-1 x MC-105 had favourable values (-4.94).

Yield characters

Yield is the most important character in any crop breeding programme. The significance of crosses for yield and related characters were observed *viz*., MC-105 x MC-10 for number of female flowers per vine (9.48); Karala Rakshuse x Uchha Small Long for sex ratio (-4.66) and individual fruit weight (24.66); Karala Rakshuse x Uchha Bolder (5.74) for fruit length; Uchha Small Long x Uchha Bolder (4.51) for fruit girth; CO -1 x Priyanka (0.15) for fruit flesh thickness; the crosses MC-105 x MC -10 (13.11), Preethi x MC -30 (8.66), Karala Rakshuse x Uchha Small Long (7.32) and Preethi x Uchha Bolder (7.01) for number of fruits per vine; MC-105 x MC -10 (1.07), Karala Rakshuse x Uchha Small Long (0.93) and Preethi x MC – 30 (0.70) for yield of fruits per vine.

Quality characters

Quality parameters are also an important factor in hybrid development; in bitter gourd iron and ascorbic acid are the major quality factors. Significant SCA effects were observed by Karala Rakshuse x MC -105 (24.99) for ascorbic acid content, MC-105 x MC -10 (0.49) for iron content.

From these studies, it is evident that SCA effects of certain crosses were related with GCA of their parents, as the best cross combination for most of the characters involved at least one parent with high or average GCA effects for particular traits. The results are in line with the earlier findings of Munshi and Sirohi (1993) and Mishra *et al*. (1994) in bitter gourd. However the parents MC-105 and MC-10 both were the medium performed parents, medium × medium leads to high performance, the cross had

Table 4. Estimates of *sca* values of hybrids for ancillary characters of bitter gourd

Hybrids	Individual fruit weight	Fruit flesh thickness	Number of fruits per vine	Yield of fruits per vine	Ascorbic acid content	Iron content
CO -1 x GL	6.85**	-0.01	-2.86**	-0.37**	-0.89	-0.29**
CO -1 x Priyanka	2.59**	0.15**	6.55**	0.46**	21.02**	0.03**
CO -1 x Preethi	4.06**	0.01*	5.31**	0.48**	0.31	-0.07**
CO -1 x KR	-1.89**	-0.02**	0.24	-0.20**	4.16**	-0.19**
CO -1 x USL	-10.54**	-0.06**	-3.59**	-0.33**	-0.71	0.12**
CO -1 x UB	2.69**	-0.08**	-12.31**	-0.19**	-1.94**	-0.16**
CO -1 x MC - 30	8.29**	0.05**	0.32	0.04**	-18.53**	-0.32**
CO -1 x MC - 105	1.04	0.08**	-3.05**	-0.32**	-26.72**	-0.05**
CO -1 x MC - 10	-2.86**	-0.05**	5.76**	0.11**	8.62**	0.42**
GL x CO -1	-1.32*	-0.09**	0.61**	0	-0.9	-0.16**
GL x Priyanka	1.85**	0.01**	0.74**	0.03**	-1.19*	-0.19**
GL x Preethi	-9.87**	0.03**	4.84**	0.22**	-0.06	0.16**
GL x KR	-6.70**	0.01	-2.11**	-0.26**	-8.84**	-0.13**
GL x USL	-0.94	-0.04**	-1.15**	-0.01	-12.28**	-0.11**
GL x UB	-10.74**	0.02**	-0.56**	0.08**	9.44**	0.09**
GL x MC - 30	3.70**	-0.09**	-1.11**	-0.16**	3.58**	-0.18**
GL x MC - 105	6.43**	-0.01**	-2.71**	-0.22**	-6.75**	0.23**
GL x MC - 10	-3.32**	0.07**	3.46**	0.28**	-1.17*	-0.04**
Priyanka x CO -1	5.42**	0.01	6.34**	0.67**	11.42**	0.40**
Priyanka x GL	8.91**	0.09**	-2.62**	-0.13**	14.18**	0.23**
Priyanka x Preethi	1.78**	-0.05**	-3.36**	-0.24**	-20.47**	-0.05**
Priyanka x KR	-2.85**	-0.08**	0.47*	-0.22**	-23.74**	-0.09**
Priyanka x USL	-10.64**	-0.12**	-1.97**	-0.44**	-8.59**	0.03**
Priyanka x UB	-5.70**	0.01**	-2.49**	-0.05**	13.20**	0
Priyanka x MC - 30	-1.68**	0.04**	1.90**	0.13**	0.87	-0.02*
Priyanka x MC - 105	-5.69**	-0.11**	-1.83**	-0.12**	-2.36**	-0.14**
Priyanka x MC - 10	2.98**	-0.05**	-2.14**	-0.12**	-5.91**	-0.19**
Preethi x CO -1	1.54*	0.02**	3.37**	0.16**	9.01**	0.33**
Preethi x GL	-3.36**	-0.07**	-8.48**	-0.92**	-17.89**	-0.77**
Preethi x Priyanka	2.64**	-0.07**	0.97**	-0.05**	6.53**	-0.21**
Preethi x KR	7.78**	0.01	-7.65**	-0.49**	-1.60**	-0.47**
Preethi x USL	-9.01**	-0.11**	-4.18**	-0.45**	-4.15**	-0.27**
Preethi x UB	-0.7	0.07**	7.01**	0.19**	0.21	-0.15**
Preethi x MC - 30	-5.39**	0.12**	8.66**	0.70**	10.05**	0.46**
Preethi x MC - 105	0.33	-0.07**	-5.71**	-0.43**	-7.41**	-0.17**
Preethi x MC - 10	3.98**	-0.07**	-4.75**	-0.55**	5.96**	-0.26**
KR x CO -1	2.91**	-0.01**	2.50**	0.09**	10.47**	0.17**
KR x GL	3.65**	-0.12**	0.89**	0.09**	21.12**	-0.28**
KR x Priyanka	-10.19**	-0.02**	0.89**	-0.13**	5.98**	-0.13**
KR x Preethi	1.30*	-0.03**	-0.62**	0.01	8.28**	0.06**
KR x USL	24.66**	0.11**	7.32**	0.93**	8.73**	0.42**
KR x UB	-8.13**	0.14**	2.23**	0.13**	8.42**	-0.13**
KR x MC - 30	-2.38**	0.02**	3.03**	0.22**	0.48	-0.13**
KR x MC - 105	4.62**	-0.13**	-1.28**	-0.16**	24.99**	0.03*
KR x MC - 10	-3.27**	-0.03**	-2.38**	-0.26**	-14.70**	-0.24**
USL x CO -1	14.12**	-0.05**	-3.94**	0.05**	10.51**	-0.30**
USL x GL	-6.53**	-0.12**	-3.38**	-0.33**	13.52**	-0.17**
USL x Priyanka	-22.36**	-0.16**	3.94**	0.03*	-23.27**	0.10**
USL x Preethi	-15.29**	-0.17**	0.11	-0.19**	6.50**	-0.04**
USL x KR	-4.93**	-0.10**	-11.06**	-1.03**	-18.78**	-0.59**
USL x UB	5.07**	0.06**	-0.79**	0.18**	3.03**	0.07**
USL x MC - 30	17.44**	0.01*	-3.95**	-0.01	1.67**	0.03**
USL x MC - 105	-1.83**	-0.01*	3.64**	-0.07**	-2.20**	-0.40**
USL x MC - 10	-8.76**	0.04**	-0.18	-0.02*	2.63**	0.14**
UB x CO -1	-3.37**	-0.04**	-12.89**	-0.66**	0.24	0.17**
UB x GL	13.52**	-0.12**	-1.00**	0.25**	7.66**	0.04**
UB x Priyanka	-14.38**	-0.01**	-1.19**	-0.22**	-6.81**	-0.44**
UB x Preethi	-4.12**	-0.05**	-2.04**	-0.28**	-9.63**	-0.25**
UB x KR	7.94**	0	-0.91**	-0.03**	-3.30**	-0.10**
B x USL	8.86**	-0.09**	-1.95**	0.16**	-7.47**	-0.13**
UB x MC - 30	4.57**	-0.11**	-4.81**	0.07**	-4.24**	-0.06**
UB x MC - 105	7.49**	0	-0.99**	0.23**	1.31**	-0.12**
UB x MC - 10	6.66**	-0.06**	-9.92**	-0.20**	-17.32**	-0.23**

Hybrids	Individual fruit weight	Fruit flesh thickness	Number of fruits per vine	Yield of fruits per vine	Ascorbic acid content	Iron content
MC - 30 x CO -1	8.81**	-0.02**	0.95**	0.17**	14.82**	-0.06**
MC - 30 x GL	-2.91**	-0.22**	2.18**	0.41**	11.86**	0.11**
MC - 30 x Priyanka	11.90**	0.06**	3.00**	0.34**	5.10**	-0.06**
MC - 30 x Preethi	-8.42**	-0.06**	-7.60**	-1.05**	-14.83**	-0.38**
MC - 30 x KR	-5.61**	-0.04**	2.52**	-0.07**	-11.02**	0.02*
MC - 30 x USL	-11.80**	-0.05**	1.68**	0.08**	13.02**	-0.11**
MC - 30 x UB	10.92**	0.01*	0.08	-0.08**	-6.44**	-0.18**
MC - 30 x MC - 105	-10.00**	-0.06**	-2.38**	-0.53**	0.36	-0.11**
MC - 30 x MC - 10	-4.09**	-0.05**	-3.68**	-0.58**	-5.80**	-0.28**
MC - 105 x CO -1	-1.22*	-0.09**	2.74**	0.26**	-6.28**	0.31**
MC - 105 x GL	-0.66	-0.11**	3.76**	0.13**	23.00**	-0.05**
MC - 105 x Priyanka	7.10**	0.03**	4.01**	0.22**	8.40**	-0.27**
MC - 105 x Preethi	-5.01**	-0.06**	2.27**	0.07**	-14.50**	0.05**
MC - 105 x KR	-0.78	-0.10**	-1.04**	0.01	8.65**	0.18**
MC - 105 x USL	-29.90**	-0.10**	7.25**	-0.09**	20.17**	-0.07**
MC - 105 x UB	2.77**	-0.12**	0.79**	-0.01	10.76**	0.21**
MC - 105 x MC - 30	-9.04**	0.03**	1.29**	-0.06**	6.08**	-0.10**
MC - 105 x MC - 10	-3.35**	0.07**	13.11**	1.07**	5.27**	0.49**
MC - 10 x CO -1	3.58**	-0.16**	-3.10**	-0.51**	-4.91**	-0.20**
MC - 10 x GL	-0.24	0.04**	9.16**	0.53**	2.04**	-0.25**
MC - 10 x Priyanka	-6.05**	-0.08**	3.28**	0.30**	-25.00**	-0.20**
MC - 10 x Preethi	-5.80**	0	4.42**	0.14**	2.00**	-0.26**
MC - 10 x KR	-0.58	-0.06**	1.36**	0.07**	-9.85**	-0.15**
MC - 10 x USL	24.15**	-0.09**	3.10**	0.29**	0.85	-0.07**
MC - 10 x UB	-13.42**	-0.07**	-0.85**	-0.35**	-17.51**	0.26**
MC - 10 x MC - 30	-6.58**	0.15**	0.17	-0.08**	-23.61**	0
MC - 10 x MC - 105	6.35**	-0.12**	-5.19**	-0.24**	-18.89**	-0.59**
SE (s_{ij})	0.55	0.003	0.20	0.01	0.48	0.01
SE (r_{ij})	0.61	0.004	0.23	0.01	0.54	0.01

* Significant at 5 per cent level ** Significant at 1 per cent level

significant SCA effects for three important characters *viz*., number of female flowers per vine, number of fruits per vine, yield of fruits per vine and iron content followed by Karala Rakshuse x Uchha Small Long (medium × poor) for sex ratio, individual fruit weight and yield of fruits per vine. With respect to earliness Preethi x MC-30 (good × good) had favourable SCA effects for days to first female flower appearance and days to first harvest. These three cross combinations with desirable SCA could be well utilized in heterosis breeding as reported earlier by Sirohi and Choudhury (1977) and Tewari *et al*., (2001) in bitter gourd.

In future breeding programmes, the desirable general combiners *viz*., Preethi, Uchha Bolder and MC-30 may be used for crop improvement studies of bitter gourd. The cross combinations MC-105 × MC-10 and Preethi × MC-30 needs test verification in different locations for assessing yield stability.

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