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Research Paper

Combining ability studies for earliness and quality traits in bitter gourd (*Momordica charantia* L.)

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ABSTRACT

The present investigation was carried out to generate information on combining ability (gca and sca) and nature and magnitude of gene action in bitter gourd at Division of Vegetable Science, SKUAST-Kashmir. During the study ten diverse lines were crossed with three testers to generate thirty crosses through line x tester mating design (Kempthorne, 1957). The set of thirty crosses along with their parents were evaluated in a RCBD with three replications at three different locations viz.; SKUAST-Kashmir, Shalimar (E_1); Faculty of Agriculture, Wadura Sopore (E_2) and KVK Pulwama (E_3). The observations were recorded on twelve earliness and quality traits. Analysis of variance revealed significant differences among the parents and crosses for almost all the traits in individual as well as pooled environments. The variance due to SCA was significant for almost all the traits except total carotenoids. In general σ^2_{sca} was found to be more than σ^2_{gca} for all the traits which indicated the preponderance of non-additive gene action for the traits. Although dominance component was more in magnitude for all the traits in the present study but both the variances (σ^2_{gca} and σ^2_{sca}) were significant for most of the traits which reflects the importance of both additive and non-additive gene effects in the inheritance of these traits. The narrow sense heritability (n.s) was found to be low (< 30%) for node to first male flower appearance, days to anthesis of first male flower, days to first fruit harvest, total carotenoids, total phenols, total chlorophyll and iron content. It was moderate (30-50%) for node to first female flower appearance, days to anthesis of first female flower,[1] vitamin -C, dry matter content and dietary fibre content. The analysis of the parents for desirable high general combining ability effects revealed that out of twelve traits, the line NDBG-4 showed high desirable gca effects for seven traits followed by NDBG-1 (7 traits),NDBG-5 (6 traits), NDBG-7(6 traits),Pant Karela-1 (7 traits) and NDBG-17 (5 traits), NDBG-12(4 traits), NDBG-3(1 trait) and PBTH-52(1 trait). Such parents can be used as a potent source for improving most of the traits in the present set of material through hybridization of good general combiners for the concerned trait. The SCA analysis revealed that the best cross combinations with respect to SCA effects and *per se* performance were NDBG-17 × Jounpuri, NDBG-7 × Arka Harit and NDBG-6 × Local bitter gourd and NDBG-12 × Local bitter gourd for earliness; NDBG-1 × Arka Harit, NDBG-12 × Arka Harit, NDBG-17 × Local bitter gourd for quality traits. Thus the parents of such crosses may be used for developing hybrids followed by multi-location testing and release of promising ones on commercial scale.

Key words: Bitter gourd, combining ability, gca, LxT, sca

Bitter gourd (*Momordica charantia* L.) is an important cucurbitaceous vegetable with high nutritional and medicinal value. Bitter gourd contains about 25 calories, 1.2 g protein, 0.2 g fat, 5 g carbohydrate, 1.0 g fiber13 mg calcium, 32 mg phosphorus, 0.2 mg iron, 0.02 mg thiamine and 0.07 mg riboflavin per 100 grams of the bitter gourd fruit (Rose *et al*. 2014). Therefore, from nutrient and health benefit considerations, it is desirable to improve the crop in terms of yield and quality. Bitter gourd being a monoecious cross pollinated crop offers a bright scope for development of open-pollinated as well as hybrid variety. Information on nature and magnitude of combining ability effects of parents and crosses may be of great value to the breeder in selecting the appropriate parents and crosses. In a hybridization programme, approach of selecting parents on the basis of *per se* performance does not necessarily lead to the best result (Labroo *et al*. 2021)). The studies on combining ability help to extract ideas about the nature and magnitude of gene action for particular traits which help in selecting diverse parents and hybrid combinations. In addition to this knowing the nature of gene action for different traits will be helpful to develop efficient crop improvement programme. General combining ability(gca) is due to additive and additive × additive gene action and is fixable in nature while specific combining ability(sca) is due to non-additive gene action which may be due to dominance or epistasis or both and is non-fixable in nature. The presence of non-additive genetic variance is the primary justification for initiating the hybrid breeding programme (Pali and Mehta, 2014). Keeping these points into consideration, the present investigation was carried out to determine general combining ability and specific combining ability in bitter gourd.

MATERIALS AND METHODS

The present investigation was conducted at Vegetable Experimental Farm, Division of Vegetable Science, SKUAST-Kashmir, and Shalimar. Ten diverse lines viz; NDBG-1, NDBG-3, NDBG-4, and NDBG-5, NDBG-6, NDBG-7, NDBG-12, NDBG-17, Pant Karela-1 and PBTH-52 were crossed with three testers viz; Arka Harit, Jounpuri and Local Bitter gourd to generate thirty crosses following line x tester mating design (Kempthorne, 1957). The details/source of the lines used in the study are presented in table 1. The set of thirty crosses along with their parents (10 lines and 3 testers) were evaluated in RCBD with three replications at three locations viz., Vegetable Experimental Farm, Division of Vegetable Science, SKUAST-Kashmir, Shalimar, central Kashmir (E_1) with altitude 1685 meter above msl and situated 34° N of latitude and 74.89 °E of longitude; Faculty of Agriculture, Wadura, North Kashmir (E_2) with latitude of 1524 meters above msl and is situated at 34°.28′ N of latitude and 74°.55′ E of longitude; KVK Malangpora, South Kashmir (E_3) with altitude of 1600 metre above msl and situated at 33.53° N of latitude and 74.58° E of longitude in South Kashmir about 32 km away from Srinagar city. The observations were recorded on twelve traits viz., node to first male flower appearance, node to first female flower appearance, days to anthesis of first male flower, days to anthesis of first female flower, days to first fruit harvest, total carotenoids (mg $100g^{-1}$), total phenols ($mg100g^{-1}$), total chlorophyll (mg $100g^{-1}$), iron content (mg $100g^{-1}$), vitamin-C content (mg $100g^{-1}$), dry matter (%) and dietary fibre content (%). The crop was raised following recommended package of practices and the observations were recorded on five randomly tagged plants in each treatment over the replications for each trait. The average of the five plants was taken for analysis.

Table-1: Parents used in the study

S. No.	Lines	Source
1.	NDBG-1, NDBG-3,NDBG-4,NDBG-5, NDBG-6, NDBG-7, NBDG-12, NDBG-17	From Narendra Dev University of Agriculture & Technology, UP. (Selections)
2.	Pant Karela-1	GBPUA&T, Pantnagar (Selection)
3.	PBTH-52	GBPUA&T, Pantnagar
4.	Arka Harit	IIHR -ICAR (Pureline selection)
5.	Jounpuri	Local selection from Jounpur
6.	Local Bitter gourd (LBG)	SKUAST-K (Selection)

Data Analysis: Analysis of variance for each of the character in randomized block design was performed utilizing the technique of Fisher and Yates (1938).

Means of observations were subjected to pooled combining ability analysis using model described by Dhillon and Pollmer (1978).

$$Yijkp = \mu + g_i + g_j + S_{ij} + E_p + (gE)_i + (gE)_j + (SE)_{ij} + rk_p + e_{ijkp}$$

Where,

Yijkp	=	ij^{th} observation in k^{th} replication and p^{th} environment,
M	=	general mean,
Ep	=	effect of p^{th} environment,
gi/gj	=	general combining ability effect of i^{th} (j^{th}) parents,
Sij	=	specific combining effects of cross between i^{th} and j^{th} parents,
(gE)i/ (gE)j	=	interaction between gca effect of i^{th} (j^{th}) parent with the p^{th} environment,
(SE)ij	=	interaction between sca effect of ij^{th} hybrid with p^{th} environment,
Rkp	=	effect of k^{th} replication in p^{th} environment and
Eijkp	=	residual effect associated with $ijkp^{th}$ observations

The analysis of variance for combining ability pooled over the environments was taken as under:

Source of variation	**d.f.**	**S.S**	**M.S**	**Expected mean squares**
Environnent (E)	(p-1)	SS_E	-	-
Line (L)	(l-1)	SS_l	M_{41}	$\sigma^2 e + \frac{tpr}{(l-1)} \sum_i^l g^2 i$
Tester (T)	(t-1)	SS_t	M_{42}	$\sigma^2 e + \frac{lpr}{(t-1)} \sum_j^t g^2 j$
Line × Tester (L × T)	(l-1) (t-1)	SS_{lt}	M_{43}	$\sigma^2 e + \frac{pr}{(l-1)(t-1)} \sum_i^l \sum_j^t s^2 ij$
L × E	(l-1) (p-1)	SS_{lE}	M_{44}	$\sigma^2 e + \frac{lr}{(l-1)(p-1)} \sum_i^l (gE)^2 i$
T × E	(t-1) (p-1)	SS_{tE}	M_{45}	$\sigma^2 e + \frac{lr}{(t-1)(p-1)} \sum_j^t (gE)^2 j$
L × T× E	(l-1)(t-1)(p-1)	SS_{ltE}	M_{46}	$\sigma^2 e + \frac{r}{(t-1)(p-1)^{ij}} \sum_i^l \sum_j^t (SE)^2 ij$
Pooled error	P (r-1) (lt-1)	SS_e	M_{47}	$\sigma^2 e$

Where,

l, t, p and r were number of females, males, environments and replications, respectively.

Mean squares were obtained after dividing the sum of squares by their respective degrees of freedom. Significance of various mean squares was tested by the ‘F’ test employing pooled error mean squares as denominator.Fixed model effects were used to estimate the components since the materials used and the location over two years was fixed. The model of Kempthorne (1957) was used for estimating the GCA and SCA effects in combining ability analysis for F_1 generation. The model underlying this analysis is:

$$Xijk = \mu + gi + gj + sij + eijk$$

Where,

μ	=	general mean
gi	=	general combining ability effect of the i^{th} line
gj	=	general combining ability effect of the j^{th} tester
sij	=	specific combining ability effect of i^{th} lines and j^{th} tester
eijk	=	error associated with ijk^{th} observation
i	=	number of lines (i......... 1 to 8)
j	=	number of testers (j.......... 1 to 3)
k	=	number of replications (k..........1to 2)

RESULTS AND DISCUSSION

Analysis of variance: The present study revealed that mean sum of squares due to lines, testers, crosses and line × tester were significant for node to first male flower appearance, node to first female flower appearance, days to anthesis of first male flower, days to anthesis of first female flower, days to first fruit harvest, total phenols ($mg100g^{-1}$), total chlorophyll ($mg\ 100g^{-1}$), iron content ($mg\ 100g^{-1}$), vitamin-C content ($mg\ 100g^{-1}$), dry matter (%) and dietary fibre content (%) in pooled analysis. Thus a significant variability was reported among parents and crosses and the diverse lines upon crossing with testers produced substantial variability among crosses.

Table-2: Mean squares for different earliness traits ANOVA (Pooled data over Locations)

Source of variation	d.f	Node to first male flower appearance	Node to first female flower appearance	Days to anthesis of first male flower	Days to anthesis of first female flower	Days to first fruit harvest
Replications	2	0.21*	0.74**	43.69**	2.09	1.51
Environments	2	23.32**	23.63**	310.68**	276.81**	395.17**
Parents + crosses	42	5.19**	11.31**	138.93**	91.45**	107.87**
Parents vs crosses	1	15.28**	36.95**	92.46**	363.92**	374.00**
Replications x Environments	4	$1xe^{-4}$	$1xe^{-5}$	$1xe^{-3}$	$1xe^{-4}$	$2xe^{-3}$
Crosses	29	4.50**	8.24**	37.60**	71.35**	72.69**
Lines	9	3.98**	15.87**	378.07**	98.22**	182.38**
Testers	2	17.87**	22.14**	140.21**	102.49**	134.62**
Lines x testers	1	0.521**	11.97**	967.28**	318.82**	137.84**
Crosses x Environments	58	$1xe^{-3}$	$1xe^{-4}$	$1xe^{-5}$	$1xe^{-3}$	$1xe^{-3}$
Lines x Environments	18	$2 x e^{-3}$	$1xe^{-3}$	$2xe^{-3}$	$3xe^{-3}$	$2xe^{-3}$
Testers x Environments	4	$1xe^{-6}$	$1xe^{-3}$	$1xe^{-3}$	$1xe^{-3}$	$1xe^{-5}$
Lines x Testers x Environments	24	$1xe^{-5}$	$2xe^{-3}$	$2xe^{-3}$	$2xe^{-3}$	$1xe^{-3}$
Pooled Error	252	0.05	0.05	7.10	1.71	1.12

*, ** significant at 5 &1 per cent level

For total carotenoids (mg100g^{-1}) mean squares due to crosses were significant while mean squares due to various other sources of variation were non-significant which indicates that less variability was found within the parents for this trait which depicts that variability has been created by crossing programme for total carotenoids as depicted by significant mean squares due to crosses. The mean squares due to parents vs crosses were significant for all the traits under study except total carotenoids which indicated the possibility of sufficient amount of heterosis exploitation for these traits. The interactions resulting from lines x environment, tester × environment, crosses x environment and line × tester ×environment were non-significant for all the traits except dietary fiber (Table 2&3). The similar studies were carried by Kundu, B.C *et al*. 2021 for earliness in bitter gourd; Acharya, S.K *et al*. 2019 in bitter gourd for earliness and Vitamin C content; Mallikarjunarao *et al*. 2018 for earliness and quality in bitter gourd.

Table -3: Mean squares for different quality traits ANOVA (Pooled data over Locations)

Source of variation	d.f	Total Carotenoids (mg 100g^{-1})	Total Phenols (mg 100g^{-1})	Total Chlorophy ll (mg 100g^{-1})	Iron content (mg 100g^{-1})	Vitamin C (mg 100g^{-1})	Dry matter (%)	Dietary fibre (%)
Replications	2	9.27	0.563	225.06**	0.0001	1.69**	1.34**	0.01**
Environments	2	0.06	279.57**	364.53**	0.05**	392.46**	53.73**	0.187**
Parents + crosses	42	15.17*	185.90**	14440.13**	0.028**	671.75**	29.99**	0.387**
Parents vs crosses	1	2.08	264.09**	8875.93**	0.027**	768.70**	9.24**	8.88**
Replications x Environments	4	1xe^{-3}	1xe^{-4}	1xe^{-3}	1xe^{-4}	1xe^{-3}	1xe^{-3}	1xe^{-4}
Crosses	29	21.77**	165.32**	12032.53**	0.03**	541.05**	23.77**	0.184**
Lines	9	0.336	266.82**	22236.27**	0.02**	360.69**	51.54**	0.095**
Testers	2	0.081	169.02**	23440.46**	0.038**	826.70**	22.29**	0.100**
Lines x testers	1	0.595	9.91**	1658.54**	0.23**	6854.75**	52.72**	0.768**
Crosses x Environments	58	1xe^{-4}	1xe^{-3}	1xe^{-5}	1xe^{-4}	1xe^{-3}	1xe^{-4}	0.01**
Lines x Environments	18	1xe^{-3}	1xe^{-3}	1xe^{-3}	1xe^{-3}	1xe^{-3}	1xe^{-3}	0.001**
Testers x Environments	4	2xe^{-3}	1xe^{-4}	2xe^{-4}	1xe^{-4}	2xe^{-3}	1xe^{-3}	0.002**
Lines x Testers x Environments	24	1xe^{-4}	0.24	1xe^{-4}	1xe^{-5}	0.174	0.013	1xe^{-3}**
Pooled Error	252	5.13	0.48	12.03	1xe^{-3}	0.52	0.11	1xe^{-4}

*,** significant at 5 &1 per cent level

Components of Genetic Variance: The present study revealed that the variance due to lines (σ^2_{lines}) was significant for most of the traits except total carotenoids, total phenols, total chlorophyll and iron content in pooled analysis. The $\sigma^2_{testers}$ was non-significant for all the traits over environments and in combined analysis. In general σ^2_{lines} was more than σ^2_{tesers} for all the traits under study. This reveals that the contribution of lines towards total variability for these traits is more as compared to testers. The interactions arising from $\sigma^2_{lines\ x\ E}$ was significant for total carotenoids and total phenols while it was non-significant for rest of the traits. The interaction of $\sigma^2_{testers\ x\ E}$ was non-significant for all the traits total phenols and total chlorophyll. The variance due to SCA (σ^2_{sca}) was significant for all the traits under study in combined analysis except total carotenoids. The variance due to GCA (σ^2_{gca}) was significant for most of the traits except days to anthesis of first male flower, days to first fruit harvest, total carotenoids, total phenols and iron content. The variance due to interactions σ^2_{gca} × E was significant for total carotenoids, total phenols, node to first male flower appearance and variance due to σ^2_{sca} × E was significant for all the traits except iron content and dietary fibre. In general σ^2_{sca} was found to be more than σ^2_{gca} for all the traits which indicates that there is the preponderence of non-additive gene action for the traits (Table 4&5). Similar studies were carried by Acharya, S.K *et al*. 2019 for maturity and quality traits; Mahboob *et al*. 2015 for various maturity traits; Sridhar and Mulge (2015) for quality and maturity traits. Dominance variance (σ^2_D) was found predominant for controlling the inheritance of traits. The average degree of dominance was >1 for all the traits which indicates the over dominant expression of the traits depicting non-additive gene expression for the traits. The degree of dominance was in over dominant range for all the traits in pooled analysis. The same results with average degree

Table-4: Estimation of the components of variance, genetic components of variance, degree of dominance and heritability for various Earliness traits in Bitter gourd (*Momordica charantia* L.) (Pooled data over locations)

Components of variance/genetic components of variance	Node to first male flower appearance	Node to first female flower appearance	Days to anthesis of first male flower	Days to anthesis of first female flower	Days to first fruit harvest
σ^2_{lines}	0.171 ±0.10	0.610** ± 0.27	1.571* ±0.7	4.582** ±2.04	4.432** ±2.01
$\sigma^2_{lines\ x\ E}$	-0.005 ±1xe^{-4}	-0.007 ±1xe^{-2}	-0.052 ±1xe^{-4}	-0.051 ±1xe^{-4}	-0.05 ±0.00
$\sigma^2_{testers}$	0.008 ±0.02	0.020 ± 0.02	0.281 ± 0.23	0.463 ± 0.40	0.061 ±0.20
$\sigma^2_{testers\ x\ E}$	0.002** ±1xe^{-4}	0.002** ±1xe^{-5}	-0.015 ±1xe^{-3}	-0.015 ±1xe^{-3}	-0.014 ±0.00
σ^2_{gca}	0.051 ±0.03	0.181** ±0.06	0.572 ±0.25	1.421** ±0.55	1.061 ±0.48
$\sigma^2_{gca\ x\ E}$	-0.002** ±1xe^{-4}	-0.004 ±1xe^{-4}	-0.02 ±1xe^{-4}	-0.02 ±1xe^{-3}	-0.02 ±0.00
σ^2_{sca}	0.480** ±0.15	0.512** ±0.16	3.901** ±1.20	5.321** ±1.61	6.220** ±1.98
$\sigma^2_{sca\ x\ E}$	0.015** ±0.002	0.021** ±0.002	0.15** ±0.02	0.151** ±0.02	0.14** ±0.01
σ^2_E	0.48**	0.13**	1.68**	1.49**	2.13**
σ^2_A	0.11	0.31	1.15	2.82	2.15
σ^2_D	0.48	0.51	3.9	5.3	6.22
σ^2_A/σ^2_D	0.23	0.60	0.28	0.53	0.36
Av. Degree of dominance	2.15	1.28	1.8	1.36	1.71
Heritability (n.s) %	18.16	34.45	23.08	35.42	25.95

of dominance greater than unity were observed by Singh *et al*. 2012 for node to first female flower, days to first female flower appearance. Although dominance component was more in magnitude for all the traits in the present study but both the variances (σ^2_{gca} and σ^2_{sca}) were significant for most of the traits viz., node to first female flower appearance, days to anthesis of first female flower, vitamin-C, dry matter content and dietary fibre content which reflects the importance of both additive and non-additive gene effects in the inheritance of these traits. The role of additive and dominant genes in the inheritance various traits in bitter gourd was observed by various researchers viz., Acharya, S.K *et al*. 2019 ; Bhatt *et al*. 2017 for various maturity and quality traits; Sundaram 2008 for days to first male and female flower, node number at 1st male & female flower. The preponderance of non-additive gene action is very useful for the exploitation of heterosis in F_1 hybrids. However the differences in the results might have due to the differences in the genetic material studied. Narrow sense heritability (n.s) provides a measure of fixable component of genetic variance in a genotype. In the present study the heritability (n.s) was found to be low (< 30%) for node to first male flower appearance, days to anthesis of first male flower, days to first fruit harvest, total carotenoids, total phenols, total chlorophyll and iron content. It was moderate (30-50%) for node to first female flower appearance, days to anthesis of first female flower, vitamin-C, dry matter content and dietary fibre content. In general the estimates of heritability were low to moderate which vary due to influence of environment and due to non-additive gene actions. Kempthorne (1957) also observed that heritability estimates can be biased upwards due to G×E interactions, linkage or epistasis.

Table-5: Estimation of the components of variance, genetic components of variance, degree of dominance and heritability for various quality traits in Bitter gourd (*Momordica charantia* L.) (Pooled data over locations)

Components of variance/genetic components of variance	Total carotenoids (mg 100g^{-1})	Total phenols (mg 100g^{-1})	Total chlorophyll (mg 100g^{-1})	Iron content (mg 100g^{-1})	Vitamin C (mg 100g^{-1})	Dry matter (%)	Dietary fibre (%)
σ^2 lines	0.521 ±0.42	5.711 ±3.2	561.190 ±274.23	0.002 ±0.0008	33.271** ±14.74	1.882** ±0.81	0.016** ±0.005
σ^2 lines x E	-0.81** ±0.00	0.062* ±0.00	27.151** ±0.00	0.0001 ±1xe^{-4}	-0.038 ±1xe^{-3}	-0.01 ±0.00	0.00 ±0.00
σ^2 testers	0.202 ±0.21	1.782 1.40	83.231 ±71.75	0.0002 ±0.0003	8.250 ±5.9	0.04 ±0.05	0.0014 ±0.001
σ^2 testers x E	-0.24 ±0.00	0.02** ±0.00	8.141** ±0.00	1xe^{-4} ±1xe^{-3}	-0.011 ±1xe^{-4}	-0.003 ±0.00	0.00 ±0.00
σ^2 gca	0.271 ±0.19	2.691 ±1.9	193.601** ±83.97	0.0031 ±0.003	14.081 ±5.7	0.410 ±0.22	0.005** ±0.002
σ^2 gca x E	-0.372* ±0.00	-0.03** ±0.00	-12.53 ±0.00	1xe^{-5} ±1xe^{-4}	-0.02 ±1xe^{-4}	-0.005 ±0.00	0.00 ±0.00
σ^2 sca	1.572** ±0.75	18.901** ±6.01	1175.84** ±380.42	0.0034** ±0.0011	37.710** ±11.93	1.372** ±0.43	0.006** ±0.002
σ^2sca x E	2.45** ±0.26	0.18** ±0.02	81.47** ±8.68	-0.0001 ±0.00	2.191** ±0.01	0.03** ±0.003	0.0001 ±0.00
σ^2_E	0.05**	1.58**	0.08**	0.0003**	2.17**	0.29**	0.001**
σ^2_A	0.54	5.38	387.20	0.0008	28.05	0.92	0.009
σ^2_D	1.5	18.93	1175.84	0.0034	37.71	1.37	0.006
σ^2_A/σ^2_D	0.34	0.28	0.39	0.24	0.74	0.67	1.50
Av. degree of dominance	1.7	1.87	1.74	2.05	1.15	1.22	0.81
Heritability (n.s) %	15.50	22.31	26.09	19.44	42.73	34.78	43.66

Combining ability: None of the parents revealed significant and desirable gca effects for all the traits under study simultaneously (Table 6 &7). The parents exhibiting desirable and significant gca effects were NDBG-1 NDBG-5, NDBG-7, NDBG-17 and Local bitter gourd for node to first male and female flower appearance; NDBG-17, NDBG-12, Arka Harit, NDBG-4 and NDBG-5 for days to anthesis of first male flower; NDBG-17, NDBG-12, NDBG-5, Arka Harit and Local bitter gourd for days to anthesis of first female flower; NDBG-17, NDBG-1, Pant Karela-1, NDBG-4 and Arka Harit for days to first fruit harvest; NDBG-5, Arka Harit and NDBG-4 for total carotenoids; NDBG-4, Pant Karela-1, NDBG-6, NDBG-5, NDBG-1 for total phenols; NDBG-1, NDBG-4, NDBG-6, NDBG-7 and Arka Harit for total chlorophyll; NDBG-4, NDBG-7, Pant Karela-1, NDBG-1 and Arka Harit for iron content; Pant Karela-1, NDBG-4, NDBG-7, Arka Harit and NDBG-12 for vitamin-C content; NDBG-4, NDBG-1, NDBG-7, Pant Karela-1 and Arka Harit for dry matter; NDBG-1, NDBG-4, Pant Karela-1, PBTH-52 and Arka Harit for dietary fibre.

Table-6: Estimation of GCA effects of lines and testers used in bitter gourd for Earliness (Pooled data over locations)

Lines	Node to first male flower appearance	Node to first female flower appearance	Days to anthesis of first male flower	Days to anthesis of first female flower	Days to first fruit harvest
NDBG-1	-0.77**	-0.66**	0.08	1.14**	-0.003
NDBG-3	0.08	0.15*	2.05**	2.32**	2.76**
NDBG-4	0.57**	0.18**	-0.38*	-0.01	-0.61**
NDBG-5	-0.42**	-1.02**	-0.15	-0.76**	0.64**
NDBG-6	0.42**	0.03	-0.05	0.87**	0.88**
NDBG-7	-0.30**	-0.62**	-0.03	-0.002	-0.08
NDBG-12	0.65**	0.39**	-1.01**	-1.95**	-1.19**
NDBG-17	-0.17**	-0.33**	-2.41**	-4.56**	-4.52**
Pant Karela-1	-0.03	0.04	0.16	0.003	-0.77**
PBTH-52	-0.05	1.84**	1.74**	2.95**	2.91**
Line- S.E(g_i)	0.04	0.05	0.13	0.13	0.12
S.E(g_i-g_j)	0.06	0.07	0.18	0.20	0.18
C.D (p≤ 0.05)	0.11	0.14	0.36	0.36	0.35
C.D (p≤ 0.01)	0.15	0.18	0.48	0.48	0.46
Testers					
Arka Harit	0.103**	0.13**	-0.46**	-0.44**	-0.26**
Jounpuri	-0.023	0.02	0.58**	0.78**	0.05
Local bitter gourd	-0.073**	-0.15**	-0.12	-0.34**	0.21*
Tester - S.E	0.02	0.03	0.07	0.07	0.07
S.E(g_i-g_j)	0.09	0.04	0.10	0.10	0.09
C.D (p≤ 0.05)	0.06	0.07	0.19	0.19	0.19
C.D (p≤ 0.01)	0.08	0.10	0.26	0.26	0.25
No. of parents showing desirable gca effects	5	5	4	5	5

As for as desirable gca effects along with good *per se* performance is concerned, for node to first male flower appearance, the parent NDBG-5 had significant gca effects and good *per se* performance while as for node to first female flower appearance, the parents NDBG-5 and NDBG-7 were having high desirable gca effects along with good *per se* performance. Thus NDBG-5 proved to be best combiner for both node to first male and female flower appearance and NDBG-7 for node to first female flower appearance.

However genotypes NDBG-1, NDBG-7 and NDBG-17 had high gca effects for node to first male flower appearance but poor performance while NDBG-1 and NDBG-17 were having high desirable gca effects for node to first female flower appearance but with low *per se* performance.

The parents NDBG-5 and NDBG-4 were good both in terms of gca effects and per se performance for days to anthesis of first male flower while parent NDBG-5 had good significant gca effects along with *per se* performance for days to anthesis of first female flower. Thus the genotype NDBG-5 exhibited good general combining ability for both days to anthesis of first male flower and days to anthesis of first female flower and parent NDBG-4 was observed as best combiner for days to anthesis of first male flower. The parents NDBG-17, NDBG-12 and Arka Harit were having high desirable gca effects but were low performing. For days to first fruit harvest, parent NDBG-17 recorded high gca effects and per se performance and thus proved as good combiner. However NDBG-12, Pant Karela-1, NDBG-4 and Arka Harit exhibited high desirable gca effects but with low performance.(Table 8 & 9) Similar studies in bitter gourd were carried by Sundharaiya and Venkatesan (2007) for earliness; Radha Kaniti (2015) for earliness; Acharya *et.al* (2019) for earliness and quality traits.

Table-7: Estimation of GCA effects of lines and testers used in bitter gourd for quality traits (Pooled data over locations)

Lines	Total Carotenoids (mg 100g^{-1})	Total Phenols (mg 100g^{-1})	Total Chlorophyll (mg 100g^{-1})	Iron content (mg 100g^{-1})	Vitamin C (mg 100g^{-1})	Dry matter (%)	Dietary fibre (%)
NDBG-1	-0.13	0.77**	35.81**	0.005*	-3.98**	1.35**	0.24**
NDBG-3	-0.11	-4.36**	-20.20**	-0.041**	-3.03**	-1.83**	-0.004
NDBG-4	0.04	3.81**	27.22**	0.06**	7.88**	2.95**	0.17**
NDBG-5	2.49**	**1.01****	-21.93**	-0.05**	-3.36**	-0.97**	-0.13**
NDBG-6	-0.41	1.31**	26.09**	0.0001	-3.03**	-0.76**	-0.12**
NDBG-7	-0.40	-0.25	11.18**	0.042**	5.22**	0.57**	-0.03**
NDBG-12	-0.38	-2.35**	-24.15**	-0.001	1.61**	-0.70**	-0.08**
NDBG-17	-0.44	-0.99**	-26.44**	-0.031**	-8.84**	-0.75**	-0.14**
Pant Karela-1	-0.26	2.47**	3.35	0.03**	9.03**	0.34**	0.07**
PBTH-52	-0.39	-1.42**	-10.93	-0.01**	-1.47**	-0.17**	0.01**
Line- S.E(g_i)	0.52	0.14	3.01	0.0024	0.11	0.06	0.0025
S.E(g_i-g_j)	0.73	0.20	4.25	0.0033	0.16	0.08	0.0035
C.D (p≤ 0.05)	1.45	0.39	8.39	0.0066	0.31	0.17	0.007
C.D (p≤ 0.01)	1.92	0.52	11.08	0.0087	0.41	0.22	0.009
Testers							
Arka Harit	0.61*	-0.34**	6.13**	0.013**	3.31**	0.21**	0.04**
Jounpuri	-0.27	1.47**	4.54**	-0.001	-1.46**	-0.19**	-0.002
Local Bitter gourd	-0.33	-1.14**	-10.67**	-0.012**	-1.85**	-0.02	-0.04**
Tester - S.E	0.28	0.07	1.64	0.0013	0.06	0.033	0.001
S.E(g_i-g_j)	0.40	0.11	2.33	0.0018	0.08	0.05	0.002
C.D (p≤ 0.05)	0.79	0.22	4.59	0.0036	0.17	0.09	0.0038
C.D (p≤ 0.01)	1.05	0.28	6.06	0.0048	0.23	0.12	0.005
No. of parents showing desirable gca effects	2	6	6	5	5	5	5

For total carotenoids only parent NDBG-5 was observed to have good general combining ability for having high desirable gca effects along with good *per se* performance. Parents NDBG-5 and NDBG-1 were better in terms of both gca effects and per se performance for total phenols and thus proved good general combiner for the trait. However NDBG-4, Pant Karela-1and NDBG-6 were having high desirable gca effects but poor performance for total phenols. For total chlorophyll parents NDBG-1 and NDBG-6 were found good general combiners for the trait having high desirable gca effects and good *per se* performance, while NDBG-4 and NDBG-7 were poor performing with good gca effects. In case of iron content NDBG-4, NDBG-7 and Pant Karela-1were superior in terms of gca effects and *per se* performance and thus good combiners for the trait, while as NDBG-1 and Arka Harit were poor performing with high desirable gca effects. The genotypes Pant Karela-1, NDBG-7 and Arka Harit were good in terms of gca effects and *per se* performance for vitamin-C content while as NDBG-4 and NDBG-12 were having high desirable gca effects but poor performance. For dry matter content NDBG-4 and NDBG-7 were good in terms of gca effects and *per se* performance and proved to be good combiners for the trait.

Table-8: Best Parents identified on the basis of GCA effects and *per se* performance for earliness in bitter gourd (*Momordica charantia* L.) (Pooled data over locations)

Trait	Parent	GCA effect	Parent	*Per se* Performance
Node to first male flower appearance	NDBG-1	-0.77**	Jounpuri	6.05
	NDBG-5	-0.42**	PBTH-52	6.50
	NDBG-7	-0.30**	NDBG-5	6.60
	NDBG-17	-0.17**	NDBG-12	6.68
	Local Bitter Gourd	-0.073**	Arka Harit	6.70
Node to first female flower appearance	NDBG-5	-1.02**	NDBG-12	8.05
	NDBG-1	-0.66**	PBTH-52	8.20
	NDBG-7	-0.62**	Arka Harit	8.65
	NDBG-17	-0.33**	NDBG-5	8.80
	Local Bitter Gourd	-0.15**	NDBG-7	8.82
Days to anthesis of first male flower	NDBG-17	-2.41**	NDBG-7	50.43
	NDBG-12	-1.01**	NDBG-5	51.43
	Arka Harit	-0.46**	NDBG-4	51.90
	NDBG-4	-0.38**	PBTH-52	53.18
	NDBG-5	-0.15	NDBG-6	53.28
Days to anthesis of first female flower	NDBG-17	-4.56**	NDBG-7	58.40
	NDBG-12	-1.95**	NDBG-5	60.56
	NDBG-5	-0.76**	NDBG-4	61.48
	Arka Harit	-0.44**	NDBG-6	62.95
	Local Bitter Gourd	-0.34**	PBTH-52	63.21
Days to first fruit harvest	NDBG-17	-4.52**	NDBG-7	69.18
	NDBG-12	-1.19**	NDBG-6	70.48
	Pant Karela-1	-0.77**	NDBG-5	70.50
	NDBG-4	-0.61**	NDGB-4	75.23
	Arka Harit	-0.26**	NDBG-17	73.45

However NDBG-1, Pant Karela-1and Arka Harit were having high desirable gca effects with low *per se* performance. For Dietary fibre content parents NDBG-1, NDBG-4, Pant Karela-1 and PBTH-52 were having good gca effects and *per se* performance and thus indicated good general combining ability for the trait while Arka Harit was having high desirable gca effects with poor performance.

The desirable and significant gca effect for most of the traits indicates the preponderance of additive gene action. Significant advancement could be achieved in the segregating generations involving these or either of the parents using simple selection procedures. Similar studies were carried by Jadhav *et al.* (2010) for earliness and yield; Mishra, and Singh (2018) for earliness; Sit and Sirohi (2005) for earliness.

None of the crosses were found to have high desirable sca effects for earliness (Table 10). For node to first male flower appearance crosses NDBG-17 × Local Bitter Gourd, Pant Karela-1 × Jounpuri, NDBG-4 × Arka Harit, NDBG-1 × Arka Harit and NDBG-3 × Jounpuri possessed high desirable sca effects. The crosses namely Pant Karela-1 × Jounpuri, NDBG-3 × Jounpuri, PBTH-52 × Arka Harit, NDBG-7 × Local Bitter Gourd, NDBG-12 × Arka Harit were the best specific combinations for node to first female flower appearance.

For maturity traits, NDBG-17 × Jounpuri, NDBG-7 × Arka Harit, NDBG-3 × Local Bitter Gourd, NDBG-5 × Jounpuri, NDBG-6 × Local Bitter Gourd were best combinations for days to anthesis of first male flower.

Table-9: Best Parents identified on the basis of GCA effects and *per se* performance for quality traits in Bitter gourd (*Momordica charantia* L.) (Pooled data over locations)

Trait	Parent	GCA effect	Parent	*Per se* Performance
Total carotenoids ($mg\ 100g^{-1}$)			NDBG-3	0.94
	NDBG-5	2.49**	NDBG-1	0.68
	Arka Harit	0.61*	NDBG-4	0.63
	NDBG-4	0.04	NDBG-6	0.57
			NDBG-5	0.45
Total phenols ($mg\ 100g^{-1}$)	NDBG-4	3.81**	NDBG-3	46.31
	Pant Karela-1	2.47**	NDBG-5	36.48
	NNDBG-6	1.31**	NDBG-17	36.28
	NDBG-5	1.01**	NDBG-12	34.95
	NDBG-1	0.77**	NDBG-1	34.60
Total chlorophyll ($mg\ 100g^{-1}$)	NDBG-1	35.81**	NDBG-3	348.56
	NDBG-4	27.22**	NDBG-12	288.23
	NDBG-6	26.09**	NDBG-1	280.68
	NDBG-7	11.18**	NDBG-6	277.18
	Arka Harit	6.13**	Jounpuri	297.13
Iron content ($mg\ 100g^{-1}$)	NDBG-4	0.06**	NDBG-4	0.38
	NDBG-7	0.042**	Pant Karela-1	0.35
	Pant Karela-1	0.03**	NDBG-7	0.31
	NDBG-1	0.005*	NDBG-17	0.30
	Arka Harit	0.013*	NDBG-3	0.30
Vitamin C content ($mg\ 100g^{-1}$)	Pant Karela-1	9.03**	NDBG-1	45.31
	NDBG-4	7.88**	Pant Karela-1	39.48
	NDBG-7	5.22**	NDBG-17	37.21
	Arka Harit	3.31**	NDBG-7	34.56
	NDBG-12	1.61**	Arka Harit	59.90
Dry matter (%)	NDBG-4	2.95**	NDBG-4	14.57
	NDBG-1	1.35**	NDBG-12	14.10
	NDBG-7	0.57**	NDBG-6	13.03
	Pant Karela-1	0.34**	NDBG-7	12.10
	Arka Harit	0.21**	NDBG-17	11.04
Dietary fibre (%)	NDBG-1	0.24**	Pant karela-1	0.86
	NDBG-4	0.17**	NDBG-6	0.85
	Pant Karela-1	0.07**	NDBG-4	0.81
	PBTH-52	0.01**	PBTH-52	0.72
	Arka Harit	0.04**	NDBG-1	0.71

The crosses NDBG-17 × Jounpuri, PBTH-52 × Arka Harit, NDBG-1 × Local Bitter Gourd, NDBG-3 × Arka Harit, NDBG-7 × Arka Harit were good specific combinations for days to anthesis of first female flower. For days to first fruit harvest crosses namely NDBG-17 × Jounpuri, NDBG-3 × Arka Harit, NDBG-1 × Local bitter gourd, NDBG-12 × Local Bitter Gourd, NDBG-6 × Arka Harit were good combinations with high sca effects. From table-10 it was revealed that for total carotenoids NDBG-5 × Arka Harit was best specific combination (good sca effects) for this trait. The crosses Pant Karela-1 × Arka Harit, NDBG-5 × Jounpuri, NDBG-4 × Arka Harit, NDBG-6 × Local Bitter Gourd and NDBG-3 × Jounpuri were best combinations for total phenols with respect to sca effects.

For total chlorophyll content NDBG-17 × Local Bitter Gourd, NDBG-12 × Arka Harit, PBTH-52 × Jounpuri, NDBG-7 × Local Bitter Gourd and NDBG-1 × Arka Harit were best combinations with respect to sca effects. For iron content NDBG-17 × Jounpuri, NDBG-7 × Arka Harit, NDBG-6 × Local Bitter Gourd, NDBG-12 × Arka Harit, Pant Karela-1 × Local Bitter Gourd were best in terms of sca effects. For vitamin-C content, NDBG-7 × Arka Harit, NDBG-12 × Arka Harit, PBTH-52 × Jounpuri, NDBG-17 × Local Bitter Gourd, NDBG-3 × Arka Harit showed high sca effects.

Table-10: Estimates of SCA effects for earliness in crosses of bitter gourd (*Momordica charantia* L.) (Pooled data over locations)

Crosses	Node to first male flower appearance	Node to first female flower appearance	Days to anthesis of first male flower	Days to anthesis of first female flower	Days to first fruit harvest
NDBG-1 × Arka Harit	-0.72**	-0.42**	-0.37	0.65**	1.81**
NDBG-1 × Jounpuri	-0.16*	0.45**	1.36**	2.02**	-0.20
NDBG-1 × Local bitter gourd	0.87**	-0.03	-0.99**	-2.68**	-1.61**
NDBG-3 × Arka Harit	0.13	0.03	-0.39	-2.28**	-2.87**
NDBG-3 × Jounpuri	-0.94**	-0.61**	2.37**	2.33**	0.42
NDBG-3 × Local bitter gourd	0.81**	0.58**	-1.98**	-0.05	2.45**
NDBG-4 × Arka Harit	-0.65**	0.054	-1.03**	-1.67**	-0.43*
NDBG-4 × Jounpuri	0.41**	-0.21*	2.13**	1.13**	1.12**
NDBG-4 × Local bitter gourd	0.24**	0.15	-1.11**	0.54*	-0.69**
NDBG-5 × Arka Harit	0.058	0.80**	-0.66**	0.86**	-0.22
NDBG-5 × Jounpuri	-0.33**	-0.66**	-1.90**	-1.43**	0.27
NDBG-5 × Local bitter gourd	0.27**	-0.13	2.56**	0.56*	-0.05
NDBG-6 × Arka Harit	-0.025	-0.08	2.39**	0.43	-1.47**
NDBG-6 × Jounpuri	0.63**	0.43**	-0.91**	0.72**	1.58**
NDBG-6 × Local bitter gourd	-0.61**	-0.35**	-1.47**	-1.15**	-0.10
NDBG-7 × Arka Harit	-0.16**	-0.49**	-2.03**	-1.73**	0.67**
NDBG-7 × Jounpuri	0.77**	0.82**	1.33**	1.19**	1.79**
NDBG-7 × Local bitter gourd	-0.17**	-0.33**	0.70**	0.54**	-1.13**
NDBG-12 × Arka Harit	0.35**	-0.42**	0.24	0.42	-0.74**
NDBG-12 × Jounpuri	0.45**	-0.12	0.22	-0.53*	2.31**
NDBG-12 × Local bitter gourd	-0.09	0.54**	-0.47*	0.10	-1.57**
NDBG-17 × Arka Harit	1.02**	0.99**	2.54**	3.78**	5.28**
NDBG-17 × Jounpuri	-0.09	0.57**	-3.87**	-4.58**	-6.11**
NDBG-17 × Local bitter gourd	-0.92**	-1.57**	1.33**	0.79**	0.82**
Pant Karela-1 × Arka Harit	0.16**	0.17*	0.07	2.33**	0.73**
Pant Karela-1 × Jounpuri	-0.65**	-0.67**	0.08	-0.99**	-0.81**
Pant Karela-1 × Local bitter gourd	0.49**	0.49**	-0.15	-1.33**	0.08
PBTH- 52 x Arka Harit	0.52**	-0.64**	-0.77**	-2.80**	-1.42**
PBTH- 52 x Jounpuri	-0.08	0.005	-0.81**	0.13	-0.36
PBTH-52 × Local bitter gourd	-0.44**	0.64**	1.58**	2.67**	1.78**
S.E(S_{ij})	0.07	0.08	0.22	0.23	0.22
C.D (p≤ 0.05)	**0.19**	**0.25**	**0.63**	**0.63**	**0.60**
C.D (p≤ 0.01)	**0.25**	**0.33**	**0.83**	**0.83**	**0.80**
No. of crosses showing desirable significant sca effects	11	11	13	11	11

Table-11: Estimates of SCA effects for quality traits in crosses of bitter gourd (*Momordica charantia* L.) (Pooled data over locations)

Crosses	Total Carotenoids (mg 100g^{-1})	Total Phenols (mg 100g^{-1})	Total Chlorophyll (mg 100g^{-1})	Iron content (mg 100g^{-1})	Vitamin C (mg 100g^{-1})	Dry matter (%)	Dietary fibre (%)
NDBG-1 × Arka Harit	-0.51	4.89**	29.93**	-0.035**	2.23**	-0.27**	0.15**
NDBG-1 × Jounpuri	0.30	-1.63**	21.35**	-0.001	-0.62**	-0.49**	-0.03**
NDBG-1×Local bitter gourd	0.21	-3.26**	-51.29**	0.04**	-1.60 **	0.77**	-0.12**
NDBG-3 × Arka Harit	-0.49	-0.38	15.70**	0.02**	4.05**	2.38**	-0.06**
NDBG-3 × Jounpuri	0.55	4.34**	-1.48	0.001	2.26**	-1.43**	0.04**
NDBG-3×Local bitter gourd	0.16	-3.95**	-14.21**	-0.02**	-6.32**	-0.95**	0.02**
NDBG-4 × Arka Harit	-0.55	-3.38**	-14.75**	0.0001	-1.86**	1.26**	0.06**
NDBG-4 × Jounpuri	0.23	2.05**	10.52*	0.01**	-1.66**	-1.46**	0.004
NDBG-4×Local bitter gourd	0.32	1.33**	4.22	-0.01**	3.52**	0.20	-0.07**
NDBG-5 × Arka Harit	5.08**	-1.77**	14.21**	-0.038**	-5.44**	0.14	-0.06**
NDBG-5 × Jounpuri	-2.56**	-0.22	-22.43**	0.0002	1.49**	0.034	0.001
NDBG-5×Local bitter gourd	-2.52**	1.99**	8.22	0.037**	3.97**	-0.17	0.06**
NDBG-6 × Arka Harit	-0.62	-2.08**	-19.27**	-0.07**	-5.17**	-1.37**	-0.05**
NDBG-6 × Jounpuri	0.29	5.31**	14.92**	-0.01*	3.89**	0.96**	-0.02**
NDBG-6×Local bitter gourd	0.34	-3.23**	4.35	0.07**	1.28**	0.41**	0.06**
NDBG-7 × Arka Harit	-0.51	2.54**	-18.80**	0.13**	12.09**	-0.59**	-0.02**
NDBG-7 × Jounpuri	0.24	-3.44**	-20.75**	-0.04**	-9.34**	1.01**	-0.11**
NDBG-7×Local bitter gourd	0.27	0.90**	39.56**	-0.08**	-2.75**	-0.41**	0.12**
NDBG-12 × Arka Harit	-0.59	4.57**	50.18**	0.06**	7.12**	0.27**	-0.03**
NDBG-12 × Jounpuri	0.30	-7.66**	-27.62**	-0.002	-2.72**	0.63**	0.04**
NDBG-12×Local bitter gourd	0.29	3.09**	-22.56**	-0.06**	-4.38**	-0.90**	-0.01*
NDBG-17 × Arka Harit	-0.64	-6.06**	-41.68**	-0.1**	-8.43**	-0.53**	-0.06**
NDBG-17 × Jounpuri	0.28	0.03	-18.85**	0.05**	3.95**	0.42**	0.004
NDBG-17×Local bitter gourd	0.75	6.03**	60.54**	0.02**	4.47**	0.11	0.05**
Pant Karela-1 × Arka Harit	-0.54	2.46**	7.75	-0.03**	-0.72**	-0.52**	0.06**
Pant Karela-1 × Jounpuri	0.27	-1.48**	-3.92	-0.01**	-0.30**	-0.89**	-0.02**
Pant Karela-1×Local bitte gourd	0.30	-0.97**	-3.83	0.04**	3.72**	1.42**	-0.04**
PBTH- 52 x Arka Harit	-0.61	-0.78**	-23.27**	0.02**	-3.85**	-0.75**	-0.02**
PBTH- 52 x Jounpuri	-0.31	2.71**	48.27**	0.007	5.75**	1.22**	0.07**
PBTH-52× Local bitter gourd	0.29	-1.93**	-25.01**	-0.03**	-1.89**	-0.46**	-0.06**
S.E(S_{ij})	0.9	0.24	5.21	0.004	0.20	0.10	0.004
C.D ($p \leq 0.05$)	2.52	0.68	14.54	0.01	0.54	0.28	0.012
C.D ($p \leq 0.01$)	3.33	0.90	19.19	0.02	0.72	0.38	0.015
No. of crosses showing desirable significant sca effects	1	13	10	11	14	11	11

For dry matter content NDBG-3 × Arka Harit, Pant Karela-1 × Local Bitter Gourd, NDBG-4 × Arka Harit, PBTH-52 × Jounpuri and NDBG-7 × Jounpuri were best combinations in terms of sca effects. The crosses NDBG-1 × Arka Harit, NDBG-7 × Local Bitter Gourd, PBTH-52 × Jounpuri, NDBG-6 × Local Bitter Gourd and NDBG-5 × Local Bitter Gourd were having high desirable sca effects for dietary fibre. Overall perusal of the results (Table-11) revealed that NDBG-17 × Jounpuri, NDBG-7 × Arka Harit and NDBG-6 × Local Bitter Gourd and NDBG-12 ×

Local Bitter gourd were best cross combinations with respect to sca effects and *per se* performance for earliness in bitter gourd. Thus the parents of such crosses could be used for developing hybrids followed by multi-location testing and release of promising ones on commercial scale in Kashmir valley.

The superior performance of the cross combinations (Table-12) with H×L, H×M, M×M, M×L general combiners for the respective traits might be due to presence of fixable and non-fixable genes which depicts that improvement can be made through adoption of suitable breeding methods which utilizes both additive and non-additive genetic variation. The promising cross combinations with significant desirable sca and *per se* for different traits (earliness) could yield transgressive seggregants in subsequent generations (Venkateshwarlu and Singh 1982). The results are in conformity with Mishra, and Singh (2018) for earliness.

Table-12: Best crosses identified on the basis of SCA effects, and *per se* performance for different traits in bitter gourd (*Momordica charantia* L.) (Pooled data over locations)

Trait	Cross combinations	Per se performance	Cross combinations	Sca Effect	Gca effect of parents
Total phenols (mg 100g^{-1})	NDBG-6 x Jounpuri	39.85	NDBG-17 x Local Bitter Gourd	6.03**	L x L
	NDBG-4 x Jounpuri	39.10	NDBG-6 x Jounpuri	5.31**	H x M
	NDBG-1x Arka Harit	37.09	NDBG-1 x Arka Harit	4.89**	H x L
	Pant Karela-1 x Arka Harit	36.35	NDBG-12x Arka Harit	4.57**	Lx L
	NDBG-4 x Local Bitter Gourd	35.77	NDBG-3 x Jounpuri	4.34**	L x H
Total chlorophyll (mg 100g^{-1})	NDBG-1x Arka Harit	309.35	NDBG-17 x Local Bitter Gourd	60.54**	Lx L
	NDBG-1 x Jounpuri	299.18	NDBG-12 x Arka Harit	50.18**	L x M
	NDBG-6 x Jounpuri	283.03	PBTH-52 x Jounpuri	48.27**	L x M
	NDBG-4 x Jounpuri	279.77	NDBG-7x Local Bitter Gourd	39.57**	H x L
	PBTH-52 x Jounpuri	279.30	NDBG-1 x Arka Harit	29.93**	H x M
Iron content (mg 100g^{-1})	NDBG-7 x Arka Harit	0.45	NDBG-7 x Arka Harit	0.13**	H x M
	NDBG-12 x Arka Harit	0.34	NDBG-6 x Local Bitter Gourd	0.07**	L x L
	NDBG-6x Local Bitter Gourd	0.33	NDBG-12 x Arka Harit	0.06**	L x M
	NDBG-4 x Arka Harit	0.33	NDBG-17 x Jounpuri	0.05**	L x L
	Pant Karela-1 x Local Bitter Gourd	0.32	Pant Karela-1xLocal Bitter Gourd	0.04**	H x L
Vitamin C content (mg 100g^{-1})	NDBG-7 x Arka Harit	55.03	NDBG-7 x Arka Harit	12.09**	H x H
	NDBG-12 x Arka Harit	46.43	NDBG-12 x Arka Harit	7.12**	H x H
	Pant Karela-1 x Arka Harit	46.02	PBTH- 52 x Jounpuri	5.75**	L x L
	Pant Karela-1 x LOCAL BITTER GOURD	45.30	NDBG-17 x Local Bitter Gourd	4.47**	L x L
	NDBG-4 x Arka Harit	43.73	NDBG-3 x Arka Harit	4.05**	L x H
Dry matter (%)	NDBG-4 x Arka Harit	14.75	NDBG-3 x Arka Harit	2.38**	L x M
	NDBG-4 x Local Bitter Gourd	13.47	Pant Karela-1xLocal Bitter Gourd	1.42**	H x L
	NDBG-1xLocal Bitter Gourd	12.41	NDBG-4 x Arka Harit	1.26**	H x M
	Pant karela-1xLocal Bitter Gourd	12.07	PBTH- 52 x Jounpuri	1.22**	L x L
	NDBG-7 x Jounpuri	11.72	NDBG-7 x Jounpuri	1.01**	H x L
Dietary fibre (%)	NDBG-1x Arka Harit	0.76	NDBG-1x Arka Harit	0.15**	H x M
	NDBG-4 x Arka Harit	0.61	NDBG-7 x Local Bitter Gourd	0.12**	L x L
	NDBG-1 x Jounpuri	0.54	PBTH- 52 x Jounpuri	0.07**	M x L
	NDBG-4 x Jounpuri	0.51	NDBG-6 x Local Bitter Gourd	0.06**	L x L
	Pant Karela-1 x Arka Harit	0.50	NDBG-5 x Local Bitter Gourd	0.06**	L x L

CONCLUSION

From the present study it could be concluded that the experimental material in the present study was diverse and the environment played a significant role in the expression of earliness related traits. earliness was governed by both additive and non-additive gene actions. Thus an appropriate breeding procedure viz. heterosis breeding could be adopted for the development of high yielding hybrids for harnessing non-additive genes. The lines NDBG-5, NDBG-17, NDBG-12 and NDBG-4 exhibited high gca effects along with good *per se* performance for earliness and thus could be considered as good combiners for improving earliness related traits in bitter gourd. The crosses viz; NDBG-17 × Jounpuri, NDBG-7 × Arka Harit and NDBG-6 × Local Bitter Gourd and NDBG-12 × Local Bitter gourd were best cross combinations with respect to sca effects and *per se* performance for earliness in bitter gourd. Thus the parents of such crosses could be used for developing hybrids after testing at different locations in Kashmir and release of best ones on commercial scale. The promising cross combinations for earliness with parents having low × high or low × medium *gca* effects, could yield transgressive segregates in later generations using appropriate mating design.

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