The Pharma Innovation Journal 2023; 12(9): 2589-2596

www.ThePharmaJournal.com

The Pharma Innovation

ISSN (E): 2277-7695
ISSN (P): 2349-8242
NAAS Rating: 5.23
TPI 2023; 12(9): 2589-2596

www.thepharmajournal.com
Received: 10-08-2023
Accepted: 07-09-2023

Daleep Kumar
Department of Vegetable Science, Punjab Agricultural University, Ludhiana, Punjab, India

Mamta Pathak
Department of Vegetable Science, Punjab Agricultural University, Ludhiana, Punjab, India

Corresponding Author:
Daleep Kumar
Department of Vegetable Science, Punjab Agricultural University, Ludhiana, Punjab, India

Estimation of gene action and combining ability of bitter gourd (*Momordica charantia* L.)

Daleep Kumar and Mamta Pathak

Abstract
Gene action and combining ability for some traits were analyzed in 49 crosses along with their 14 parents in randomized complete block design consist of three replications. All the characters under investigation showed high significant difference for genotypes, general and specific combining ability. The SCA effect for all the character greater than GCA effects that showed variance due to non-additive gene action for all the characters. The parent DBG-35 is good combiner for node at which first female flowers appear, number of fruits per plant, days to last harvest and vitamin-C. The parents Punjab Kareli-1, Arka Harit, Pant Karela were good combiner for number of fruits per plant, total and marketable yield, and days to last harvest. However, Punjab-14, PAUBG-4, PAUBG-13, and Arka Harita were good combiner for total sugar. The cross PAUBG-4 x Pant Karela was recorded highest significant *sca* effect for day to first female flowers appear, number of fruits per plant, fruit weight, total and marketable yield. The hybrid Punjab-14 x PAUBG-20 and PAUBG-13 x VR-1 were showed highest significant for *SCA* effects for vitamin-C and total sugar, respectively.

Keywords: Gene action, SCA, GCA Line x, tester, variance

Introduction

Bitter gourd (*Momordica charantia* L.) is an important commercial cucurbit belonging to the family cucurbitaceae, genus Momordica (Jeffrey 1990) [11]. It was probably originated and domesticated in Asia, possibly in eastern India having secondary centre of diversity in China (Grubben 1977) [8]. 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) [26]. It has been used for centuries in the ancient traditional medicine of India, China, Africa, and Latin America as its extract possess antioxidant, antimicrobial, antiviral, antihepatotoxic, antiulcerogenic properties and could lower blood sugar (Welthinda *et al*. 1986, Raman and Lan 1996) [34, 24]. During the past decade, the antidiabetic properties of the crop have been studied extensively and a hypoglycemic principle called "Charantin" has been isolated. The bitterness of bitter gourd is due to the cucurbitacin like alkaloid momordicine and triterpene glycosides *viz*., momordicoside K and L (Jeffrey 1980 and Okabe *et al* 1982)[10, 21]. One of the possible approaches for achieving the targeted production is to identify and develop suitable hybrids with high yield and good quality. Bitter gourd remains an unexploited crop from genetic and breeding point of view.

In bitter gourd, Indian variability is quite distinct than that of African, South-East Asian region (Seshadri and Chatterjee1996) [27]. There are several cultivars with wide range of variability in size, shape and colour of fruits available in this country (Behera 2008) [3]. Many varieties and F_1 hybrids have been developed utilizing those variability. It is a monoecious and highly cross-pollinated crop and has been known to offer good potentialities for increased yield. Considering these facts, it is essential and desirable to carry out a successful breeding programme utilizing the land races available in Indian subcontinent (Verma *et al*. 2013) [3].

The concept of general and specific combining ability was introduced by Sprague and Tatum (1942) [30]. The estimation of combining ability and genetics variance components is important in breeding programs for hybridization (Fehr 1993) [7]. In any breeding programme, the choice of the correct parents is the secret of the success. Before initiating any crop improvement programme, it is necessary to understand the genetic nature of the parents. Combining ability analysis helps in identifying the parents and these parents can be used for hybridization Programme in order to produced superior hybrids. As a general rule general combining ability (*GCA*) is the results of additive gene effects, while the specific combining ability (*SCA*) is the results of non-allelic interaction (Jinks 1954) [12]. The estimates of combining ability are useful to predict the relative performance of different lines in hybrids combinations. The information on the nature and magnitude of gene action is important in understanding the genetic potential of a population and deciding the breeding procedure to be adopted in a given population. Though many reports on combining ability are available in bitter gourd (Sirohi and Choudhury 1977, Pande *et al*. 2008, Singh *et al.* 2013 and Rani *et al*. 2014) [35, 28, 25] information on identification of better parents for F_1 production is lacking. The objective of present study was to identification of bitter gourd parental lines and hybrids with desirable combining ability, nature and magnitude of gene action governing various economic traits.

Material and Methods

Experimental Material

The experiment was conducted on research farm at Department of Vegetable Science, Punjab Agricultural University, Ludhiana, Punjab (India) during the spring season of 2014. The experimental materials of comprised 14 diverse genotypes. The seven lines *viz*. DBG-45, PAUBG-13, DBG-35, Punjab-14, PAUBG-4, WBBG-28, PAUBG-1 and seven testers *viz*. VR-1, PAUBG-20, PAUBG-50, Punjab Kareli, ArkaHarit, Pant Karela and Pusa Do Mausami, along with one commercial check (Prachi).

Experimental Design

The experimental plant material comprised of 7 lines, 7 testers, 49 F_1 hybrids and one check (Prachi) was sown in plug tray on 18 Feb 2014. The transplanting was done in the field on 26 March 2014 in a Randomized Block Design with three replications. For the experiments, five plants were grown on raised beds of width 1.5 m at plant to plant spacing of 0.45 m. The recommended NPK fertilizer doses and cultural practices along with plant protection measures were followed using recommended package of practices (Anonymous 2013) [2].

Data Collection

Data were recorded on five randomly selected vines for fifteen characters *viz*. Anthesis of first male flowers appear (DAS), Anthesis of first female flowers appear (DAS), Node at which first male flowers appear, Node at which first female flowers appear, Fruit length (cm), Fruit width (cm), Number of fruits per plant, Fruit weight (gm), Number of seeds per fruit, Total yield (kg/plant), Marketable fruit (kg/plant), Days to last harvest (DAS),Vine length (m), Vitamin-C (mg/100 g) by Albrecht (1993) [1] method and Total sugar (g/100g) by Dubios *et al.* (1956)[6] method.

Data analysis

The data were compiled for analysis of variance of different traits using method suggested by Panse and Sukhatme (1985) [23]. 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) [13].

Results and Discussion

Analysis of variance for experimental design

The analysis of variance revealed highly significant difference among the parents and crosses for all the 15 characters (Table 1). Interaction between parents and crosses showed significant difference for all the characters except for days to anthesis of first male flower and node at which first male and female flower appears. These results are in line with the findings of Rani *et al.* (2014) [25] who have reported similar results for these traits. It indicates parents and their hybrids possessed high genetic variation for most of the characters.

Estimates of genetic components of variance

The data presented in Table 2 revealed that *SCA* effects greater than *GCA* effects. Which were indicates the non-addative gene effects in governing the inheritance of 15 characters of bitter gourd. The ratio of *GCA* to *SCA* variances (Average degree of dominance) was observed to be more than unity for all the characters revealing over dominance, indicating that predominance of non-additive gene effects representing non-fixable dominance and epistatic components of genetic variance. This indicated that maintenance of heterozygocity would be highly fruitful for improving the characters. These results are in accordance with Singh *et al.* (2006) [29], Sundhariaya and Shakila (2011) [31]. These characters indicated that may beimproved through hybridization. However, Mishra *et al.* (1994) [19], Devadas and Ramdas (1997) [4], Matoria and Khandelwal (1999) [18] and Kushwaha and Karnwal (2011) [16] reported both additive and non-additive gene action for number of fruits per plant, fruit length, fruit width, fruit weight and yield. The differences in the results might have been due to the differences in the genetic material studied.

Estimates of general and specific combining ability effects

Estimation of general combining ability (*GCA*) effects and specific combining ability (*SCA*) effects are tabulated in Table-3 and Table-4, respectively. In respect to days to anthesis of first male flower parents Punjab-14 and PAUBG-20 recorded significantly negative *GCA* effects that is -2.16 and -1.18 and are best combiners. The highest significant *SCA* effects were recorded in cross combinations *viz*., DBG-35 x Pant Karela (-4.14), PAUBG-1 x VR-1 (-4.00), PAUBG-13 x PAUBG-50 (-4.05) and PAUBG-4 x Pant Karela (-3.95), whereas *GCA* effects both parents of all the four crosses were non-significant indicating that heterosis breeding can results in early flowering. Kumara *et al*. (2011) [15], Dey *et al* (2010)

[5] and Panda *et al*. (2008) [22] has also recorded *GCA* and *SCA* effects for day to anthesis of male flower in bitter gourd. For days to anthesis of first female flower the best combiner were Punjab-14, WBBG-28 Arka Harit and VR-1 recorded significant negative *GCA* effects (-1.84, -1.46, -1.07 and -1.12, respectively). The cross combinations *viz*., PAUBG-4 x Pant Karela (-4.63), PAUBG-13 x PAUBG-20 (-3.11) and DBG-45 x Pant Karela (-3.92) were showed significant negative *sca* effects. Similarly results of significant *GCA* and *SCA* effects repoted by Munshi and Sirohi (1994) [20], Panda *et al.* (2008) [22] and Laxuman *et al.* (2012) [17] in bitter gourd.
PAUBG-20 (-0.73) was best general combiner for node at which first male flower appears because negative significant *GCA* effects. The cross combinations *viz*., DBG-35 x PAUBG-50 (-2.40), PAUBG-1 x Pusa Do Mausami (-1.86) and DBG-35 x ArkaHarit (-1.79) were showed significant negative *SCA* effect fornode at which first male flower appears. The best general combiner for node at which first female flower appears were DBG-35 (-1.41), Punjab-14 x ArkaHarit (-3.68), DBG-45 x Pant Karela (-2.77), DBG-35 x PAUBG-20 (-2.77) and PAUBG-4 x Punjab Kareli-1 (-2.68) had high significant negative *SCA* effects. So DBG-35 could be could be utilizedfor development of high performance inbreds. The findings similar results to Dey *et al*. (2010) [5], Panda *et al*. (2008) [22] and Kumara *et al* (2011) [15] for these characters.
The parents PAUBG-13 (0.65), WBBG-28 (0.64), DBG-45 (1.50), Punjab Kareli-1 (2.69), Pusa Do Mausami (0.57) and Pant Karela (0.9) showed significant positive *GCA* effects for fruit length**.** The cross combinations *viz*., PAUBG-4 x Pant Karela (5.53), PAUBG-1 x Punjab Kareli-1 (2.53), PAUBG-4 x Arka Harit (2.52) and DBG-45 x Pant Karela (2.46) showed significant positive *SCA* effects for fruit length. The parental lines Punjab Kareli-1 and Pant Karela could be utilized for development of high performance inbreeds. The significant *GCA* and *SCA* effects were also reported by Munshi and Sirohi (1994) [20], Khattra *et al*. (1994) [14] for fruit length in bitter gourd. For the parents DBG-35 (4.14), DBG-45 (9.32) Punjab Kareli-1 (2.37), Arka Harit (4.78), Pant Karela (3.42) and VR-1 (2.32) significant positive *GCA* effects were recorded number of fruits per plant**.** Significant positive *SCA* effects were recorded in hybrids *viz*., DBG-45 x Pusa Do Mausami (24.47) and DBG-45 x Pant Karela (17.50), PAUBG x PAUBG-50 (15.96) and PAUBG-4 x Pant Karela (15.54). These results agreement to Munshi and Sirohi (1994) [20], Panda *et al*. (2008) [22], Thangamani *et al*. (2011) [32], and Kumara *et al.* (2011). The parental lines PAUBG-1, PAUBG-13, WBBG-28, PAUBG-50 and Punjab Kareli-1 showed significant positive *GCA* effects (2.97, 4.54, 2.78, 3.01 and 3.25, respectively) for fruit weight**.** The cross combinations *viz*., PAUBG-4 x Pant Karela (13.89), PAUBG-13 x VR-1 (13.12), PAUBG-13 x Pusa Do Mausami (10.93) and DBG-45 x PAUBG-20 (10.79) were observed significant positive *SCA* effects for fruit weight. Parents DBG-45 (-1.17), PAUBG-20 (-0.72), Pusa Do Mausami (-0.76), and Arka Harit (-1.37) were observed as good combiner for number of seeds per fruit. The hybrids PAUBG-4 x Pusa Do Mausami (-4.09), Punjab-14 x PAUBG-50 (-3.63), PAUBG-1 x Pant Karela (-3.59) and PAUBG-1 x PAUBG-50 (-3.5) were showed significant negative *SCA* effects for number of seeds per fruits. Similar results reported by Kumara *et al.* (2011) [15].
With the respect to total and marketable yield parents PAUBG-1 PAUBG-4, DBG-45, Punjab Kareli-1, Arka Harit and Pant Karela recorded significant positive *GCA* effects. PAUBG-13 x Arka Harit, DBG-45 x Pusa Do Mausami, Punjab-14 x PAUBG-50, PAUBG-4 x Pant Karela, PAUBG-1 x VR-1 and PAUBG-1 x PAUBG-20 were the best crosses respectively for these characters which had positive and significant *SCA* effects. High SCA and GCA effects reported by Thangamani *et al*. (2011) [32], Kumara *et al*. (2011) [15] and Luxuman *et al.* (2012) [17].
The parents PAUBG-1 (2.16), DBG-35 (3.59) Punjab Kareli-1 (3.97), Arka Harit (4.63), Pant Karela (2.20) and VR-1 (1.59) showed significant positive *GCA* effects for days to last harvest. The hybrids *viz*., PAUBG-1 x PAUBG-20 (18.03), PAUBG-13 x Arka Harit (13.65), WBBG-28 x VR-1 (11.51) and PAUBG-4 x Pant Karela (9.27) were significant positive *SCA* effects for days to last harvest. Significant negative *GCA* effects was observed in parent Pusa Do Mausami (-0.4), DBG-35 x VR-1 (-38.63), DBG-45 x Pant Karela (-30.77) and DBG-35 x Pusa Do Mausami (-27.58) had high significant SCA effects for vine length. High significant *GCA* and *SCA* effects were also reported for vine length by Munshi and Sirohi (1994) [20], Panda *et al*. (2008) [2].
Line DBG-35 and testers PAUBG-50, PAUBG-20, Pusa Do Mausami and VR-1 were observed as good combiners due to their significant positive *GCA* effects (12.19, 9.13, 3.01, 7.77 and 12.53, respectively) for vitamin-C. Hybrids *viz*., Punjab-14 x PAUBG-20 (29.28), PAUBG-1 x Arka Harit (21.12), PAUBG-13 x VR-1 (18.74), WBBG-28 x PAUBG-20 (17.04)and DBG-45 x Pusa Do Mausami (17.04) significant positive *SCA* effects were observed for vitamin-C. Thangamani *et al.* (2011) [32] reported significant *SCA* effect for vitamin-C, it ranged from -7.11 (Preethi x UB) to 11.65 (Priyanka x CO-1).The parents Punjab-14 (-0.43), PAUBG-4 (-0.44), PAUBG-13 (-0.68) and Arka Harit (-0.93) depicted significant negative *GCA* effects for total sugar. The hybrids *viz*., PAUBG-13 x VR-1 (-2.28), Punjab-14 x PAUBG-50 (-2.27), WBBG-28 x VR-1 (-2.06) and DBG-45 x Punjab Kareli-1 (-2.05) were recorded significant negative *SCA* effects for total sugar.

Table 1: Analysis of variance for experimental design for different traits of bitter gourd

Source of variation	df	Mean sum of square														
		Anthesis of 1st male flower	Anthesis of 1st female flower	Nodeat which 1st male flower	Nodeat which 1st female flower	Fruit length (cm)	Fruit width (cm)	No of fruits/ plant	Fruit weight (g)	No of seeds/fruit	Total Yield/ plant (kg)	MarketableYield/Plant (kg)	Days to last harvest	Vine length (m)	Vitamin C (mg/100g)	Totalsugars (g/100g)
Replication	2	106.98**	21.37*	0.383	3.33	1.01	2.92**	111.47**	7.50	2.65	0.34	0.19	13.7	1.4**	260.9	0.116
Parents	13	26.25**	20.74**	5.47**	10.44**	23.93**	0.246	95.44**	77.27**	22.49**	0.16	0.13	99.61**	0.23**	1324.06**	2.36**
Lines	6	19.31**	26.93**	6.2**	18.52**	15.66**	0.102	139.98**	87.66**	16.28**	0.15	0.12	85.88**	0.21**	1469.51**	2.14**
Testers	6	22.31**	13.31*	1.07	0.761	28**	0.254	44.19**	72.07*	27.9**	0.12	0.09	87.85**	0.29**	989.65**	2.91**
Lines vs Testers	1	91.52**	29.16*	27.52**	20.02*	49.07**	1.06**	135.72**	46.09	27.36**	0.46	0.35	252.56**	0.02	2457.87**	0.343*
Parents vs Hybrids	1	23.6*	1.93	0.199	7.09	17.82**	4.92**	1164.71**	957.87**	75.54**	0.91	0.75	371.12**	1.6**	1272.68**	12.57**
Hybrids	48	22.11**	18.69**	5.15**	12.21**	19.51**	0.219	436.95**	229.75**	19.59**	0.44	0.35	219.49**	0.27**	802.34**	6.33**
Error	124	5.2	4.8	0.895	3.45	0.621	0.17	9.52	26.56	1.06	0.02	0.02	21.54	0.025	87.34	0.0721

Table 2: Estimation of gene action and Contribution of Lines, Testers and their interaction for different traits in bitter gourd

Source	Anthesis of 1st male flower	Anthesis of 1st female flower	Node at which 1st male flower	Nodeat which 1st female flower	Fruit length (cm)	Fruit width (cm)	No of fruits/ plant	Fruit weight (g)	No of seeds/fruit	Total Yield/ plant (kg)	Marketable Yield/Plant (kg)	Days to last harvest	Vine length (m)	Vitamin C (mg/100g)	Totalsugars (g/100g)
$\sigma^2 gca$	0.057	0.3	-0.044	0.012	1.2	0.013	4.61	0.003	-0.11	0.004	0.003	2.14	0.003	46.63	-0.922
$\sigma^2 sca$	5.53	4.08	1.49	2.9	4.18	-0.007	134.41	67.73	6.37	0.132	0.104	62.22	0.07	156.71	1.92
$\sigma^2 gca/\sigma^2 sca$	0.01	0.074	-0.03	0.004	0.287	-1.857	0.034	0	-0.017	0.03	0.03	0.034	0.043	0.298	-0.48
Contribution of Lines, Testers and their interaction															
Lines	22.64	296.18	149.54	134.53	227.54	472.55	89.49	424.64	101.47	2.23	2.23	7.79	53.92	111.34	139.34
Testers	3.39	23.96	71.96	45.64	134.75	216.06	120.07	54.83	66.15	26.10	26.22	400.82	221.25	346.08	322.03
Lines x Testers	73.95	90.05	95.59	104.15	67.17	45.62	97.4	67.58	103.12	71.61	71.56	92.08	87.84	64.34	66.24

$\sigma^2 gca$ = Estimates of general combining ability variance$\sigma^2 sca$ = Estimates of specific combining ability varianc

Table 3: *GCA* effects of female and male parents for different traits of bitter gourd

Source	Anthesis of 1st male flower	Anthesis of 1st female flower	Node at which1st male flower	Nodeat which 1st female flower	Fruit length (cm)	No of fruits/ plant	Fruit width (cm)	Fruit weight (g)	No of seeds/fruit	Total Yield/ plant (kg)	Marketable Yield/Plant (kg)	Days to last harvest	Vine length (m)	Vitamin C (mg/100g)	Totalsugars (g/100g)
	Female parents														
Punjab-14	-2.61**	-1.84**	-0.26	0.63	-2.23**	-3.62**	-0.03	-0.75	-0.37	-0.08*	-0.07*	0.16	-0.06	-2.09	-0.43*
PAUBG-1	0.1	1.12*	-0.14	0.25	-0.7*	-2.02**	0.28	2.97**	-0.66	0.04	0.03	2.16**	-0.11	-6.85**	0.68**
PAUBG-4	0.48	0.31	0.71*	0.63	0.26	-0.55	0.04	0.73	0.37	0.04	0.04	-0.56	0.09	1.31	-0.44*
PAUBG-13	1.82**	0.93	-0.67	-0.89	0.65*	-5.26**	0.14	4.54**	0.54	0	0	-1.37	0.22	-1.07	-0.68**
WBBG-28	-0.76	-1.46**	0.44	-0.37	0.64*	-2**	0	2.78**	1.31**	-0.06	-0.05	-2.18**	-0.08	-1.75	-0.21
DBG-35	0.34	1.02	0.19	-1.41**	-0.11	4.14**	-0.22	-4.65**	-0.02	-0.04	-0.03	3.59**	0.05	12.19**	0.21
DBG-45	0.63	-0.07	-0.27	1.16*	1.5**	9.32**	-0.21	-5.61**	-1.17**	0.09*	0.08*	-1.8*	-0.12	-1.75	0.87**
CD (p=0.05)	1.09	1.06	0.7	0.97	0.62	1.26	0.46	1.63	0.72	0.07	0.06	1.54	0.29	2.19	0.37
CD (p=0.01)	1.43	1.39	0.92	1.28	0.81	1.66	0.61	2.14	0.94	0.09	0.09	2.03	0.38	2.88	0.49
Male parents															
PAUBG-50	0.05	0.54	0.58	0.73	-1.3**	-6.58**	0.2	3.01**	1.19**	-0.19**	-0.17**	-5.75**	0.06	9.13**	-0.13
Punjab Kareli-1	0.15	0.35	-0.06	0.3	2.69**	2.37**	-0.08	3.25**	0.59	0.23**	0.20**	3.97**	-0.08	-8.55**	-33
PAUBG-20	-1.18*	-0.5	-0.73*	-0.56	-1.58**	-6.99**	-0.03	-1.22	-0.72*	-0.29**	-0.26**	-6.27**	-0.2	3.01**	0.44*
Pusa Do Mausami	0.2	0.83	-0.42	-0.22	0.57*	0.67	-0.09	0.49	-0.76*	-0.03	-0.03	-0.37	-0.4**	7.77**	-0.15

ArkaHarit	0.1	-1.07*	0.21	0.63	-0.69*	4.78**	0.03	0.49	-1.37**	0.29**	0.26**	4.63**	0.2	-12.63**	-0.93**
Pant Karela	0.29	0.97	0.31	-0.13	0.9**	3.42**	0	-2.65**	-0.1	0.05	0.05	2.2**	0.03	-11.27**	0.07
VR-1	0.39	-1.12*	0.1	-0.75	-0.59	2.32**	-0.04	-3.37**	1.16**	-0.06	-0.06*	1.59*	0.03	12.53**	1.03**
CD (p=0.05)	1.09	1.06	0.7	0.97	0.62	1.26	0.46	1.63	0.72	0.07	0.06	1.54	0.29	2.19	0.37
CD (p=0.01)	1.43	1.39	0.92	1.28	0.81	1.66	0.61	2.14	0.94	0.09	0.09	2.03	0.38	2.88	0.49

*Significant at 5%**Significant at 1%

Table 4: *SCA* effects of hybrids for different traits of bitter gourd

Source	Anthesis of 1st male flower	Anthesis of 1st female flower	Nodeat which1st male flower	Nodeat which1st female flower	Fruit length (cm)	Fruit width (cm)	No of fruits/ plant	Fruit weight (g)	No of seeds/fruit	Total Yield/ plant (kg)	Marketable Yield/Plant (kg)	Days to last harvest	Vine length (m)	Vitamin C (mg/100g)	Total sugars (g/100 g)
Punjab-14 x PAUBG-50	-1.62	0.93	0.81	-0.1	0.29	0.21	3.63**	-3.63**	1	0.55**	0.49**	8.51**	-0.38	-5.39**	-2.27**
Punjab-14 x Punjab Kareli-1	-1.38	-1.21	-0.67	0.65	-3.1**	0.12	-1.25	-12.2**	-2.63**	0.08	0.08	3.79**	0.04	-9.13**	-0.75*
Punjab-14 x PAUBG-20	-1.38	0.97	-0.4	-0.15	0.77	-0.14	-2.55*	7.27**	-1.52**	-0.16	-0.14	-5.63**	0.39	29.28**	1.21**
Punjab-14 x Pusa Do Mausami	-0.43	-1.02	0.02	1.51	-1.07*	-0.26	-0.35	-1.77**	-0.08	-0.27	-0.25*	-8.53**	0.24	5.48**	1.16**
Punjab-14 x ArkaHarit	-1.67	-2.44**	-0.24	-3.68**	1.24*	-0.17	2.23*	7.55**	4.79**	0.07	0.06	3.12*	0.27	-9.81**	0.99**
Punjab-14 x Pant karela	1.46	0.83	-0.24	1.08	-0.17	0.04	-13.49**	7.03**	-2.24**	-0.20	-0.08	-7.44**	-0.3	-8.79**	0.08
Punjab-14 x VR-1	5.04**	1.93*	0.36	0.7	2.04**	0.19	11.79**	-4.25**	0.69	-0.08	-0.07	6.17**	-0.26	-1.65	-0.37
PAUBG-1 x PAUBG-50	0.32	2.31**	-0.06	-0.72	1.06*	0.18	9.06**	7.31**	-3.5**	0.19*	0.17*	-1.82	-0.16	4.12**	0.87**
PAUBG-1 x Punjab Kareli-1	0.56	-0.49	0.84	1.36	2.53**	-0.2	-7.21**	13.08**	1.61**	0.04	0.04	-0.2	-0.18	7.52**	1.46**
PAUBG-1 x PAUBG-20	2.23**	-0.3	-0.82	-1.44	-0.39	0.18	9.64**	5.55**	0.69	0.45**	0.41**	18.03**	-0.16	-13.55**	-1.13**
PAUBG-1 x Pusa Do Mausami	-2.48**	-2.63**	-1.86**	-1.77*	0.45	0.3	11.58**	-6.15**	1.76**	0.06	0.06	-0.53	0.35	-20.69**	-1.47**
PAUBG-1 x ArkaHarit	2.94**	2.26**	2.14**	2.7**	-0.71	0.15	-8.79**	-4.82**	-1.42*	-0.68**	-0.61**	-10.53**	-0.24	21.12**	-0.25
PAUBG-1 x Pant Karela	0.42	0.88	0.03	0.12	-2.11**	-0.19	-17.42**	-3.68**	-3.59**	-0.53	-0.47**	-5.44**	0.19	7.86**	0.5
PAUBG-1 x VR-1	-4**	-2.02*	-0.25	-0.25	-0.82	-0.41	3.13**	-11.29**	4.44**	0.46**	0.41**	0.51	0.2	-6.41**	0.01
PAUBG-4 x PAUBG-50	1.61	1.78*	0.84	2.55**	-1.86**	-0.25	15.96**	-15.1**	-0.3	-0.09	-0.09	0.55	0.48*	-1.65	0.27
PAUBG-4 x Punjab Kareli-1	0.85	-1.68*	-1.44**	-2.68**	0.8	0.35	-3.44**	7.31**	4.61**	0.15	0.14	5.17**	-0.26	16.02**	0.56
PAUBG-4 x PAUBG-20	0.18	-0.16	-1.01	-0.48	-2.28**	-0.08	-5.75**	-4.87**	0.2	-0.24*	-0.21*	-3.58**	-0.29	-24.09**	0.52
PAUBG-4 x Pusa Do Mausami	-2.19**	2.5**	2.08**	0.17	-4.46**	0	-8.88**	-11.25**	-4.09**	0.05	0.05	1.84	0.22	-0.29	-0.84**
PAUBG-4 x ArkaHarit	1.56	-0.59	-0.71	0.31	2.52**	-0.01	-7.25**	5.08**	0.34	-0.24*	-0.22**	-1.15	-0.016	-6.07**	-0.36
PAUBG-4 x Pant Karela	-3.95**	-4.63**	-1.15*	-0.25	5.53**	-0.12	15.54**	13.89**	-0.58	0.52**	0.46**	9.27**	-0.16	13.98**	-0.66*
PAUBG-4 x VR-1	1.94*	2.78**	1.39*	0.36	-0.24	0.11	-6.16**	4.93**	-0.18	-0.14	-0.13	-12.1**	0.03	2.08	0.5
PAUBG-13 x PAUBG-50	-4.05**	-2.49**	0.43	-1.25	-2.25**	-0.21	-6.19**	-8.25**	0.05	-0.46**	-0.36**	-7.63**	-0.39	3.1	0.37
PAUBG-13 x Punjab Kareli-1	0.517	0.69	-0.79	-2.15**	-1.11*	-0.24	-0.44	-0.48	0.14	-0.10	-0.09	-6.01**	0.31	-10.15**	1.66**
PAUBG-13 x PAUBG-20	-0.81	-3.11**	-0.42	0.36	0.91	-0.05	14.91**	-17.34**	-0.7	0.17*	0.15	-1.44	0.27	-7.43**	0.2
PAUBG-13 x Pusa Do Mausami-0.17	1.46	-0.11	0.1	0.36	0.83	0.16	-5.11**	10.93**	2.66**	0.03	0.03	-0.34	-0.28	4.46*	-1.87**
PAUBG-13 x Arka Harit0.02	0.56	1.12	1.14*	1.84*	-0.3	0.05	9.34**	3.27*	-2.95**	0.79**	0.70**	13.65**	-0.15	-8.45**	1.11**
PAUBG-13 x Pant Karela-0.30	2.7**	4.07**	0.3	2.27**	1.1*	0.2	-10.45**	-1.25	2.53**	-0.29	-0.25*	-4.58**	0.38	-0.29	0.8**
PAUBG-13 x VR-10.17	-0.38	-0.16	-0.75	-1.44	0.82	0.08	-2.05*	13.12**	-1.75**	-0.19*	-0.17*	6.36**	-0.13	18.74**	-2.28**
WBBG-28 x PAUBG-5-0.550	2.51**	-2.44**	1.78**	0.55	1.45**	-0.33	-10.25**	9.51**	3.02**	0.02	0.02	0.17	0.07	10.92**	2.47**
WBBG-28 x Punjab Kareli—0.131	-1.91*	-0.92	-1.73**	-2.01**	1.19*	0.004	6.26**	-4.06**	-3.11**	-0.34**	-0.30**	-10.2**	-0.01	7.18**	-0.83**
WBBG-28 x PAUBG-200.41	-1.24	1.93*	0.49	1.51	1.16*	-0.004	12.05**	-0.25	-3.17**	0.19*	0.17*	2.7*	-0.24	17.04**	-1.2**
WBBG-28 x Pusa Do Maus0.38ami	-0.62	-1.06	-1.74**	-2.48**	0.68	0.24	-18.96**	5.36**	-1.66**	-0.62**	-0.55**	-11.87**	-0.37	-25.79**	0.85**
WBBG-28 x Arka Harit0.04	-1.5	-0.49	-0.3	1.98*	-1.19*	0.03	-5.07**	-3.29*	3.94**	-0.14	-0.13	-0.53	0	-5.39**	-0.22
WBBG-28 x Pant Karela0.13	5.6**	5.12**	1.79**	-0.58	-3.71**	0.05	9.02**	-7.15**	0.97	0.46	0.41**	8.22**	0.05	0.38	1**
WBBG-28 x VR-1-0.29	-2.81**	-2.11*	-0.29	1.03	0.4	0	6.94**	-0.1	0.01	0.44**	0.38**	11.51**	0.49*	-4.37*	-2.06**
DBG-35 x PAUBG-500.07	0.42	-0.92	-2.4**	-1.72*	1.27*	0.2	1.34	3.27*	-0.41	0.04	0.04	4.08**	0.08	4.12*	-1.55**
DBG-35 x Punjab Kareli-10.31	-2.34**	0.26	2.74**	2.7**	-0.05	-0.18	3.66**	-0.63	-0.62	0.14	0.13	2.7*	0.16	-1.99	-0.06

DBG-35 x PAUBG-20-0.14	3.32**	2.45**	0.34	-2.77**	0.38	0.27	-11.34**	-1.15	1.79**	-0.33**	-0.29**	0.15	15.7**	0.72	-0.62*
DBG-35 x Pusa Do Mausami	3.27**	1.45	0.43	3.55**	1.97**	-0.2	-2.74**	9.46**	0.29	0.07	0.07	-0.27	-27.58**	19.76**	0.56
DBG-35 x ArkaHarit	-1.95*	-0.92	-1.79**	-2.63**	0.29	-0.11	13.64**	-2.2	-2.59**	0.35**	0.31**	0.11	11.6**	2.08	-0.71*
DBG-35 x Pant Karela	-4.14**	-2.35**	-0.23	0.12	-3.09**	0.2	-0.68	-5.06**	2.93**	-0.15	-0.14	0.14	14.51**	11.17**	-0.42
DBG-35 x VR-1	1.42**	0.07	0.91	0.74	-0.77	-0.18	-3.88**	-3.68**	-1.38*	-0.03	-0.12	-0.38	-38.63**	-13.5**	2.81**
DBG-45 x PAUBG-50	0.8	0.83	-1.4*	0.7	0.03	0.2	-13.56**	6.89**	0.13	-0.30**	-0.27**	0.3	30.27**	-15.25**	-0.17
DBG-45 x Punjab Kareli-1	3.7**	3.36**	1.06	2.12**	-0.26	0.14	2.41*	-3.01*	-0.004	0	0	-0.05	-5.44**	-9.47**	-2.05**
DBG-45 x PAUBG-20	-2.29**	-1.78*	1.46**	2.98**	-0.55	-0.16	-16.95**	10.79**	2.71**	-0.8**	-0.07	-0.12	-12.58**	-1.99	1.01**
DBG-45 x Pusa Do Mausami	0.99	0.88	96	-1.34	1.59**	-0.24	24.47**	-6.58**	1.11	0.66**	0.59**	0.11	11.12**	17.04**	1.67**
DBG-45 x ArkaHarit	0.08	1.12	-0.23	-0.53	-1.84**	0.07	-4.09**	-5.58**	-2.1**	-0.15	-0.13	0.03	1.31**	6.5**	-0.54
DBG-45 x Pant Karela	-2.1*	-3.92**	-0.5	-2.77**	2.46**	-0.2	17.5**	-3.77**	-0.01	0.20*	0.18*	-0.3	-30.77**	-1.99	-1.31**
DBG-45 x VR-1	-1.19	-0.49	-1.35*	-1.15	-1.41**	0.2	-9.76**	1.27	-1.83**	-0.34**	-0.30**	0.06	6.08**	5.14**	1.39**
CD (p=0.05)	1.69	1.66	1.09	1.53	1	0.72	1.97	2.56	1.14	0.17	0.16	2.42	0.45	3.44	0.58
CD (p=0.01)	2.23	2.18	1.43	2.01	1.31	0.94	2.59	3.36	1.5	0.23	0.21	3.18	0.59	4.52	0.76

*Significant at 5% **Significant at 1%

Conclusion

The highest significant *SCA* effects were recorded in cross combinations *viz*., DBG-35 x Pant Karela (-4.14), PAUBG-1 x VR-1 (-4.00), PAUBG-13 x PAUBG-50 (-4.05) and PAUBG-4 x Pant Karela (-3.95) in early flowering. The cross combinations *viz*., PAUBG-4 x Pant Karela (5.53), PAUBG-1 x Punjab Kareli-1 (2.53), PAUBG-4 x Arka Harit (2.52) and DBG-45 x Pant Karela (2.46) showed significant positive *SCA* effects for fruit length. The cross combinations *viz*., PAUBG-4 x Pant Karela (13.89), PAUBG-13 x VR-1 (13.12), PAUBG-13 x Pusa Do Mausami (10.93) and DBG-45 x PAUBG-20 (10.79) were observed significant positive *SCA* effects for fruit weight. The hybrids *viz*., PAUBG-1 x PAUBG-20 (18.03), PAUBG-13 x Arka Harit (13.65), WBBG-28 x VR-1 (11.51) and PAUBG-4 x Pant Karela (9.27) were significant positive *SCA* effects for days to last harvest. Hybrids *viz*., Punjab-14 x PAUBG-20 (29.28), PAUBG-1 x Arka Harit (21.12), PAUBG-13 x VR-1 (18.74), WBBG-28 x PAUBG-20 (17.04) and DBG-45 x Pusa Do Mausami (17.04) significant positive *SCA* effects were observed for vitamin-C. The SCA effects and *per se* performance the crosses hold great promise in improving the fruit yield in future breeding programme of bitter gourd.

References

1. Albrecht JA. Ascorbic acid retention in lettuce. J Food Quality.1993;16:311-16.
2. Anonnymous. Package of practices for cultivation of vegetables. Punjab Agricultural University, Ludhiana; c2013. p. 16-17.
3. Behara TK, Singh AK, Staub JE. Comparative analysis of genetic diversity of Indian bitter gourd (*Momordica charantia* L.) using RAPD and ISSR marker for developing crop improvement strategies. SciHortic. 2008;115:209-17.
4. Devadas VS, Ramadas S. Gene actions of seed yield and quality traits in bitter gourd. Hort J. 1997;10:51-56.
5. Dey SS, Behera TK, Munshi AD, Pal A. Combing ability analysis in bitter gourd. Indian J Hort. 2010;67:399-401.
6. Dubios M, Gilles KA, Hamilton JK, Roberts PA, Smith F. Colorimetric method for determination of sugars and related substances. Anal Chem. 1956;26:350-56.
7. Fehr WR. Principal of cultivar development. Macmillan Publication co. New Yark;c1993. p. 342.
8. Grubben GJN. Tropical vegetable and their genetic resources. IBPGR, Rome; c1977. p. 51-52.
9. Jadhav KA, Garad BV, Kshirsagar DB, Dhumal SS, Pati lBT. Combining ability studies in bitter gourd (*Momordica charantia* L.). J Maharashtra AgriUni.2010;35:203-6.
10. Jeffrey C A reviews of the Cucurbitaceae. Bot J Linn Soc. 1980;81:233-47.
11. Jeffrey C. An outline classification of the Cucurbitaceae (Appendix). In D M Bates., W R Robinson, and C Jeffrey (eds.), Biology and utilization of the Cucurbitaceae, Cornell Univ. Press, Ithaca, New York; c1990. p. 449-463.
12. Jinks JL. Analysis of continuous variation in diallel cross of *Nicotiana rustica* varieties. Gent. 1954;39:767-88.
13. Kempthorne. An Introduction to Genetic Statistics John Wiley and Sons Inc, New York; c1957.p. 545.
14. Khattra AS, Singh NJ, Thakur JC. Studies on combining abilityin bitter gourd (*Momordica charantia* L.).Veg Sci.1994;21:158-62.
15. Kumara BS, Puttaraju TB, Hongal S, Prakash K, Jainag K, Sudheesh NK. Combining ability studies in bitter gourd (*Momordica charantia* L.) for quantitative characters. Asian J Hort.2011;6:135-40.
16. Kushwaha ML, Karnwal MK. Combining ability studies in bitter gourd (*Momordica charantia* L.) under dry temperate conditions. Pantnagar J Res.2011;9:41-45.
17. Laxuman Patil SA, Salimath PM, Dharmatti PR, Byadgi AS, Nirmalayenagi. Heterosis and combining ability analysis for productivity traits in bitter gourd (*Momordica charantia* L.) Karnataka J Agric. Sci. 2012;25:9-13.
18. Matoria GR, Khandelwal RC. Combining ability and stability analysis in bitter gourd (*Momordica charantia* L.). J Appl. Hort1; c1999. p. 139-41.
19. Mishra HN, Mishra RS, Mishra SN, Parhi G. Heterosis and combining ability in bitter gourd (*Momordica charantia* L.). Indian J Agri. Sci.1994;64:310-13.
20. Munshi AD, Sirohi PS. Combining ability estimates in bitter gourd (*Momordica charantia* L.). Veg Sci. 1994;21:132-36.
21. Okabe H, Miyahara Y, Yamauchi T. Studies on the constituents of *Momordica charantia* L. III. Chem Pharmaceutical Bull.1982;30:3977-86.
22. Panda A, Singh DK, Bairagi SK. Study of combining ability to produce bitter gourd hybrids. Prog Hort. 2008;40:33-37.
23. Panse VG, Sukhatme PV. Statistical Methods for Agricultural Workers, Indian Council of Agricultural Research, New Delhi; c1985. p. 347.
24. Raman A, Lan C. Anti-diabetic properties and phytochemistry of *Momordica charantia* L. (Cucurbitaceae). Phyto medicine.1996;2:349-62.
25. Rani RK, Raju SC, Reddy RK. A study on heterosisi for yield and earliness in bitter gourd. Indian J Sci Res Tech.2014;2:89-97.
26. Satkar KP, Kulth AA, Chalke PR. Preparation of bitter gourd ready-to-serve beverage and effect of storage temperature on its keeping quality. The Bioscan. 2013;8:115-17.
27. Seshadri VS, Chatterajtee SS. The history and adaptation of some introduced vegetable crops in India. VegSci.1996;23:114-40.
28. Singh AK, Pan RS, Bhavana P. Heterosis and combining ability analysis in bitter gourd (*Momordica charantia* L.). Suppl Genet Pl Breed.2013;8:1533-36.
29. Singh B, Singh SK, Ram D, Pandey S, Rai M. Combining ability analysis in bitter gourd (*Momordica charantia* L.). Hort J. 2006;19:112-15.
30. Sprague GF, Tatum LA. General and specific combining ability in single crosses of corn. J Am SocAgron. 1942;34:923-32.
31. Sundharaiya K, Shakila A. Line x Tester analysis in bitter gourd (*Momordica charantia* L.). Adv Pl Sci. 2011;24:637-41.
32. Thangamani C, Pugalendhi L, Sumathi T, Kavitha C, Rajashree V. Estimation of combining ability and heterosis for yield and quality characters in bitter gourd (*Momordica charantia* L.). Electronic J Pl Breed.2011;2:62-66.
33. Verma RS, Pratap N, Dubey DK, Singh SS. Combining

ability and gene action in indigenous bitter gourd (*Momordica charantia* L.). SAARC J Agri.2013;11:117-27.

34. Welthinda J, Karunanayake EM, Sheriff MH, Jayasinghe KS. Effect of *Momordica charantia* on the glucose tolerance in maturity onset diabetes. J Ethnopharmacol. 1986;17:277-82.
35. Feero BS, Pande PP. Networks-on-chip in a three-dimensional environment: A performance evaluation. IEEE Transactions on computers. 2008 Aug 15;58(1):32-45.
36. Sirohi PS, Choudhury B. Combining ability in bitter gourd. Veg. Sci. 1977;4:107-115