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Estimation of heterosis and combining ability for biochemical traits in bitter gourd (*Momordica charantia* L.)

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Abstract
The present study was conducted to estimate the effects of combining ability and heterobeltiosis in bitter gourd under rainy season, 2013 at Vegetable research farm, Department of Vegetable Science, PAU, Ludhiana. The seven line and six tester which were mated in a line x tester manners to produce forty two hybrid. The sca effect greater than gca effects that indicates that non addative effect for carotene, vitamin-C, total Sugar and reducing sugars. Parents PAUBG-13 and PAUBG-50 Significant gca for Vitamin-c and total Sugar and cross combination Punjab-14 x PAUBG-50 significant sca effect for total and reducing sugar. The heterosis over batter parent siganificant in crosses PAUBG-4 x PAUBG-50 (18.58%), Punjab-14 x PBIG-56 (52.92%) and Punjab-14 x PAUBG-50 (-57.73) for vitamin-C, carotene and total sugar, respectively.

Keywords: carotene, total sugar, vitamin-c, line, tester and heterosis

Introduction

Bitter gourd (*Momordica charantia* L.) is an important vegetable crop belonging to the family cucurbitaceae, genus *Momordica* (Jeffrey, 1990) [12]. It is a large genus with many species of annual or perennial climbers among all the species; *Momordica charantia* L. is cultivated largely due to its nutritional and medicinal properties (Satkar *et al.*, 2013). Bitter gourd has been used in various herbal medicine systems for a long time because of its disease preventing and health promoting phyto chemical compounds like, carotenoids, phenolics and high amount of momordicin antioxidant, antimicrobial, antiviral, anti-hepatotoxic, anti-ulcerogenic properties and also has the ability to lower blood sugar in treatment of type-2 daibetes (Welthinda *et al.*, 1986 and Raman and Lan, 1996) [20, 29]. These medical activities are attributed to an array of biologically active plant chemicals, including triterpenes, pisteins and steroids (Grover and Yadav, 2004). Ethno-medical reports of *M. charantici*a indicate that it is used in folkloric medicine for treatment of various ulcers, diabetes, and infections (Gurbu *et al.*, 2000; Scartezzini and Speroni, 2000 and Beloin *et al.*, 2005) [10, 23, 5]. The bitterness of most cucurbits is mainly due to cucurbitacins (Decker-Walters, 1999). The bitterness of bitter gourd is due to the cucurbitacin like alkaloid momordicine and triterpene glycosides (momordicoside K and L) (Jeffrey, 1980 and Okabe *et al.*, 1982) [11, 18]. These compounds lack the oxygen function at C-1l that characterizes 'true' cucurbitacins (Neuwinger, 1994) [17] and are the bitterest compounds in the plant kingdom (Johns 1990). In addition, juice of *M. charantia* drawn directly from fruit traditionally has been used for medicinal purposes worldwide. Likewise, the extracted juice from leaf, fruit and even whole plant are routinely used for treatment of wounds, infections, parasites (e.g., worms), measles, hepatitis, and fevers (Behera *et al.*, 2008b) [4].

There are a number of cultivars with wide range of variability in size, shape and colour of fruits available in this country (Behera, 2008a) [3]. Due to the existence of wide variability, monoecious nature, conspicuous and convenient flowers and large number of seeds per fruit, bitter gourd can serve as the most potent material for the exploitation of heterosis on commercial scale. Due to efforts of vegetable breeders, improved varieties and hybrids have been developed. Breeding for nutritional and medicinal quality typically emphasizes accessions with relatively high vitamin C content, carotene and total sugar (Day *et al.*, 2006 and Kumar *et al.*, 2014) [15]. The heterosis and combining ability studies are prerequisite in any plant breeding programme, which provides the desired information regarding the varietal improvement or exploiting heterosis for commercial purposes. Desirable combining ability and heterosis has been reported for many of the economical attributes in bitter gourd (Kumar *et al.*, 2014; Singh *et al.*, 2013 and Thangamani *et al.*, 2011) [15, 28]. Therefore, this study was conducted to generate information about general, specific combining ability and heterosis for different quality characters.

Material and Methods

The experimental plant material for comprised of seven lines (Punjab-14, PAUBG-1, PAUBG-4, PAUBG-13, WBBG-28, DBG-35 and DBG-45), six testers (PAUBG-50, PAUBG-20, Pusa Do Mausami, VR-1, Pusa Vishesh and PBIG-56), 42 F_1 hybrids and one checks (Prachi) was sown in plug tray on 3rd July 2013. The transplanting was done in the field on 1st August 2013 in a Randomized Block Design with three replications. The seven plants were grown on raised beds of width 1.5 m at plant to plant spacing of 45 cm. The recommended NPK fertilizer doses and cultural practices along with plant protection measures were followed using recommended package of practices (Anonymous 2012). Data were recorded on five randomly selected vines for four characters viz. Vitamin-C (mg/100g) by Albrecht (1993) [1] method, Carotene content (mg/100g) by Ranganna (1986) [21] method and Total sugar (g/100g) by Dubios *et al.* (1956) [8] method and reducing sugar (g/100g). The data were compiled for analysis of variance of different traits using method suggested by Panse and Sukhatme (1986) [19]. The data recorded was statistically analyzed following standard procedures for the estimation of components of genetic variation. Combining ability analysis was done in the line x tester fashion as given by Kempthorne (1957) [14].

Results and Discussion

The parental genotypes are selected not only on the basis of their *per se* performance but combining ability effects also play an important role in the selection. Genetic constitution of the parents involved in hybridization governs the nature of gene action in hybrids. It is therefore necessary to assess the genetic potentialities of the parents in hybrid combination through systematic studies in relation to general and specific combining abilities, which are due to additive and non-additive gene effects respectively. The variance due to lines and variance due to tester and their interaction were significantly different for all the characters. The *sca* effects were greater than *gca* effects that indicates the non-additive gene effect in governing the inheritance of carotene, vitamin-C, total sugar and reducing sugar in bitter gourd (Table 1). The testers to a greater contribution extent for vitamin-C, carotene, moisture content, total sugar and reducing sugar. Similar results were found by Singh *et al.* (2006), Sundharaiya and Shakila (2011) [26] and Kumara *et al.* (2011) [15].

The female parents Punjab-14 (12.18), DBG-35 (11.39),PAUBG-13 (5.84) and male parents Pusa Vishesh (7.2), VR-1 (3.12), PAUBG-50 (2.44) are recorded significant gca effect for vitamin-C(Table-2) and the cross combinations Punjab-14 x PAUBG-20 (24.88), DBG-45 x VR-1 (21.48)and PAUBG-4 x PAUBG-50 (20.57) recorded significant positive *sca* effects for Vitamin-C (Table-3).Similarly result finding by Thangamani *et al.* (2011) [28] and Dey *et al.* (2010) [7]. The male parent Pusa Do Mausami (0.35) showed significant positive *gca*effects (Table-2) and crossesPunjab-14 x PBIG-56 (0.94), PAUBG-1 x PBIG-56 (0.61), DBG-35 x Pusa Vishesh or DBG-45 x Pusa Do Mausami (0.54) recorded as good combiners due to significant positive *sca* effects for carotene (Table-3). The female parent PAUBG-13(-1.43) and male parents, Pusa Do Mausami, Pusa Vishesh and PAUBG-50 were observed as very good combiners due to significant negative *gca* effects (-0.66 -0.54 and -0.44 respectively) (Table-2) and crosses Pnjab-14 x PAUBG-50 (-2.84), WBBG-28 x VR-1 (-2.47), and DBG-45 x PAUBG-50 (-2.35)showed significant negative *sca* effects for total sugar and (Table-3)and the female parent PAUBG-4 (-0.24), DBG-35 (-0.23)and male parent PAUBG-50 (-0.14) showed significant negative*gca* effects whereas, cross combination PAUBG-1 x VR-1, Punjab-14x PAUBG-50 and PAUBG-13 x Pusa Do Mausami (-0.94, -0.93 and -0.93 respectively). Similarly result finding for carotene, vitamin-c, total and reducing sugar by Kumar *et al.* (2014) [15].

Significant heterosis for all quality character studied was manifested by the hybrids. Hetrerosis for vitamin-C varied among genotypes and it ranged from 18.52% (PAUBG-4 x PAUBG-50) to -33.33% (WBBG-28 x Pusa Do Mausami) over better parent, whereas it was varied from 4.55% (Punjab-14 x PAUBG-20) to -36.36% (WBBG-28 x Pusa Do Mausami) over Prachi. The highest value of positive and significant heterosis was found in hybrid PAUBG-4 x PAUBG-50 (18.52 %) as presented in Table 4. These results are in consonance with Thangamani *et al.* (2011) [27] and Kumar *et al.* (2014) [15]. The magnitude heterosis for carotene varied significantly among genotypes and it ranged ranged from 52.92% (Punjab-14 x PBIG-56) to -81.92% (PAUBG-1 x Pusa Vishesh) over better parent, whereas the magnitude of heterosis over Prachi, it ranged from 21.22% (Punjab-14 x PBIG-56) to -81.34% (Punjab-14 x PAUBG-50) (Table-4). Significantly heterosis for total sugar varied from -57.73% (Punjab-14 x PAUBG-50) to 81.13% (DBG-35 x VR-1) over better parent, whereas heterosis over Prachi, it ranged from -70.57 % (Punjab-14 x PAUBG-50) to -11.43% (DBG-35 x VR-1) (Table-4). The magnitude heterosis reducing sugar varied significantly among genotypes and it ranged from -53.41% (DBG-45 x Pusa Do Mausami) to 79.77% (PAUBG-1 x Pusa Vishesh) over better parent and The magnitude of heterosis ranged from -60.43% (PAUBG-13 x Pusa Do Mausami) to -4.01% (DBG-35 x Pusa Do Mausami) over Prachi-14 (Table-4). These result for Vitamine-C, Carotene, Total and Reducing sugar agreement with Kumar *et al.* (2014) [15] and Thangamani and Pugalendhi 2013) [28].

Table 1: Genetic component for different quality traits of bitter gourd in rainy season

Genetic Component	Vitamin C (mg/100g)	Carotene (mg/100g)	Total sugars (g/100g)	Reducing sugars (g/100g)
Components of genetic variance				
Msg	773.57	0.69	9.05	0.99
Mse	122.72	0.003	0.042	0.016
$\bar{X}$	134.58	1.16	6.28	2.53
$\sigma^2 gca$	27.66	-0.01	0.04	-0.03
$\sigma^2 sca$	165.53	0.25	2.93	0.38

$\sigma^2 gca / \sigma^2 sca$	0.17	-0.03	0.01	-0.08
Contributions (%) of Line, Tester and their interactions to Total Variance				
Lines	1.39	0.23	0.03	0.11
Testers	502.25	171.54	61.77	55.65
Lines x Testers	109.37	89.63	111	48.29

Msg: Mean sum square of genotype, Mse: Mean sum square of error, X: General mean,

Table 2: *GCA* effects of female and male parents for quality traits of bitter gourd in rainy season

S. No	Source	Vitamin C (mg/100g)	Carotene (mg/100g)	Total sugars (g/100g)	Reducing sugars (g/100g)
		Female Parents			
1	Punjab-14	12.18**	-0.06	-0.03	0.3*
2	PAUBG-1	-2.89*	0.02	-0.11	0.03
3	PAUBG-4	-5.27**	0.13	0.24	-0.24
4	PAUBG-13	5.84**	0.18	-1.43**	0
5	WBBG-28	-12.01**	0.06	0.04	0.09
6	DBG-35	11.39**	-0.31**	0.45*	-0.23
7	DBG-45	-9.24**	-0.03	0.83**	0.05
	CD (p=0.05)	2.4	0.19	0.36	0.26
	CD (p=0.01)	3.2	0.25	0.48	0.34
	Male Parents				
1	PAUBG-50	2.44*	0.02	-0.44*	-0.14
2	PAUBG-20	-7.42**	-0.02	0.65**	0.28*
3	Pusa Do Mausami	-2.66*	0.35**	-0.66**	-0.05
4	VR-1	3.12**	-0.08	1.05**	0.02
5	Pusa Vishesh	7.2**	-0.13	-0.54**	-0.13
6	PBIG-56	-2.66*	-0.15	-0.06	0.02
	CD (p=0.05)	2.35	0.18	0.35	0.25
	CD (p=0.01)	3.09	0.24	0.46	0.33

*Significant at 5%, **Significant at 1%

Table 3: *SCA* effects of hybrids for different quality traits of bitter gourd in rainy season

S. No	Source	Vitamin-C (mg/100g)	Carotene (mg/100g)	Total sugars (g/100g)	Reducing sugars (g/100g)
1	Punajab-14 x PAUBG-50	-20.68**	-0.84**	-2.84**	-0.93**
2	Punjab-14 x PAUBG-20	24.88**	-0.55**	0.81**	0.54**
3	Punjab-14 x Pusa Do Mausami	-6.06**	-0.43**	1.03**	0.22
4	Punjab-14 x VR-1	-14.22**	0.40**	-0.94**	0.25
5	Punjab-14 x Pusa Vishesh	7.88**	0.48**	2.30**	0.37
6	Punjab-14 x PBIG-56	8.22**	0.94**	-0.36	-0.46*
7	PAUBG-1 x PAUBG-50	11.05**	0.10	1.93**	0.39*
8	PAUBG-1 x PAUBG-20	-5.27**	0.28	-0.60	-0.24
9	PAUBG-1 x Pusa Do Mausami	-7.65**	0.05	-0.49	0.41*
10	PAUBG-1 x VR-1	-13.43**	-0.34*	0.97**	-0.94**
11	PAUBG-1 x Pusa Vishesh	-3.23**	-0.71**	-0.58*	0.34
12	PAUBG-1 x PBIG-56	18.53**	0.61**	-1.23**	0.05
13	PAUBG-4 x PAUBG-50	20.57**	0.53**	-0.68*	0
14	PAUBG-4 x PAUBG-20	-17.17**	0.51**	1.53**	-0.06
15	PAUBG-4 x Pusa Do Mausami	16.15**	-0.19	-1.29**	0.20
16	PAUBG-4 x VR-1	5.61**	-0.35*	0.93**	0.40*
17	PAUBG-4 x Pusa Vishesh	-12.75**	0.30*	-1.68**	-0.44*
18	PAUBG-4 x PBIG-56	-12.41**	-0.80**	1.19**	-0.10
19	PAUBG-13 x PAUBG-50	-4.81**	0.06	0.53*	0.88**
20	PAUBG-13 x PAUBG-20	-11.62**	0.39**	0.21	-0.38
21	PAUBG-13 x Pusa Do Mausami	-2.10	0.07	-1.12**	-0.93**
22	PAUBG-13 x VR-1	1.64	-0.33*	-1.01**	-0.33
23	PAUBG-13 x Pusa Vishesh	2.32	0.13	0.58*	-0.08
24	PAUBG-13 x PBIG-56	14.56**	-0.32*	0.80**	0.84**
25	WBBG-28 x PAUBG-50	8.27**	0.01	3.12**	-0.25
26	WBBG-28 x PAUBG-20	13.37**	0.03	-1.78**	0.70**
27	WBBG-28 x Pusa Do Mausami	-19.95**	0.13	-1.60**	-0.74**
28	WBBG-28 x VR-1	2.83	0.16	-2.47**	0.05
29	WBBG-28 x Pusa Vishesh	5.89**	-0.13	1.62**	0.21
30	WBBG-28 x PBIG-56	-10.43**	-0.20	1.11**	0.03
31	DBG-35 x PAUBG-50	3.91*	-0.30	-2.35**	-0.33
32	DBG-35 x PAUBG-20	-10.03**	0.03	-1.23**	-0.26
33	DBG-35 x Pusa Do Mausami	18.53**	-0.17	1.77**	1.60**
34	DBG-35 x VR-1	-3.91*	0.07	1.41**	-0.05
35	DBG-35 x Pusa Vishrsh	-0.85	0.54**	-0.33	-0.57**

36	DBG-35 x PBIG-56	-7.65**	-0.18	0.74**	-0.39*
37	DBG-45 x PAUBG-50	-18.3**	0.44**	0.30	0.24
38	DBG-45 x PAUBG-20	5.84**	-0.69**	1.06**	-0.31
39	DBG-45 x Pusa Do Mausami	1.08	0.54**	1.69**	-0.76**
40	DBG-45 x VR-1	21.48**	0.39**	1.11**	0.61**
41	DBG-45 x Pusa Vishesh	0.74	-0.61**	-1.91**	0.18
42	DBG-45 x PBIG-56	-10.82**	-0.06	-2.24**	0.04
CD (p=0.05)		3.68	0.29	0.53	0.39
CD (p=0.01)		4.84	0.38	0.7	0.51

*Significant at 5% **Significant at 1%

Table 4: Heterosis (%) over better parents and standard check for different quality contributing traits of bitter gourd in rainy season

S. No	Genotypes	Per cent Heterosis							
		Vitamin-C (mg/100g)		Carotene (mg/100g)		Total sugar (g/100g)		Reducing sugar (g/100g)	
		BPH	SCH	BPH	SCH	BPH	SCH	BPH	SCH
1	Punajab-14 x PAUBG-50	-20.59*	-18.18*	-76.46**	-81.34**	-57.73**	-70.57**	-35.73**	-56.01**
2	Punjab-14 x PAUBG-20	1.47	4.55	-55.83**	-64.99**	-7.42**	-26.67**	4.24**	-13.86**
3	Punjab-14 x Pusa Do Mausami	-14.71	-12.12	-25.63**	-34.10**	-8.50**	-36.29**	11.59**	-23.62**
4	Punjab-14 x VR-1	-16.18	-13.64	-18.3**	-8.59**	-13.34**	-39.66**	-3.49**	-21.45**
5	Punjab-14 x Pusa Vishesh	0	3.03	17.71**	-6.69**	8.62**	-24.37**	10.61**	-24.29**
6	Punjab-14 x PBIG-56	-5.88	-3.03	52.92**	21.22**	-20.54**	-44.68**	-31.64**	-38.31**
7	PAUBG-1 x PAUBG-50	-8.96	-7.58	-31.58**	-16.27**	53.94**	-27.74**	5.25**	-28.05**
8	PAUBG-1 x PAUBG-20	-25.37**	-24.24**	-24.16**	-7.18**	-25.38**	-40.9**	-17.47**	-31.80**
9	PAUBG-1 x Pusa Do Mausami	-23.88**	-22.73**	-16.87**	1.73**	4.52**	-51.54**	13.12**	-27.30**
10	PAUBG-1 x VR-1	-23.88**	-22.73**	-59.85**	-50.87**	70.17**	-20.76**	-48.62**	-58.18**
11	PAUBG-1 x Pusa Vishesh	-14.93	-13.64	-81.92**	-77.87**	1.11**	-51.17**	79.77**	-21.37**
12	PAUBG-1 x PBIG-56	-7.46	-6.06	-13.7**	5.62**	-18.01**	-53.6**	-25.44**	-32.72**
13	PAUBG-4 x PAUBG-50	18.52*	-3.03	8.34**	18.00**	-8.48**	-42.79**	-49.17**	-46.41**
14	PAUBG-4 x PAUBG-20	-16.98	-33.33**	5.31**	14.70**	6.33**	-15.78**	-39.83**	-36.56**
15	PAUBG-4 x Pusa Do Mausami	-4.76	-9.09	-14.48**	-6.85**	-27.61**	-54.75**	-42.04**	-38.9**
16	PAUBG-4 x VR-1	1.75	-12.12	-50.48**	-44.59**	31.62**	-17.71**	-36.34**	-32.89**
17	PAUBG-4 x Pusa Vishesh	-1.89	-21.21*	-13.72**	-6.03**	-29.85**	-56.14**	-59.07**	-56.84**
18	PAUBG-4 x PBIG-56	-9.43	-27.27**	-79.61**	-77.79**	16.17**	-27.37**	-47.74**	-44.91**
19	PAUBG-13 x PAUBG-50	1.75	-12.12	-31.08**	-8.42**	5.52**	-50.47**	19.90**	-18.03**
20	PAUBG-13 x PAUBG-20	-10.53	-22.73*	-16.90**	10.40**	-29.42**	-44.10**	-27.78**	-40.32**
21	PAUBG-13 x Pusa Do Mausami	-9.52	-13.64	-14.79**	13.21**	-30.96**	-68.11**	-38.44**	-60.43**
22	PAUBG-13 x VR-1	7.02	-7.58	-54.82**	-39.97**	-2.38**	-54.54**	-30.46**	-43.41**
23	PAUBG-13 x Pusa Vishesh	10.53	-4.55	-35.05**	-13.71**	-2.81**	-53.06**	6.54**	-41.57**
24	PAUBG-13 x PBIG-56	12.28	-3.03	-57.43**	-43.44**	-6.17**	-46.90**	-3.42**	-12.85**
25	WBBG-28 x PAUBG-50	-6.67	-15.15	-5.64**	-19.90**	77.93**	-11.88**	-18.32**	-44.16**
26	WBBG-28 x PAUBG-20	-10.00	-18.18*	-7.10**	-21.14**	-37.31**	-50.35**	10.51**	-8.68**
27	WBBG-28 x Pusa Do Mausami	-33.33**	-36.36**	23.11**	9.08**	-12.53**	-56.68**	-29.22**	-51.67**
28	WBBG-28 x VR-1	-10.00	-18.18*	-25.39**	-16.52**	-1.16**	-51.05**	-16.92**	-32.39**
29	WBBG-28 x Pusa Vishesh	-5.00	-13.64	-27.43**	-38.4**	47.55**	-26.92**	-0.98**	-32.39**
30	WBBG-28 x PBIG-56	-23.33*	-30.30**	-34.34**	-44.26**	24.91**	-29.31**	-26.09**	-33.31**
31	DBG-35 x PAUBG-50	-9.86	-3.03	-68.84**	-62.51**	-14.05**	-57.50**	-41.78**	-51.84**
32	DBG-35 x PAUBG-20	-23.94*	-18.18*	-53.47**	-44.01**	-22.83**	-38.88**	-28.96**	-41.24**
33	DBG-35 x Pusa Do Mausami	-4.23	3.03	-44.61**	-33.36**	55.11**	-23.3**	16.04**	-4.01**
34	DBG-35 x VR-1	-14.08	-7.58	-54.63**	-45.42**	81.13**	-10.44**	-32.39**	-44.07**
35	DBG-35 x Pusa Vishesh	-9.86	-3.03	-32.33**	-18.58**	21.45**	-39.95**	-45.61**	-55.01**
36	DBG-35 x PBIG-56	-19.72*	-13.64	-71.52**	-65.73**	28.83**	-27.09**	-41.72**	-47.41**
37	DBG-45 x PAUBG-50	-28.13**	-30.3**	-5.62**	2.64**	7.45**	-31.24**	-25.63**	-28.05**
38	DBG-45 x PAUBG-20	-18.75*	-21.21*	-74.64**	-72.42**	7.78**	-14.63**	-32.87**	-35.06**
39	DBG-45 x Pusa Do Mausami	-18.75*	-21.21*	19.44**	29.89**	21.19**	-22.44**	-53.41**	-54.92**
40	DBG-45 x VR-1	-1.56	-4.55	-17.05**	-7.18**	38.41**	-11.43**	-18.55**	-21.2**
41	DBG-45 x Pusa Vishesh	-12.50	-15.15	-76.77**	-74.73**	-34.94**	-58.36**	-31.23**	-33.47**
42	DBG-45 x PBIG-56	-26.56**	-28.79**	-45.41**	-40.63**	-27.75**	-53.76**	-30.37**	-32.64**
	CD (p=0.05)	17.73	17.73	0.09	0.09	0.33	0.33	0.21	0.21
	CD (p=0.01)	23.29	23.29	0.12	0.12	0.43	0.43	0.27	0.27

*Significant at 5%, **Significant at 1%
SCH: Standard check heterosis over Prachi, BPH: Better parent heterosis

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