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Combining Ability Analysis for Fruit Yield and its Component Traits in Bitter Gourd (*Momordica charantia* L.)

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ABSTRACT: During the summer of 2017, a diallel set of seven parents and their 21 F_1s were evaluated at the experimental field of Vegetable & Floriculture, Bihar Agricultural University, Sabour, Bihar to assess the combining ability and degree of heterosis for fruit yield and its component traits. The importance of both additive and non-additive genetic components for these traits was confirmed by combining ability analysis, which demonstrated that both general and specific combining ability differences were important for all of the characters. The per se performance was found to be a good indicator of the parents' GCA effects and the crosses' SCA impacts. Pusa Aushadhi and Konkon Tara were found as the best general combiners for yield and its components features among the parents assessed. The superior specific cross combinations Konkan Tara × Gangajali Small, Konkan Tara and Pirpaiti local, and Thailong × Gangajali Small seemed suitable for further use in bitter gourd breeding. The findings also suggested that cross selection should be based on per se performance combined with significant SCA effects. With more than 25% standard heterosis (over standard check variety Pusa Rasdar), the crosses Gangajali Small × Pusa Rasdar, Karela Safed × Pusa Rasdar, Konkon Tara × Gangajali Small, Thailong × Pusa Aushadhi, and Konkon Tara × Pirpaiti Local give additional scope for exploitation of hybrid vigour in bitter gourd.

Keywords: Bitter gourd, combining ability, GCA and SCA, diallel, fruit yield.

INTRODUCTION

Bitter gourd (*Momordica charantia* L.) is a popular cucurbit in the Cucurbitaceae family. This crop is said to have originated in India, with China serving as a secondary centre of diversity. The Latin term *'Momordica'* means 'to bite,' and relates to the jagged corners of the bitter melon plants' leaves, which appear to have been bitten. Karela is the indigenous name, although it's also known as Balsam pear or bitter cucumber in English. Bitter melon has long served as both a meal and a medication. Bitter gourd possesses comparatively high concentrations of ascorbic acid and iron as compared to other cucurbits (Behera, 2005). In a variety of culinary recipes, the immature fruits and soft vine tips are used. After soaking in salt water to eliminate part of the bitterness, the fruits and shoots are cooked, fried, or pickled. The nutritional value of bitter gourd fruits is similar to that of other cucurbits, with the difference that it is substantially higher in folate and vitamin C. Vitamin A can be found mainly in the vine tips. Bitter melon's active ingredients are unknown, however we do know that it contains alkaloids, glycosides, peptides, acids, cucurbitins, charantin, cucurbitacins, momordine, momorcharins, and proteins (Raman and Lao 1996). Charantin, insulin-like peptide, cucurbutanoids, momordcin, and oleanolic acids are suggested to be the major ingredients responsible for the hypoglycemic characteristics (Wei *et al*., 2013). Crop enhancement approaches include methods for increasing yield potential and quality components. Due to various of factors, full exploitation of heterosis through the development of hybrids in bitter gourd has yet to be commercialized. The shape, size, and colour of fruits show the most diversity, which provides a lot of opportunity for heterosis breeding to increase yield (Bhatt *et al*., 2017). It's long been recognised that crossing nature and heterosis in cross pollinated crops can lead to higher yields. Determining the relative relevance of general combining ability and specific combining ability for quantitative features determining yield and its components is extremely useful when selecting parents for superior hybrid production. The effects of general combining ability (GCA) and specific combining ability (SCA) help in the selection of superior parents and hybrids, respectively. The data obtained during the process will help in determining the amount of heterosis in F_1 hybrids. The heterosis and combining ability indicate the kind of gene action involved, which aids in the selection of appropriate breeding methodology and parameters for the bitter gourd crop development programme.

MATERIALS AND METHODS

During the Kharif of 2016, seven different parents, Thailong (P_1), Konkon Tara (P_2), Pusa Aushadhi (P_3), Pirpaiti Local (P_4), Karela Safed (P_5), Gangajali Small (P_6), and Pusa Rasdar (P_7), were crossed in a diallel fashion avoiding reciprocals. During in the summer of 2017, the $21F_1$'s and their nine parents were tested in an RBD with 3 replicates at the Bihar Agricultural University's experimental farm of Vegetable and Floriculture in Sabour, Bihar. The plot was 9.0 m^2 in size. Irrigation, weeding, stacking, and other intercultural operations were completed on time and as needed. Five randomly selected labeled plants from each treatment were observed for yield and yield attributing features, such as node at which the first female flower occurs, and node at which the first male bloom appears. Number of primary branches, days to first fruit harvest, days to last harvest, number of fruits per plant, yield of marketable fruits per plant (kg), fruit weight (g), fruit length (cm), fruit girth (cm), number of seeds/fruit, internodal length (cm), days to 50% flowering. TSS was determined using a digital refractometer and ascorbic acid (mg/100 g) was determined using the AOAC (2001) technique. For five fruits of each treatment, a fine slice of bitter gourd was squashed and the reading was taken. Total chlorophyll content ($\mu mol/m^{2)}$ was estimated as per Arnon, (1949). Griffing's Method 2 Model 1 was used to examine the data for combining ability (1956). Hayes *et al.* (1955) proposed a method for calculating heterosis based on the better parent and the check parent .

RESULTS AND DISCUSSION

The mean sum squares owing to GCA and SCA were positive response for all sixteen yield and quality characters in the analysis of variance for combining ability (Table 1). This revealed that both additive and non-additive gene action was involved in the heredity of bitter gourd yield and yield component traits. For all traits except total chlorophyll, the SCA variance factor was found to be larger than the GCA variance component, indicating that non-additive gene action predominates in trait inheritance. Similar genetic structure was found in bitter gourd by Mishra *et al.*, (1994); Rahman *et al.,* (2002); Acharya *et al.,* (2019). Combining ability is a measure of gene function, which can be additive or non-additive. Griffing, (1956) proposed that GCA accounted for both additive and additive × additive interactions. Parents with a positive GCA effect are thought to have more favourable genes for the traits in discussion. Table 2 shows the estimations of parents' general combining ability (GCA) effects. Pusa Aushadhi was discovered to be the best and most reliable combiner in terms of fruit yield per plant, fruit length, node number during which first female flower appears, earliness, and days to first fruit harvest. In terms of fruit output, internodal length, days to last fruit harvest, number of fruits per plant, and fruit weight, parent Konkan Tara would have been the best overall combiner once again.

In addition to vine length, number of primary branches, less number of seeds, and total chlorophyll, the parent Thailong was determined to be an excellent general combiner for ascorbic acid content and TSS. Pusa Rasdar was found to be a good general combiner for fruit girth. The parents' per se performance was shown to be a direct reflection of their individual GCA effects in the majority of cases. The parents with the maximum GCA effect for a specific trait also had a high mean for that character. In bitter gourd, Khattra *et al.,* (2000); Acharya *et al.* (2019) got similar significant GCA effects upon fruit yield, components, and quality parameters. The GCA effects of parents were estimated, and the parent Pusa Aushadhi and Konkon Tara have been the best general combiners for yield and its components features among the seven parents. In above, parents could be considered in a bitter gourd hybridization programme. Konkan Tara × Gangajali Small were considered to be the best particular combiner for fruit yield per plant, fruit weight, fruit length, and fruit girth based on SCA effects (Table 3). Again, the cross combination Konkan Tara and Pirpaiti local was observed to be the best specific combiner for node number at which the first female flower appears, internodal length, early in days to 50% flowering, and early in days to first fruit harvest, while the cross combination Thailong × Gangajali Small had been found to be a good specific combiner for getting more fruits per plant and days to first fruit harvest. Thailing × Konkan Tara had high desirable SCA effects for smaller number of seeds and high overall chlorophyll content, whereas Gangajali tiny × Pusa Rasdar had high ideal SCA benefits for primary branches. In Pusa Aushadhi × Pusa Rasdar, appropriate estimates of SCA effects for ascorbic acid were found, while in Pusa Aushadhi × Gangajali Small, desirable estimates of TSS were found. As a result, the above combinations were the most effective in improving the respective snakegourd characters. In bitter gourd, Khattra *et al.* (2000); Acharya *et al.,* (2019) reported comparable results. Another key point to note is that, in addition to having significant SCA effects, the mentioned hybrids also had a significant amount of heterosis in terms of fruit yield per plant when compared to their check parents (Table 4). The hybrids that performed well on their own also had favourable high SCA impacts. This explained why hybrid's individual performance was mirrored in their unique SCA impacts. It's noteworthy that the crossovers with more favourable SCA effects in the desired direction also had higher heterosis than the check parent. As a result, hybrid mean performance may be used as a criteria for SCA effects, and bridge selection on per se performance would be feasible.

Table 1: Analysis of variances and combining ability for yield, its component and quality traits in bitter gourd.

Source	DF	Node no. 1st female flower	Inter nodal length (cm)	Days to 50% flowering	Vine length (cm)	Primary branches	1st fruit harvest	Last fruit harvest	No. of fruit/ plant	Fruit yield /plant (kg)	Fruit weight (gm)	fruit length (cm)	Fruit girth (cm)	No..of seeds/ fruit	Aascorbic acid	TSS	Total Chlorophyll
Rep.	1	0.10	0.04	0.16	0.01	0.83	1.02	0.09	0.87	0.01	0.34	0.20	0.04	0.01	0.61	0.02	0.01
Treat.	27	3.02**	1.10**	3.04**	0.46**	1.15**	10.31**	20.88**	17.21**	0.25**	262.38**	8.37**	8.33**	22.78**	398.24**	2.30**	0.26**
Error	27	0.61	0.26	0.79	0.02	0.60	2.89	12.73	5.58	0.03	25.98	1.02	1.20	2.04	17.93	0.04	0.01
GCA	7	4.15**	1.24**	4.20**	0.14**	0.51**	8.58**	8.88**	17.99**	0.15**	44.98**	6.43**	2.91**	26.29**	379.22**	2.46**	0.34**
SCA	21	12.80**	4.11**	12.84**	0.65**	13.18**	190.07**	713.39**	90.99**	0.59**	369.74**	14.90**	15.97**	51.48**	532.20**	3.42**	0.11**
GCA/SCA		0.32	0.30	0.32	0.21	0.03	0.04	0.01	0.19	0.25	0.12	0.43	0.18	0.51	0.71	0.71	3.09

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

Table 2: Estimates of general combining ability (GCA) of different parents on yield ,quality and its components traits in bitter gourd.

Parents	NFFF	IL	D50F	VL	PB	DFH	DLH	FrP	YP	FrW	FrL	FrG	NS	AA	TSS	Tchl
Thailong	8.39**	3.87**	8.39**	0.26**	9.21**	39.77**	76.97**	24.17**	0.12	40.98**	7.97**	7.85**	15.47**	60.96**	2.67**	1.23**
Konkon Tara	8.66**	3.21**	8.72**	0.13	8.64**	39.66**	77.86**	28.10**	0.37**	44.86**	7.43**	7.89**	20.33**	55.02**	2.79**	-0.94**
Pusa Aushadhi	7.09**	4.16**	7.09**	0.05	8.52**	37.10**	74.95**	25.10**	0.47**	43.84**	8.98**	8.37**	19.39**	53.59**	2.69**	-1.15**
Pirpaiti Local	8.85**	4.24**	8.85**	0.02	8.56**	38.87**	77.62**	25.30**	0.22*	39.65**	8.77**	7.52**	17.92**	49.43**	2.64**	-1.16**
Karela Safed	8.56**	4.13**	8.63**	0.04	8.69**	38.07**	76.97**	24.47**	0.14	42.21**	8.68**	8.14**	18.01**	47.50**	3.23**	-1.52**
Gangajali Small	9.16**	4.21**	9.16**	0.13	8.82**	38.92**	77.12**	26.63**	0.19	39.19**	6.76**	8.91**	16.31**	62.97**	4.06**	-1.25**
Pusa Rasdar	8.69**	3.85	8.69**	-0.15	8.73**	38.14**	76.34**	24.98**	0.27*	40.07**	8.61**	8.99**	17.81**	62.60**	3.01**	-0.99**
Gi	0.16	0.10	0.18	0.03	0.16	0.35	0.74	0.49	0.03	1.06	0.21	0.22	0.29	0.88	0.04	0.01
gi-gj	0.24	0.16	0.28	0.05	0.24	0.53	1.12	0.74	0.05	1.61	0.32	0.34	0.45	1.33	0.06	0.01

Abbreviation: NFFF (Node number at 1st female flower appear); IL (Inter nodal length), D50F (Days to 50% flowering); VL(Vine length), PB (Number of primary branches); DFH (Days to first fruit harvest); DLH (Days to last fruit harvest); NFP(Number of fruits per plant); YP (yield of marketable fruit per plant); FrW (Fruit weight); FrL (Fruit length); FrG (Fruit girth), NS (Number of seeds per fruit), AA (Ascorbic acid); TSS, Tchl. (Total chlorophyll); * and ** Significant at 5 % and 1 % probability level respectively

Table 3: Effects of specific combining ability for yield, quality and its component traits in bitter gourd.

Source of variation	NFFF	IL	D50F	VL	PB	DFH	DLH	NFP
Thalong × Konkon Tara	-5.79**	-2.32**	-5.85**	-0.04	-6.70**	-27.97**	-53.37**	-22.60**
Thailong × Pusa Aushadhi	-0.95*	-0.19	-0.94	0.05	-0.86	1.33	3.98	0.15
Thailong × Pirpaiti Local	0.53	0.61*	0.54	0.08	1.01*	1.49	4.24*	0.32
Thailong × Karela Safed	-7.87**	-4.08**	-7.94**	-1.71**	-7.71**	-29.08**	-57.18**	-20.26**
Thailong × Gangajali Small	2.59**	1.46**	2.59**	0.06	2.55**	11.60**	24.40**	12.31**
Thailong × Pusa Rasdar	2.29**	1.40**	2.29**	0.98**	2.79**	9.40**	19.20**	6.35**
Konkon Tara × Pusa Aushadhi	1.12*	-0.25	1.07*	0.18	0.60*	5.24**	7.89**	1.70
Konkon Tara × Pirpaiti Local	-8.59**	-4.68**	-8.65**	-1.56**	-7.42**	-29.88**	-59.83**	-21.42**
Konkon Tara × Karela Safed	-0.04	0.10	0.50	0.19	1.54**	0.60	3.20	-0.21
Konkon Tara × Gangajali Small	2.52**	1.54**	2.45**	0.53**	3.33**	7.66**	17.46**	7.49**
Konkon Tara × Pusa Rasdar	3.24**	1.40**	3.17**	0.53**	3.03**	6.75**	16.55**	7.89**
Pusa Aushadhi × Pirpaiti Local	0.81	0.42	0.82	0.12	0.29	-1.34	1.26	0.54
Pusa Aushadhi × Karela Safed	1.24*	0.72*	1.20*	0.27**	0.28	-0.74	2.21	0.29
Pusa Aushadhi × Gangajali Small	2.95**	1.82**	2.95**	-0.07	2.44**	8.48**	19.63**	7.94**
PusaAushadhi × Pusa Rasdar	3.01**	1.37**	3.01**	-0.21*	2.20**	9.51**	20.66**	8.98**
Pirpaiti Local × Karela Safed	1.25**	0.35	1.20*	-0.70**	0.31	1.05	2.11	4.45**
Pirpaiti Local × Gangajali Small	2.94**	1.04**	2.94**	0.29**	1.53**	7.51**	16.76**	7.64**
Pirpaiti Local × Pusa Rasdar	1.22*	1.64**	1.22*	-0.12	1.69**	8.03**	18.28**	6.02**
Karela Safed × Gangajali Small	2.71**	1.46**	2.65**	0.27**	2.39**	8.24**	16.34**	7.58**
Karela Safed × Pusa Rasdar	1.74**	0.79*	1.67**	-0.80**	2.41**	9.86**	17.96**	7.13**
Gangajali Small × Pusa Rasdar	2.35**	1.04**	2.34**	-1.22**	3.34**	9.17**	16.97**	5.47**
S.E.(+-)	0.30	0.13	0.39	0.01	0.30	1.44	6.36	2.79

Abbreviation: NFFF (Node number at first female flower appear); IL (Inter nodal length); D50F (Days to 50% flowering); VL(Vine length), PB (Number of primary branches); DFH (Days to 1 st fruit harvest); DLH (Days to last fruit harvest); NFP (Number of fruits per plant); * and ** Significant at 5 % and 1 % probability level respectively.

Cont….

Source of variation	YP	FrW	FrL	FrG	NS	AA	TSS	Tchl
Thalong × Konkon Tara	0.17	-32.00	-6.24**	-5.50**	-19.57**	-41.95**	-1.95**	1.05**
Thailong × Pusa Aushadhi	0.29**	-1.44	-0.33	0.39	1.12	8.98**	0.60**	0.08**
Thailong × Pirpaiti Local	0.33**	3.61	0.57	0.31	1.46	6.81**	0.72**	0.17**
Thailong × Karela Safed	-1.87**	-33.40**	-7.67**	-6.89**	-12.19**	-41.69**	-3.55**	-0.57**
Thailong × Gangajali Small	-0.06	5.29**	0.30	3.55**	1.68	20.31**	2.70**	-0.33**
Thailong × Pusa Rasdar	-0.16	8.92**	2.53**	3.24**	4.82**	15.46**	1.02**	0.00
Konkon Tara × Pusa Aushadhi	0.02	18.09**	0.43	2.09**	1.34	-3.02	0.48**	0.24**
Konkon Tara × Pirpaiti Local	-1.27**	-12.95**	-5.21**	-4.73**	-12.71**	-49.37**	-4.10**	-0.26**
Konkon Tara × KarelaSafed	0.17	13.31**	0.73	2.52**	2.15*	-13.62**	1.63**	-0.19**
Konkon Tara × Gangajali Small	0.41**	35.89**	5.30**	4.45**	7.51**	8.47**	2.47**	0.06**
Konkon Tara × Pusa Rasdar	-0.27*	5.44	3.64**	4.48**	6.64**	18.10**	0.33**	-0.34**
Pusa Aushadhi × Pirpaiti Local	-0.56**	-3.03	0.75	2.21**	-0.14	-1.00	0.32*	-0.13**
Pusa Aushadhi × Karela Safed	-.15	-5.40	1.34*	0.94	0.89	21.61**	-0.31*	0.45**
Pusa Aushadhi × Gangajali Small	-0.09	5.31	0.21	2.81**	6.09**	30.99**	2.78**	-0.34**
Pusa Aushadhi × Pusa Rasdar	0.03	7.57*	2.11**	3.25**	3.89**	32.31**	0.96**	-0.37**
Pirpaiti Local × Karela Safed	0.23*	-1.06	0.59	2.22**	-0.66	-0.29	0.29*	0.45**
Pirpaiti Local × Gangajali Small	0.29**	8.71*	1.51*	2.76**	4.03**	26.51**	2.70**	-0.34**
Pirpaiti Local × Pusa Rasdar	-0.48**	9.97**	1.53*	2.58**	3.58**	30.66**	0.49**	-0.37**
Karela Safed × Gangajali Small	0.21*	7.94*	0.89	3.36**	1.04	28.98**	2.16**	-0.41**
Karela Safed × Pusa Rasdar	0.37**	8.12*	1.84**	2.44**	2.09*	29.78**	1.15**	-0.52**
Gangajali Small × Pusa Rasdar	0.52**	14.23**	3.34**	2.50**	4.89**	19.22**	1.17**	-0.22**
S.E. (+-)	0.01	12.99	0.51	0.60	1.02	8.96	0.22	0.06

Abbreviation: YP (yield of marketable fruit per plant); FrW (Fruit weight); FrL (Fruit length), FrG (Fruit girth); NS (Number of seeds per fruit); AA (Ascorbic acid); TSS, Tchl. (Total chlorophyll); * and ** Significant at 5 % and 1 % probability level respectively.

Table 4: *Per se* performance, sca effects and heterosis of superior hybrids on fruit yield in bitter gourd.

Cross combination	*Per se* performance (fruit yield/plant)	sca effects	Heterosis	
			Heterobeltiosis	Standard heterosis
Thalong × Konkon Tara	2.65	0.17	1.92**	15.22**
Thailong × Pusa Aushadhi	2.92	0.29**	-16.45**	26.96**
Thailong × Pirpaiti Local	2.85	0.33**	11.33**	23.91**
Thailong × Karela Safed	1.97	-1.87**	-12.44**	-14.35**
Thailong × Gangajali Small	2.24	-0.06	-0.44*	-2.61**
Thailong × Pusa Rasdar	2.22	-0.16	-3.48**	-3.48**
Konkon Tara × Pusa Aushadhi	2.85	0.02	-18.45**	23.91**
Konkon Tara × Pirpaiti Local	2.89	-1.27**	12.89**	25.65**
Konkon tara × Karela Safed	2.67	0.17	18.67**	16.09**
Konkon Tara × Gangajali Small	3.12	0.41**	38.67**	35.65**
Konkon Tara × Pusa Rasdar	2.35	-0.27*	2.17**	2.17**
Pusa Aushadhi × Pirpaiti Local	2.12	-0.56**	-39.34**	-7.83**
Pusa Aushadhi × Karela Safed	2.45	-.15	-29.90**	6.52**
Pusa Aushadhi × Gangajali Small	2.56	-0.09	-26.75**	11.30**
Pusa Aushadhi × Pusa Rasdar	2.76	0.03	-21.03**	20.00**
Pirpaiti Local × Karela Safed	2.57	0.23*	0.39*	11.74**
Pirpaiti Local × Gangajali Small	2.68	0.29**	4.69**	16.52**
Pirpaiti Local × Pusa Rasdar	1.99	-0.48**	-13.48**	-13.48**
Karela Safed × Gangajali Small	2.53	0.21*	17.13**	10.00**
Karela Safed × Pusa Rasdar	3.20	0.37**	39.13**	39.13**
Gangajali Small × Pusa Rasdar	3.35	0.52**	45.65**	45.65**

* and ** Significant 5% and 1% level respectively.

Sharma *et al.*, (1993) in bottle gourd, Kumar and Singh (1997) in bottle gourd, and Khattra *et al.*, (2000); Bhatt *et al.* (2017); Acharya *et al.*, (2019) in bitter gourd validated past findings. According to the findings, cross selection should be based on *per se* performance combined with significant SCA effects. With more than 25% standard heterosis (over standard check variety Pusa Rasdar), the crosses Gangajali Small × Pusa Rasdar, Karela Safed × Pusa Rasdar, Konkon Tara × Gangajali Small, Thailong × Pusa Aushadhi and Konkon Tara × Pirpaiti Local offer more opportunities for enslavement of hybrid vigour in bitter gourd.

Conflict of Interest: None.

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