Gene action and Heterosis studies for Yield and its attributes in Bitter gourd *(Momordica charantia*. L)under Temperate ecologies

ABSTRACT

Thirty crosses developed through Line x Tester mating design along with their parents were evaluated for combining ability, heterosis and gene action for yield and its attributes in bitter gourd. The experimental material was evaluated in RCBD design with three replications at three different locations viz., Vegetable Experimental Farm, Division of Vegetable Science, SKUAST-Kashmir, Shalimar Srinagar (E_1); Faculty of Agriculture, Wadura, Sopore (E_2) and KVK Malangpora, Pulwama (E_3). The mean squares due to parents vs crosses were significant for all the traits, which indicated the possibility of sufficient amount of heterosis exploitation for these traits. The σ^2_{sca} was found to be more than σ^2_{gca} for all the traits under study which indicated the preponderance of non-additive gene action for the traits. However 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 lines viz: NDBG-4, NDBG-1, NDBG-5, Pant Karela-1 and NDBG-7 were found to be good general combiners for most the economic traits. The extent of heterosis exhibited by crosses were estimated over standard parent (Arka Harit). The crosses viz: Pant Karela-1 × Arka Harit, NDBG-4 × Arka Harit, NDBG-1 × Arka Harit, NDBG-7 × Jounpuri, NDBG-5 × Jounpuri, NDBG-5 × Local bitter gourd, Pant Karela-1 × Jounpuri, NDBG-4 × Local bitter gourd and NDBG-4 × Local bitter gourd showed high standard heterosis for yield and yield attributes. Thus these crosses can be exploited as desirable hybrids for yield.

KEYWORDS:*Momordica charantia*, Heterosis, combining ability, genetic effects, Bitter gourd

Introduction

Bitter gourd (*Momordica charantia* L.) is an important commercial cucurbit belonging to the family Cucurbitaceae. It is considered to be the native of Tropical Asia especially Eastern India and Southern China (Miniraj et al.,1993). Bitter gourd is a nutritional crop and 100 grams of the bitter gourd fruit contain 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 (Rose et al., 2014). Bitter gourd is used in various herbal medicine systems owing to the presence of disease preventing and health promoting phyto-chemical compounds like dietary fiber, vitamins, flavonoids and antioxidants. These compounds help act as protective scavengers against oxygen-derived free radicals and reactive oxygen species (ROS) that play a role in aging, cancers and degenerative disease. The fruits are used as laxative, antipyretic and reduces blood diseases, rheumatism and asthma and good for digestion (Thangamani and Pugalendhi, 2013). Inspite of the potential economic and medicinal importance of the crop, due attention has not been given towards a need based crop improvement programme. However recently the cultivation of bitter gourd has become increasingly popular because of the growing awareness of the anti-diabetic property and nutritive value of the crop among the consumers. Considering the nutrient and health benefits of the crop it is desirable to improve the crop in terms of yield and quality.

The increasing world population urges to a need for increasing the crop production and productivity to ensure food security and nutritional security. The basic aim of any breeding programme is to increase crop yield and quality. Plant breeder needs to identify sources of desirable genes, incorporate them into breeding population and select for a combination of desirable traits that might result in development of improved crop wealth. The improved crop is then either exploited as a commercial release to farmers or used to develop elite inbreds for hybrid or synthetic production. The choice of parents is considered as an important aspect for improving yield and its attributes and for this selection of desirable parents is of utmost importance. The importance of the estimation of gene effects in the formulation of a breeding procedure for a quantitative trait especially yield was noted by Gamble, 1962. According to him, the magnitude of gene effects depicts relative importance in the inheritance. The high degree of yield potential could result from combination of gene effects (Jinks and Janes, 1958). The parental genotypes are selected on the basis of not only their *per se* performance but also by their combining ability. The selection of best parents for hybridization has to be based on the complete genetic information and prepotency of potential parents. Therefore before any improvement programme is initiated through hybridization, there is a need to have a knowledge on combining ability of base population and the nature and magnitude of various genetic parameters operative in different characters. The combining ability helps to identify potential parents that are used for the development of hybrids and synthetics (Vasal, 2000). The nature and magnitude of gene actions controlling the quantitative traits forms the basis for selecting good combiners and superior hybrids reflected through general combining ability (GCA) effects and high specific combining ability (SCA) effects respectively (Viana, S and Matta, D.P 2003). The concept of combining ability for the evaluation of parent in a crossing programme is of immense significance. It has been extensively used to classify the parental lines and determine their ability to transmit desirable performance to hybrid combination. Therefore, it helps the breeder in identifying the best combiner which may be hybridized either to exploit heterosis or to combine the favourable fixable genes. Heterosis in cross pollinated crop has been known to offer potentialities for increased yield. Heterosis is the superiority of F_1 over the mean of the parents or over the better parent (BP) or over the standard check (Hayes et al., 1956) with respect to economic traits. Commercial exploitation of heterosis in cross pollinated vegetable crops is one of the major break-through in the field of plant breeding. The primary objective of heterosis breeding is to achieve increased yield. As cucurbits do not show inbreeding depression, superior recombinants identified in subsequent generations could also be explored for commercial exploitation. In our country, a wide range of variability in vegetative and fruit characters is available in bitter gourd. 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. Various researchers have reported significant heterosis for yield attributes in bittergourd (Naik, B.P.K etal., 2020; Adarsh etal.,2018). But not much commercially high yielding hybrids have been released from public sector organization so far. The selection of hybrids based on desirable heterosis, combining ability and good *per se* performance in the field will produce better yield on commercial basis. Keeping in view the above facts the present investigation was carried out to generate information on genetic variability, combining ability studies, nature and magnitude of gene effects and heterosis in bitter gourd.

Materials and Methods

The present investigation entitled "Genetic effects, combining ability and Heterosis for yield and its attributes in Bitter gourd *(Momordica charantia*. L)" was conducted at Vegetable Experimental Farm, Division of Vegetable Science, SKUAST-Kashmir, Shalimar Srinagar J&K during 2019-2020. Ten diverse lines of bitter gourd 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 during *Kharief* 2019 to generate a set of 30 crosses using line × tester mating design given by Kempthorne (1957). 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 ($E_{1,}$ Central Kashmir); Faculty of Agriculture, Wadura ($E_{2,}$ North Kashmir) and KVK Malangpora ($E_{3,}$ South Kashmir) during *Kharief* 2020.. Seeds of male and female parents were sown in polybags and after a month seedlings were transplanted into the main field. The crosses were attempted in line × tester (L × T) fashion (Kempthorne, 1957). The selected flower buds of male parents as well as female parents were covered with butter paper bags to avoid undesirable crossing. The pollinated buds were again covered with butter paper bags to avoid contamination and tagged. A total of 30 crosses were developed by crossing ten female parents (lines) with each of three male parents (testers). Simultaneously the male and female parents were selfed by bagging with butter paper bags. Crossed and selfed fruits were harvested separately at full matured stage. The seeds were extracted, dried in shade and preserved in butter paper bags, labelled with the details of cross. Next year, Seeds of thirty crosses along with their parents were sown in poly-bags and seedlings were transplanted after one month keeping row to row and plant to plant spacing 0.5mx1m respectively. The observations were recorded on eight traits viz., vine length(cm), fruit length (cm), fruit diameter (cm), number of fruits plant^{-1}, average fruit weight (g), fruit yield plant^{-1} (kg), fruit yield hectare^{-1} (q) and number of seeds fruit^{-1}.

Statistical analysis

The statistical Analysis was done by utilizing the mean values of the five random plants selected from each cross/Line for yield parameters. Mean of observations were subjected to pooled combining ability analysis using model described by Dhillon and Pollmer (1978); Analysis of variance for each of the character in randomized block design was performed utilizing the technique of Fisher and Yates (1938); Average degree of dominance was calculated as per the procedure given by Comstock and Robinson (1952); the magnitude of heterosis was estimated using the methods of Turner (1953) and Hayes et al. (1956) at 1% and 5 % level of significance.

Results and Discussion

The analysis of variances (Table-1) for different traits revealed that mean squares due to lines, testers, crosses and line × tester were significant for all the traits under study in all the three environments and in pooled analysis. This depicts the presence of significant variability among parents and crosses and also the presence of divergent gene complexes among lines which upon crossing with testers produce substantial variability among crosses. The mean squares due to parents vs crosses were significant for all the traits which indicates the possibility of sufficient amount of heterosis exploitation for these traits. For fruit yield plant^{-1} and fruit yield hectare^{-1} the interactions resulting from lines x environment, tester × environment, crosses x environment and line × tester × environment were significant; for vine length, number of fruits plant^{-1} and number of seeds fruit^{-1} the interaction crosses × environment was significant; for average fruit weight crosses × environment and lines x environment were significant. This indicates differential response of experimental material for various yield attributes to changing environment. The similar studies were carried by Thangamani and Pugalendhi, 2013; Acharya et al., 2019 for bitter gourd and Kaur and Dhal, 2017 for cucumber.

Components of variance

From Table-2 it was revealed that σ^2_{lines} was significant for all the traits except fruit diameter in pooled analysis. However in general the variance due to lines ($\sigma^2_{lines)}$ wasmore thanvariance due to testers(σ^2testers)for all the traits under study. The $\sigma^2_{testers}$ was non-significant for all the traits over environments and in pooled analysis. 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 fornumber of fruits plant^{-1}, average fruit weight, fruit yield plant^{-1} and fruit yield hectare^{-1} while it was non-significant for rest of the traits.Theinteraction of $\sigma^2_{testers\ x\ E}$ was non-significant for all the traits except number of fruits plant^{-1} and average fruit weight. In pooled analysis σ^2_{sca} and σ^2_{gca} was significant for all the traits under study except non significant σ^2_{gca} for fruit yield hectare^{-1} and fruit diameter. The variance due to interactions σ^2_{gca} × Ewas significant for fruit yield plant^{-1} and fruit yield hectare^{-1} and variance due toσ^2_{sca} × Ewas significant for all the traits except number of seeds fruit^{-1}. In general σ^2_{sca} was found to be more thanσ^2_{gca} for all the traits which indicates that there is the preponderance of non-additive gene action for the traits. The non-additive type of gene action for yield and yield attributing traits was observed by Mahboob et al., (2015) for various yield traits; Sridhar and Mulge (2015) number of fruits per vine, average fruit weight and fruit yield per vine.

Translating the variances of gca and sca into additive variance (σ^2_A) and dominance variance (σ^2_D), it was found that the σ^2_D was predominant for controlling the inheritance of traits. The average degree of dominance was greater than one for all the traits which indicates the over dominant expression of the traits depicting non-additive gene expression for the traits. Although dominance component was more in magnitude for all the traits in the present study but both the variances ($\sigma^2_{gca\ and}$ σ^2_{sca}) were significant for most of the traits viz, vine length, fruit length, number of fruits plant-^{1}, average fruit weight, fruit yield plant$^{-1,}$ number of seeds fruit^{-1} 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., Bhatt et al., (2017) for various yield and yield attributes. Jasim and Esho (2021) reported that additive variance was responsible for vine length whereas, non-additive for yield in summer squash. Similar results were observed by Talukder et al.(2018) in bitter gourd. The degree of dominance was in over dominant range for all the traits in all the three environments and in pooled analysis. The same results with average degree of dominance greater than unity were observed by Singh et al., (2012) for fruit diameter, fruit yield per plant, vine length; Tiwari et al., (2001) length, fruitdiameter, fruit density and fruit yield per vine. The preponderance of non-additive gene action for various yield and yield attributing traits was probably due to over-dominance of genes and such gene action is very useful for the exploitation of heterosis in F_1 hybrids. The possibilities for commercial exploitation of heterosis for yield attributes has also been reported by Jasim and Esho (2021) in summer squash;Ashwini, B (2021) in bitter gourd.. 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 the breeding value of the genotypes i.e fixable component of genetic variance. In cross pollinated crops, heritability is considered to be a good predictor of gain if the population is kept large enough to prevent inbreeding (Moll and Stuber, 1974). In the present study the heritability (n.s) was found to be low (< 30%) for fruit diameter, fruit yield hectare^{-1}; moderate (30-50%) vine length, fruit length, number of fruits plant$^{-1,}$ average fruit weight, fruit yield plant^{-1},number of seeds plant^{-1}. In general the estimates of heritability were low to moderate which vary due to influence of environment and due to non-additive gene actions. Low heritability indicates that the genes in the lines act in positive and negative directions and on combination at a particular loci might have resulted in over-dominance. Moreover Robinson et al., (1949) observed differential response of genotype under different environment which tend to reduce the heritability estimates and these estimates would be biased upwards if linkage dis-equilibrum or epistasis is present.

Combining ability effects

None of the parents revealed significant and desirable gca effects for all the traits simultaneously. The parents exhibiting desirable and significant gca effects (Table-3) for different yield and yield attributes were NDBG-1 for vine length, fruit length, number of fruits/plant; NDBG-3 for fruit diameter and number of fruits/plant ; NDBG-4 for fruit length, fruit diameter, average fruit weight, fruit yield/plant, fruit yield/ha and seed yield /fruit; NDBG-5 for number of fruits/plant; NDBG-6 for vine length, fruit length, fruit diameter and number of seeds/fruit; NDBG-7 for vine length and fruit length; NDBG-12 for vine length; NDBG-17 for vine length and number of fruits/plant; Pant karela-1 for vine length, fruit length, fruit diameter, average fruit weight, fruit yield, fruit yield/ha and seed yield/fruit; PBTH-52 for vine length, average fruit weight, number of fruits plant^{-1} fruit yield/plant and fruit yield/ha. The parents exhibiting high gca effects along with good *per se* performance (Table-4) for various yield and yield attributing traits were NDBG-4, NDBG-1, NDBG-5, Pant Karela-1 and PBTH-52. These parents can be used in multiple crossing to develop synthetics and for the isolation of elite inbred lines and as a potent source for improving the economic traits in bitter gourd. Similar work has been carried out by various researchers viz; Ashwini, B (2021); Kundu et al., (2021; Bhatt et al.(2017); Khan et al.(2017); Kaniti (2015); Sridhar and Mulge (2015); Dey et al., (2010), Jadhav et al.,(2010).It was observed that the parental lines which were high performing were also good general combiners for the respective characters. It can be inferred that the potential parents for utilization in breeding programmes to improve such traits in bitter gourd may be judged on the basis of their *per se* performance. However as discussed above, for various traits the lines showed high desirable gca effects but were low performing. This suggests that combining ability of parents cannot always be judged accurately by their *per se* performance. The same was observed by Maurya et al., (1993) in bottle gourd. Thus in present study the improvement in yield and other economic traits could be achieved through hybridization of good general combiners.

In the present study as for as SCA effects are concerned (Table-5) for vine length, NDBG-3 × Arka Harit, NDBG-4 × LBG, Pant Karela-1 × LBG, NDBG-6 × Jounpuri and NDBG-1 × Arka Harit were best combinations in terms of sca effects. The crosses NDBG-17 × LBG, NDBG-12 × Jounpuri, NDBG-7 × Jounpuri, Pant Karela-1 × Arka Harit and NDBG-4 × Arka Harit were good combinations with respect to sca effects for fruit length. For fruit diameter the best combinations in terms of sca effects were NDBG-1 × LBG, Pant Karela-1 × Arka Harit, NDBG-4 × Arka Harit, NDBG-7 × LBG, NDBG-6 × LBG. For number of fruits plant$^{-1,}$ NDBG-1 × Arka Harit, NDBG-17 × Jounpuri, NDBG-4 × LBG, NDBG-3 × Jounpuri and Pant Karela-1 × LBG were good combinations in terms of sca effects. In case of average fruit weight, Pant Karela-1 × Arka Harit, NDBG-4 × Arka Harit, NDBG-6 × LBG, NDBG-7 × Jounpuri, NDBG-1 × LBG were best combinations with respect to sca effects. For fruit yield plant^{-1} and fruit yield ha^{-1} Pant Karela-1 × Arka Harit, NDBG-5 × Jounpuri, NDBG-4 × Arka Harit, NDBG-6 × LBG and NDBG-3 × Jounpuri were good combinations in terms of sca effects. For seed yield/plant the best cross combinations with respect to sca effect were PBTH-52 × Jounpuri, NDBG-1 × Arka Harit, NDBG-6 × LBG, NDBG-17 × LBG and NDBG-7 × Jounpuri. The specific cross combination based on the high desirable sca effects along with good *per se* performance for various traits (Table 5 and 7) are mentioned below. However the combiners (parents) were mentioned as low (L), medium (M) and high (H) according to their *gca* effects for the respective traits. For vine length the best cross combinations were NDBG-17 × LBG (H×L) and NDBG-1 × Arka Harit (M×L). The cross combinations NDBG-7 × Jounpuri (H×M), Pant Karela-1 × Arka Harit (M×L) and NDBG-4 × Arka Harit (H×L) were best for fruit length. Pant Karela-1 × Arka Harit (L×L), NDBG-4 × Arka Harit (H×L), NDBG-1 × LBG (H×L), NDBG-6 × LBG (M×L) were best for fruit diameter. The best combination for number of fruits/plant was NDBG-1 × Arka Harit (H×L). For average fruit weight the best cross combinations were Pant Karela-1 × Arka Harit (H×L), NDBG-4 × Arka Harit (H×L) and NDBG-7 × Jounpuri (L×M). The cross combinations Pant Karela-1 × Arka Harit (H×M) and NDBG-4 × Arka Harit (H×M) were identified best for fruit yield plant^{-1} and fruit yield hectare^{-1}. For number of seeds fruit^{-1} the cross combinations PBTH-52 × Jounpuri (L×M) and NDBG-1 × Arka Harit (M×L) were found best. The superior performance of the cross combinations 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 indicating high success through adoption of suitable breeding methods which utilizes both additive and non-additive genetic variation. These results are in collaboration with the results of Dey et al.,(2010); Dubey and

Maurya (2004); Sit and Sirohi (2005) in bottle gourd. As for as the yield and yield attributes are concerned, the crosses mentioned above having positive x positive gca effects revealed that the high sca effects in these crosses was mainly through additive gene effects. Therefore the best option for improvement is the identification of transgressive segregants which may lead to isolation of promising high yielding lines in bitter gourd (Venkateshwarlu and Singh 1982). These results are in conformity with those of Kundu et al., (2021); Balat et al.,(2021) for bottle gourd; Acharya et al., 2019 ; Bhatt et al.,(2017), Kopped et al.,(2015); Laxuman et al., (2012) and Kaniti (2015) for various yield attributes in bitter gourd.

Heterosis

Perusal of Table-6 revealed that F_1 heterosis over standard parent (Arka Harit) ranged from -56.37 to 13.80% for vine length,-26.28 to 89.65% for fruit length, -42.38 to 16.86 % for fruit diameter, 8.35 to 46.21% for number of fruits plant^{-1} , 121.25 to 52.21 % for average fruit weight, 58.13 to 52.11% for fruit yield plant^{-1},-60.29 to 59.09 % for fruityield hectare^{-1} and -61.58 to 12.40% for number of seeds fruit^{-1}. A total of thirteen crosses showed desirable significant heterosis over standard parent for vine length. Crosses NDBG-17 × Arka Harit (13.80%), Pant Karela-1 × Local bitter gourd (10.28%), NDBG-12 × Local bitter gourd (9.97%), NDBG-1 × Arka Harit (9.18%), NDBG-7 × Jounpuri (8.37%) and PBTH-52 × Arka Harit (7.32%) showed maximum positive standard heterosis for vine length. Number of fruits plant^{-1}, average fruit weight, fruit length and fruit diameter together form the most important closely related productivity parameters. For fruit length twenty seven crosses showed desirable standard heterosis with maximum in NDBG-1 × Arka Harit (52.97%) followed by NDBG-4 × Arka Harit (50.72%), NDBG-7 × Jounpuri (50.29) NDBG-1 × Jounpuri (48.32%), Pant Karela-1×Arka Harit (47.94%), NDBG-4 × Jounpuri (43.89%), NDBG-1 × Local bitter gourd (42.95%) and NDBG-12 × Jounpuri (42.37%). For fruit diameter, the desirable significant heterosis over standard parent was observed in three crosses viz; NDBG-4 × Jounpuri (16.86%), Pant Karela-1 × Arka Harit (16.48%) and NDBG-4 × Arka Harit (11.72%). For number of fruits plant^{-1} desirable significant heterosis over standard parent was observed in twenty five crosses with maximum heterosis in NDBG-1 × Arka Harit (46.21) followed by NDBG-5 × Jounpuri (35.10), NDBG-5 × Local bitter gourd (34.82), PBTH-52 × Local bitter gourd (34.76), NDBG-5 × Arka Harit (33.95), NDBG-17 × Jounpuri (33.18), PBTH-52 × Arka Harit

(31.15), NDBG-4 × Local bitter gourd (29.91), NDBG-3 × Jounpuri (29.18) and NDBG-3 × Arka Harit (29.04). For average fruit weight the desirable significant heterosis over standard parent was observed in eleven crosses with maximum heterosis in Pant Karela-1 × Arka Harit (52.21) followed by NDBG-4 × Arka Harit (47.44), Pant Karela-1 × Jounpuri (32.96), NDBG-4 × Local bitter gourd (25.33), NDBG-7 × Jounpuri (21.25), NDBG-4 × Jounpuri (20.10) and Pant Karela-1 × Local bitter gourd (18.43). Fruit yield per vine is the ultimate and the most important trait. For fruit yield plant^{-1} the desirable significant heterosis over standard parent was observed in eighteen crosses with maximum heterosis in NDBG-4 × Arka Harit (52.11) followed by NDBG-4 × Local bitter gourd (48.38), Pant Karela-1 × Arka Harit (48.09), NDBG-1 × Arka Harit (32.67), NDBG-4 × Jounpuri (32.10), PBTH-52 × Arka Harit (26.88), NDBG-3 × Jounpuri (26.88), PBTH-52 × Jounpuri (25.27), Pant Karela-1 × Local bitter gourd (25.27) and Pant Karela-1 × Jounpuri (24.44). For fruit yield hectare^{-1} the desirable significant heterosis over standard parent was observed in eighteen crosses with maximum in Pant Karela-1 × Arka Harit (59.09) followed by NDBG-4 × Arka Harit (51.57), NDBG-4 × Local bitter gourd (44.69), NDBG-1 × Arka Harit (33.14), NDBG-4 × Jounpuri (31.53), PBTH-52 × Arka Harit (26.57), NDBG-3 × Jounpuri (26.25) and PBTH-52 × Jounpuri (24.90).For number of seeds fruit^{-1}the standard desirable heterosis in ten crosses with maximum in NDBG-4 × Arka Harit (66.25%), NDBG-4 × Local bitter gourd (57.61%), NDBG-1 × Arka Harit (44.68%), NDBG-4 × Jounpuri (39.87%), PBTH-52 × Jounpuri (39.72%) and NDBG-6 × Local bitter gourd (26.69%). Many researchers have found significant heterosis for yield and yield attributes in bitter gourd and other cucurbits viz; Acharya et al., 2019, Jadhav et al.,(2010), Laxuman et al., (2012), Verma et al., (2016) in bitter gourd; Naliyadhara et al.,(2007) in sponge gourd; Narasannavar et al., (2014) and Muthaiah et al., (2017) in ridge gourd; Kamer et al., (2015) in melon.

On the basis of sca effects, *per se* performance and heterosis over standard parent (Table-7) crosses NDBG-17 × Local bitter gourd and NDBG-1 × Arka Harit were best in terms of sca effects, *per se* performance and standard heterosis for vine length. For fruit length the best crosses in terms of sca effects, *per se* performance and standard heterosis were Pant Karela-1 × Arka Harit , NDBG-4 × Arka Harit and NDBG-7 × Jounpuri; for fruit diameter Pant Karela-1 × Arka Harit and NDBG-4 × Arka Harit; for number of fruits plant^{-1} NDBG-1 × Arka Harit ; for average fruit weight Pant Karela-1 × Arka Harit, NDBG-4 × Arka Harit and NDBG-7 × Jounpuri; for fruit yield plant^{-1} and fruit yield ha^{-1} Pant Karela-1 × Arka Harit, NDBG-4 × Arka Harit recorded higher desirable sca effects along with good *per se* performance and standard heterosis. For number of seeds fruit^{-1} PBTH-52 × Jounpuri and NDBG-1 × Arka Harit were best for sca effects, *per se* performance and standard heterosis. Thus for yield and yield attributes, the crosses Pant Karela-1 × Arka Harit, NDBG-4 × Arka Harit, NDBG-1 × Arka Harit NDBG-7 × Jounpuri (having high sca effects and standard heterosis in the desirable direction along with high per se performance) NDBG-5 × Jounpuri, NDBG-5 × Local bitter gourd, Pant Karela-1 × Jounpuri, NDBG-4 × Local bitter gourd,NDBG-4 × Local bitter gourd (having high desirable standard heterosis along with high *per se* performance) could be considered for commercial exploitation for improving yield in bitter gourd. Similar findings were reported byNaik, B.P.K et.al., 2020; Acharya et al., 2019 in bitter gourd; Golabadi et al., 2015 in cucumber for yield and its components. As is obvious from table -7 not only two good general combiners are involved in better specific combining hybrids, even some of the superior crosses were from both parents with good × good general combiner or either one of the parents with high GCA effects (good × poor or poor× good combiners) or parents that are poor × poor combiners for different traits indicating that that parents with either high GCA or low GCA would have a higher chance of having excellent complementarity with other parents (Seymour et al., 2016). The high SCA effects derived from crosses including good × poor GCA effects might be due to favorable epistatic effects of poor general combiner and additive effects of the good general combiner parent. High SCA effects of the crosses from Low×low GCA combiners may be related to dominance × dominance type of non-allelic gene interaction creating over dominance thus being non-fixable (Wassimiet.al.,1986). The non-fixable part of gene action could be shown by the high yield of such crosses and could be exploited by heterosis breeding.

Conclusion

Based upon the findings of the present study it was concluded that the experimental material (parents) in the present study was diverse. Environment played a significant role in the expression of most of the yield attributing traits. Both the additive and non-additive gene actions were significant for most of the traits. This implies that appropriate breeding procedures should be adopted for the development of high yielding hybrids for harnessing non-additive genes. Parents viz; NDBG-4, NDBG-1, NDBG-5, Pant Karela-1 and PBTH-52 showed high gca effects for yield and yield attributes and thus are best combiners and a potent source for improving the economic traits in bitter gourd. The present study assumed that a good combiner for any economic character need not be a good combiner for all other characters. Desirable significant gca effects observed for various yield attributes may be helpful in identifying best parents with favourable alleles for different components of yield. Therefore, high gca ability of a parent for a particular trait coupled with good *per se* performance may act as a reliable criterion for prediction of specific combining ability. The parents of the crosses with high desirable sca effects along with good *per se* performance could be used for developing hybrids followed by multi-location testing and release of promising ones for Kashmir valley. The crosses karela-1 × Arka Harit, NDBG-4 × Arka Harit, NDBG-1 × Arka Harit, NDBG-7 × Jounpuri, NDBG-5 × Jounpuri, NDBG-5 × Local bitter gourd, Pant Karela-1 × Jounpuri, NDBG-4 × Local bitter gourd were best in terms of sca effects, *per se* performance and standard heterosis for yield and yield attributing traits. These crosses could be utilized for the improvement of the such traits and intercrossing among superior segregants of these crosses is likely to produce desirable progenies in the subsequent later generations.

Table 1: Mean squares for different traits (Pooled data over Locations)

Source of variation	**d.f**	**Vine length (cm)**	**Fruit length (cm)**	**Fruit diameter (cm)**	**Average Fruit weight(g)**	**No. of Fruits plant^{-1}**	**Fruit yield plant^{-1}**	**Fruit yield Hactare-^{1}**	**No. of Seeds fruit^{-1}**

Replications	2	33.05*	176.85**	0.60**	22.17**	0.008	$5xe^{-3}$	23.63	0.93**
Environments	2	8085.18**	51.06**	8.06**	341.31**	202.85**	1.91**	1687980.89**	7.20**
Parents + crosses	42	12155.95**	211.75**	2.71**	8863.83**	27.79**	0.72**	4061.82**	127.44**
Parents vs crosses	1	40242.81**	148.41**	0.04*	14220.24**	3.45**	3.03**	15765.81**	931.91**
Replications x Environments	4	$1xe^{-4}$	$3xe^{-3}$	$1xe^{-3}$	$1xe^{-3}$	$1xe^{-4}$	$1xe^{-4}$	23.63	$1xe^{-3}$
Crosses	29	11519.92**	89.29**	2.58**	9949.73**	24.06**	0.52**	3142.99**	98.81**
Lines	9	10564.67**	52.30*	2.55**	4944.53**	19.86**	0.47**	2627.64**	73.83**
Testers	2	19124.00**	2483.07**	6.31**	2043.46**	24.15**	0.44**	2330.06**	25.30**
Lines x testers	1	2899.32**	718.65**	2.96**	20930.68**	238.83**	6.72**	35375.22**	840.25**
Crosses x Environments	58	24.45**	$1xe^{-3}$	$1xe^{-5}$	3.75**	0.31**	0.005**	3142.98**	0.26**
Lines x Environments	18	31.55*	$2xe^{-3}$	$1xe^{-3}$	3.21**	$1xe^{-5}$	0.003**	2627.64**	$2xe^{-4}$
Testers x Environments	4	$1xe^{-3}$	$1xe^{-5}$	$1xe^{-3}$	$1xe^{-4}$	$1xe^{-3}$	.0024*	2330.06**	$2xe^{-3}$
Lines x Testers x Environments	24	0.002	$1xe^{-3}$	$1xe^{-4}$	$2xe^{-3}$	$1xe^{-3}$	0.004**	5307.01**	$2xe^{-3}$
Pooled Error	252	10.03	12.77	0.016	1.94	0.098	0.002	17.65	0.12

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

Table-2 **Estimation of the components of variance, genetic components of variance, degree of dominance and heritability for yield and its attributes in bitter gourd (*Momordica charantia.* L) (Pooled data over Locations)**

Components of variance/genetic components of variance	Vine length (cm)	Fruit length (cm)	Fruit diameter (cm)	Average Fruit weight(g)	No. of fruits plant^{-1}	Fruit yield plant^{-1}	Fruit yield Hactare-^{1}	No. of Seeds fruit^{-1}
σ^2_{lines}	1005.501** ±432.78	7.632** ±3.27	0.102 ±0.06	765.771** ±331.79	1.511* ±0.67	0.039** ±0.017	240.401** ±130.22	8.052** ±3.04
$\sigma^2_{lines\ x\ E}$	-1.07 ±0.00	-0.012 ±1xe^{-3}	-0.002 ±1xe^{-4}	-0.19** ±0.00	-0.011** ±0.001	0.001** ±0.0004	721.213** ±232.60	-0.0073 ±0.00
$\sigma^2_{testers}$	4.021 ±17.60	0.821 ±0.59	0.0021 ±0.009	67.480 ±50.88	0.230 ±0.19	0.0022 ±0.0018	14.351 ±15.12	0.331 ±0.2
$\sigma^2_{testers\ x\ E}$	-0.321 ±0.00	-0.003 ±1xe^{-4}	-0.0005 ±1xe^{-3}	-0.058* ±0.00	-0.0033** ±0.0001	0.0001 ±0.0001	43.06 ±28.24	-0.0022 ±0.00
σ^2_{gca}	235.13* ±100.78	2.391** ±0.88	0.025 ±0.015	228.631** ±85.99	0.552** ±0.21	0.01 ±0.004	66.522 ±32.22	2.122** ±0.83
$\sigma^2_{gca\ x\ E}$	-0.49 ±0.00	-0.006 ±1xe^{-3}	-0.0008 ±1xe^{-3}	-0.090 ±0.00	-0.005** ±0.00	0.0003* ±0.0001	199.561** ±57.90	-0.0034 ±0.00
σ^2_{sca}	547.75** ±173.55	3.603** ±1.14	0.301** ±0.09	557.163** ±176.25	1.722** ±0.55	0.031** ±0.01	182.842** ±72.21	5.222** ±1.62
$\sigma^2_{sca\ x\ E}$	3.20** ±0.34	0.037** ±0.007	0.005** ±0.0008	0.58** ±0.06	0.033** ±0.0036	0.0005** ±0.0002	548.522** ±127.22	0.01 ±0.03
σ^2_E	43.65**	0.27**	0.04**	1.83**	1.11**	0.009**	8004.390**	0.04**
σ^2_A	470.27	4.79	0.05	457.25	1.10	0.02	133.04	4.23
σ^2_D	547.75	3.6	0.30	557.16	1.72	0.03	182.84	5.22
σ^2_A/σ^2_D	0.86	1.33	0.16	0.82	0.64	0.69	0.72	0.81
Av. Degree of dominance	1.08	0.86	2.4	1.10	1.24	1.20	1.17	1.10
Heritability (n.s) %	37.33	28.65	14.44	27.10	18.75	22.17	10.50	30.90

Table-3: Estimation of GCA effects of lines and testers used in crosses of bitter gourd for yield and its attributes (Pooled over Locations)

Lines	Vine length (cm)	Fruit length (cm)	Fruit diameter (cm)	Average Fruit weight(g)	No. of fruits plant^{-1}	Fruit yield plant^{-1}	Fruit yield Hactare-^{1}	No. of Seeds fruit^{-1}
NDBG-1	17.63**	3.59**	-0.18**	-0.07	0.86**	0.076**	15.34**	2.56**
NDBG-3	-45.67**	-2.072**	0.05*	-17.85**	0.49**	-0.09**	-19.26**	-1.96**
NDBG-4	-36.02**	2.90**	0.45**	44.35**	-0.07	0.42**	84.52**	6.12**
NDBG-5	-54.25**	-4.225**	-0.29**	-31.75**	1.89**	-0.17**	-33.80**	-3.29**
NDBG-6	13.73**	0.35**	0.13**	-7.63**	-0.80**	-0.11**	-22.24**	0.72**
NDBG-7	18.31**	2.77**	-0.37**	-5.19**	-1.66**	-0.16**	-32.97**	-0.71**
NDBG-12	23.72**	-1.41**	-0.19**	-12.84**	-0.39**	-0.15**	-30.07**	-0.25**
NDBG-17	24.06**	-3.29**	-0.02	-21.19**	0.90**	-0.11**	-22.37**	-2.51**
Pant Karela-1	21.19**	2.03**	0.61**	53.81**	-2.02**	0.24**	47.93**	1.45**
PBTH-52	17.29**	-0.64**	-0.18**	1.64**	0.81**	0.06**	12.87**	-0.34**
Line- S.E(g_i)	0.59	0.064	0.023	0.25	0.06	0.007	1.33	0.05
S.E(g_i-g_j)	0.84	0.091	0.033	0.36	0.08	0.009	1.18	0.07
C.D ($p \leq 0.05$)	1.66	0.18	0.07	0.71	0.17	0.018	3.71	0.13
C.D ($p \leq 0.01$)	2.19	0.23	0.09	0.94	0.22	0.024	4.90	0.18
Testers								
Arka Harit	2.05**	-0.004	-0.015	-1.88**	0.50**	0.009*	1.72*	-0.33**
Jounpuri	-0.03	0.914**	0.053**	8.99**	-0.53**	0.042**	8.38**	0.67**
Local bitter gourd (LBG)	-2.02**	-0.90**	-0.038**	-7.11**	0.03	-0.05**	-10.10**	-0.35**
Tester - S.E	0.33	0.035	0.01	0.14	0.03	0.0036	0.72	0.03
S.E(g_i-g_j)	0.46	0.049	0.02	0.20	0.05	0.0051	1.03	0.04
C.D ($p \leq 0.05$)	0.91	0.097	0.04	0.39	0.09	0.01	2.03	0.07
C.D ($p \leq 0.01$)	1.2	0.13	0.05	0.51	0.12	0.01	2.68	0.09
No. of parents showing desirable gca effects	8	6	5	4	6	6	6	6

Table-4 **Best parents identified on the basis of gca and *per se* performance for different yield attributing traits in bitter gourd (*Momordica charantia*) (Pooled data over environments)**

Trait	Parent	GCA effect	Parent	*Per se* Performance
Vine length (cm)	NDBG-17	24.06**	NDBG-1	194.85
	NDBG-12	23.72**	Arka Harit	184.18
	Pant karela-1	21.19**	NDBG-4	179.73
	NDBG-7	18.31**	NDBG-3	170.03
	NDBG-1	17.63**	NDBG-7	169.90
Fruit length (cm)	NDBG-1	3.59**	Pant Karela-1	16.23
	NDBG-4	2.90**	NDBG-1	15.25
	NDBG-7	2.77**	NDBG-4	14.33
	Pant Karela-1	2.03**	NDBG-6	13.71
	Jounpuri	0.91**	NDBG-12	13.70
Fruit diameter (cm)	Pant Karela-1	0.61**	NDBG-4	4.98
	NDBG-4	0.45**	NDBG-7	4.27
	NDBG-6	0.13**	NDBG-6	4.12
	NDBG-3	0.05*	Pant Karela-1	4.11
	Jounpuri	0.053**	NDBG-3	3.58
Number of fruits plant^{-1}	NDBG-5	1.86**	NDBG-5	10.50
	NDBG-17	0.90**	NDBG-7	9.90
	NDBG-1	0.86**	NDBG-1	9.25
	PBTH-52	0.81**	Pant Karela-1	8.55
	NDBG-3	0.49**	NDBG-12	8.45
Average fruit weight (g)	Pant Karela-1	53.81**	NDBG-4	145.50
	NDBG-4	44.35**	Pant Karela-1	112.50
	Jounpuri	8.99**	NDBG-1	99.50
	PBTH-52	1.64**	NDBG-5	94.55
			NDBG-6	90.15

Fruit yield plant^{-1}(kg)	NDBG-4	0.42**	NDBG-4	1.03
	Pant Karela-1	0.24**	NDBG-5	0.99
	NDBG-1	0.076**	Pant Karela-1	0.96
	PBTH-52	0.06**	NDBG-1	0.92
	Jounpuri	0.042**	NDBG-12	0.75
Fruit yield hectare^{-1}(q)	NDBG-4	84.52**	NDBG-4	206.50
	Pant Karela-1	47.93**	NDBG-5	198.00
	NDBG-1	15.34**	Pant Karela-1	192.77
	PBTH-52	12.87**	NDBG-1	184.95
	Jounpuri	8.38**	NDBG-12	150.22
Number of seeds fruit^{-1}	NDBG-4	6.12**	NDBG-4	21.33
	NDBG-1	2.56**	NDBG-1	17.50
	Pant Karela-1	1.45**	NDBG-5	16.26
	NDBG-6	0.72**	NDBG-12	15.86
	Jounpuri	0.67**	NDBG-17	15.66

Table-5: Estimates of sca effects for yield and its attributes in crosses of bitter gourd (*Momordica charantia* L.) (Pooled data over environments)

Crosses	Vine length (cm)	Fruit length (cm)	Fruit diameter (cm)	Average Fruit weight(g)	No. of fruits plant^{-1}	Fruit yield plant^{-1}	Fruit yield Ha^{-1}	No. of Seeds fruit^{-1}
NDBG-1 × Arka Harit	12.40**	1.35**	-1.03**	-11.93**	2.98**	0.13**	25.57**	2.82**
NDBG-1 × Jounpuri	3.95**	-0.80**	0.28**	-6.57**	-0.81**	-0.11**	-22.34**	-0.56**
NDBG-1 × Local bitter gourd	-16.35**	-0.54**	0.75**	18.51**	-2.16**	-0.02	-3.23	-2.26**
NDBG-3 × Arka Harit	44.89**	1.59**	0.20**	-1.71**	0.002	-0.01	-2.31	1.68**
NDBG-3 × Jounpuri	-3.95**	-0.79**	0.26**	10.46**	1.05**	0.18**	37.36**	-1.35**
NDBG-3 × Local bitter gourd	-40.93**	-0.80**	-0.47**	-8.75**	-1.05**	-0.17**	-35.04**	-0.33**
NDBG-4 × Arka Harit	-45.29**	1.58**	0.68**	37.53**	-1.36**	0.19**	37.78**	1.56**
NDBG-4 × Jounpuri	12.47**	-1.43**	-0.62**	-30.46**	0.19	-0.26**	-52.04**	-2.23**
NDBG-4 × Local bitter gourd	32.82**	-0.16	-0.07	-7.07**	1.17**	0.07**	14.24**	0.69**
NDBG-5 × Arka Harit	-4.22**	-0.09	-0.6**	-5.49**	-0.62**	-0.09**	-18.94**	-0.42**
NDBG-5 × Jounpuri	-5.04**	-0.33**	0.07	13.59**	0.64**	0.22**	43.35**	-0.12
NDBG-5 × Local bitter gourd	9.26**	0.42**	-0.006	-8.10**	0.006	-0.12**	-24.40	0.55**
NDBG-6 × Arka Harit	-22.41**	-1.68**	0.09*	-15.57**	0.59**	-0.08**	-17.71**	-1.09**
NDBG-6 × Jounpuri	13.81**	0.50**	-0.54**	-13.47**	0.20	-0.10**	-20.37**	-1.69**
NDBG-6 × Local bitter gourd	8.60**	1.18**	0.45**	29.05**	-0.80**	0.19**	38.07**	2.78**
NDBG-7 × Arka Harit	-6.12**	-1.06**	-0.53**	-25.65**	-0.43**	-0.21**	-42.02	-1.02**
NDBG-7 × Jounpuri	12.32**	2.49**	-0.04	20.82**	-0.18	0.12**	24.25**	2.64**
NDBG-7 × Local bitter gourd	-6.20**	-1.42**	0.49**	4.82**	0.61**	0.09**	18.76**	-1.62**

Table -5 contd…

Crosses	**Vine length (cm)**	**Fruit length (cm)**	**Fruit diameter (cm)**	**Average Fruit weight(g)**	**No. of fruits plant^{-1}**	**Fruit yield plant^{-1}**	**Fruit yield Hactare-^{1}**	**No. of Seeds fruit^{-1}**
NDBG-12 × Arka Harit	-0.94	-1.56**	-0.37**	-23.73**	0.89**	-0.15**	-29.51**	-1.31**
NDBG-12 × Jounpuri	-10.91**	2.50**	0.32**	17.54**	-1.15**	0.05**	11.48**	0.76**
NDBG-12 × Local bitter gourd	11.84**	-0.93**	0.05	6.19**	0.26*	0.08**	18.03**	0.55**
NDBG-17 × Arka Harit	14.49**	-2.09**	0.16**	-1.17**	-1.24**	-0.09**	-17.82**	-1.13**
NDBG-17 × Jounpuri	-13.69**	-1.52**	0.29**	-3.51**	1.26**	0.07**	13.16**	-1.85**
NDBG-17 × Local bitter gourd	-0.79	3.61**	-0.45**	4.68**	-0.02	0.02	4.66**	2.98**
Pant Karela-1 × Arka Harit	-2.12*	1.63**	0.74**	44.70**	-0.81**	0.27**	53.27**	0.94**
Pant Karela-1 × Jounpuri	-12.82**	-1.86**	-0.31**	-18.79**	-0.11	-0.18**	-36.73**	0.19*
Pant Karela-1 × Local bitter gourd	14.94**	0.23*	-0.42**	-25.91**	0.91**	-0.08**	-16.54**	-1.14**
PBTH- 52 x Arka Harit	9.32**	0.34**	0.12**	3.03**	-0.006	0.06**	12.69**	-2.03**
PBTH- 52 x Jounpuri	3.86**	1.26**	0.21**	10.39**	-1.06**	0.009	1.86	4.20**
PBTH-52 × Local bitter gourd	-13.19**	-1.59**	-0.33**	-13.42**	-1.07**	-0.07**	-14.56	-2.17**
S.E(S_{ij})	1.03	0.11	0.04	0.44	0.12	0.01	2.30	0.08
C.D ($p \leq 0.05$)	2.88	0.31	0.12	1.23	0.30	0.03	6.44	0.24
C.D ($p \leq 0.01$)	3.80	0.41	0.15	1.62	0.38	0.04	8.49	0.32
No. of crosses showing desirable significant sca effects	14	13	14	13	10	14	14	13

Table -6: Estimates of standard heterosis over check Arka Harit for yield and its attributes in bitter gourd (*Momordica charantia* L.) (Pooled data over environments)

Crosses	Vine length (cm)	Fruit length (cm)	Fruit diameter (cm)	Average Fruit weight(g)	No. of fruits plant^{-1}	Fruit yield plant^{-1}	Fruit yield Hactare-^{1}	No. of Seeds fruit^{-1}
NDBG-1 × Arka Harit	9.18**	51.97**	-42.38**	-20.52**	46.21**	32.67**	33.14**	44.68**
NDBG-1 × Jounpuri	3.46**	48.32**	-10.73**	1.50	17.40**	15.10**	14.81**	22.14**
NDBG-1 × Local bitter gourd	-8.65**	42.95**	-1.84	10.50**	9.47**	16.05**	15.14**	-3.45**
NDBG-3 × Arka Harit	-7.56**	30.72**	-8.43**	-34.51**	29.04**	2.85	1.88	-8.76**
NDBG-3 × Jounpuri	-35.21**	21.29**	-5.36**	0.68	29.18**	26.88**	26.25**	-27.94**
NDBG-3 × Local bitter gourd	-53.35**	5.34**	-24.52**	-65.78**	17.03**	-41.66**	-43.79**	-27.94**
NDBG-4 × Arka Harit	-41.14**	50.72**	11.72**	47.44**	13.06**	52.11**	51.57**	66.25**
NDBG-4 × Jounpuri	-21.05**	43.89**	16.86**	20.10**	18.13**	32.10**	31.53**	39.87**
NDBG-4 × Local bitter gourd	-11.08**	43.89**	-6.13**	25.33**	29.91**	48.38**	44.69**	57.61**
NDBG-5 × Arka Harit	-38.88**	-0.83	-22.61**	-84.71**	33.95**	-19.11**	-26.13**	-41.13**
NDBG-5 × Jounpuri	-40.46**	6.78**	-18.01**	-13.15**	35.10**	23.59**	22.73**	-28.89**
NDBG-5 × Local bitter gourd	-33.77**	-5.59**	-21.84***	-121.35**	34.82**	-47.82**	-49.89**	-32.18**
NDBG-6 × Arka Harit	-11.85**	25.56**	-9.20**	-42.51**	23.97**	-11.47**	-12.90**	-9.58**
NDBG-6 × Jounpuri	6.70**	41.46**	-22.22**	-17.63**	11.09**	-7.93**	-9.31**	-5.81**
NDBG-6 × Local bitter gourd	2.79**	36.47**	-1.53	13.19**	6.05**	18.07**	17.03**	26.69**
NDBG-7 × Arka Harit	-0.51	41.25**	-35.25**	-62.73**	6.01**	-58.13**	-60.29**	-22.45**
NDBG-7 × Jounpuri	8.37**	50.29**	-20.69**	21.25**	-4.40**	15.10**	13.88**	21.51**
NDBG-7 × Local bitter gourd	-2.76**	35.62**	-12.26**	-10.73**	12.14**	-0.31	-1.33	-28.26**
NDBG-12 × Arka Harit	5.24**	13.08**	-27.59**	-82.17**	29.04**	-33.33**	-34.57**	-37.83**
NDBG-12 × Jounpuri	-1.30	42.37**	-9.96**	12.65**	-0.26**	9.33**	8.20**	-8.79**

Table -6 contd…

Crosses	Vine length (cm)	Fruit length (cm)	Fruit diameter (cm)	Average Fruit weight(g)	No. of fruit plant^{-1}	Fruit yield plant^{-1}	Fruit yield Ha^{-1}	No. of Seeds fruit^{-1}
NDBG-12 × Local bitter gourd	9.97**	10.52**	-18.31**	-20.30**	20.74**	-1.40**	0.26	-20.41**
NDBG-17 × Arka Harit	13.80**	-15.48**	-11.11**	-40.56**	22.95**	-11.47**	-13.12**	-40.51**
NDBG-17 × Jounpuri	-2.63**	3.95*	-6.51**	-23.62**	33.18**	15.01**	13.61**	-37.83**
NDBG-17 × Local bitter gourd	3.29**	30.15**	-25.75**	-39.17**	28.50**	-3.03**	-4.01	-1.88
Pant Karela-1 × Arka Harit	3.22**	47.94**	16.48**	52.21**	-3.76	48.09**	59.09**	16.48**
Pant Karela-1 × Jounpuri	-3.72**	38.56**	-6.13**	32.96**	-8.35**	24.44**	23.42**	18.84**
Pant Karela-1 × Local bitter gourd	10.28**	39.80**	-10.73**	18.43**	11.62**	25.27**	24.14**	-3.45**
PBTH- 52 × Arka Harit	7.32**	31.72**	-16.09**	-1.7	31.15**	26.88**	26.57**	-28.54**
PBTH- 52 × Jounpuri	3.22**	40.47**	-12.26**	16.05**	0.41	25.27**	24.90**	39.72**
PBTH-52 × Local bitter gourd	-7.11**	11.64**	-26.82**	-36.03**	34.76**	8.10**	7.22**	-29.98**
No. of crosses showing desirable heterosis	13	27	3	11	25	18	18	10

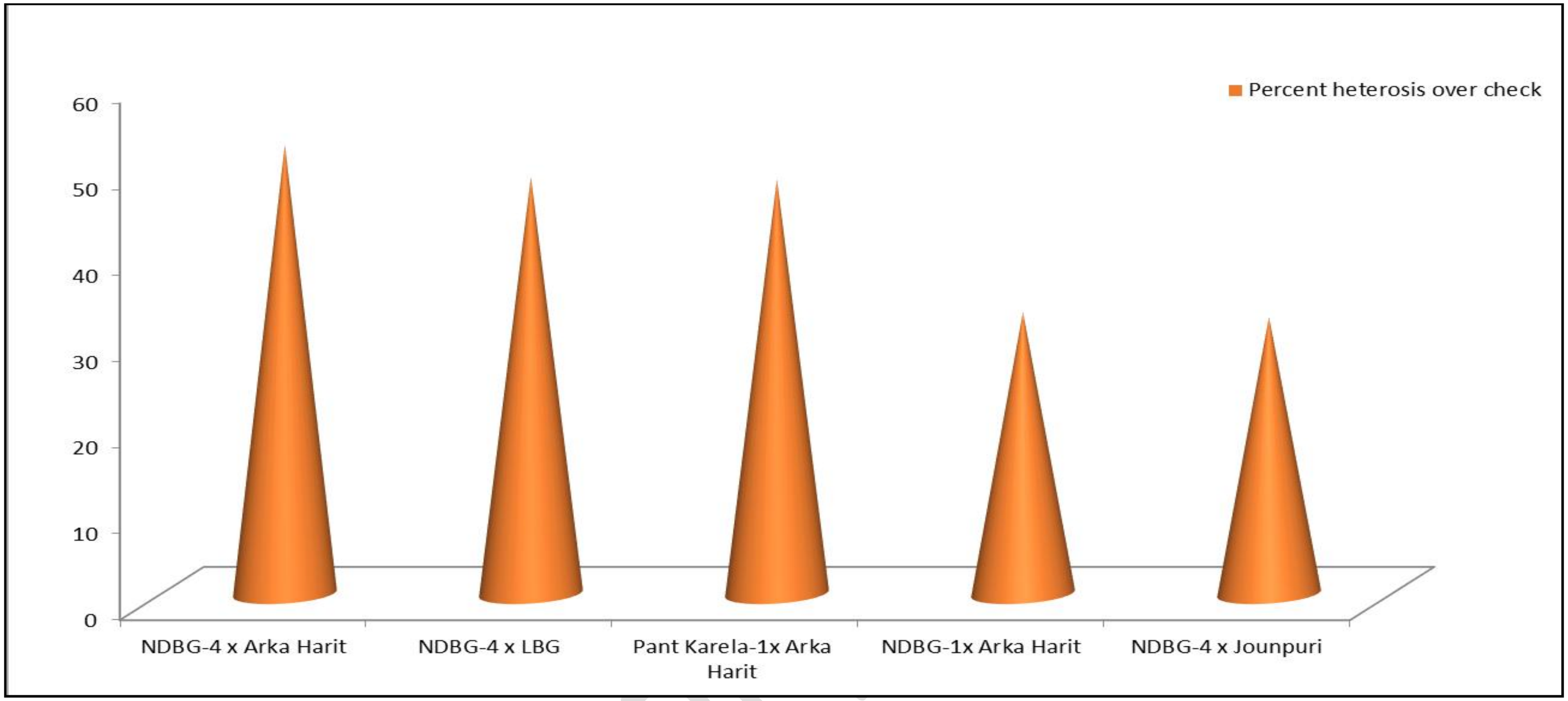

Fig. 1: Per cent heterosis of best five crosses for yield plant^{-1} (kg) over check (Arka Harit)

Table-7 Best crosses identified on the basis of SCA effects, standard heterosis and *per se* performance for yield and yield attributes in bitter gourd (*Momordica charantia* L.)

Trait	Cross combinations	*Per se* performance	Cross combinations	Standard Heterosis (%)	Cross combinations	Sca Effect	Gca effect of parents
Vine length (cm)	NDBG-17 x Arka Harit	209.60	NDBG-17xArkaHarit	13.89	NDBG-3 x Arka Harit	44.89**	L x M
	Pant karela-1 x Local bitter gourd	203.12	Pant Karela-1 x LBG	10.28	NDBG-4 x Local bitter gourd	32.82**	L x L
	NDBG-12 x Local bitter gourd	202.55	NDBG-12 x LBG	9.97	Pant karela-1 x Local bitter gourd	14.94**	H x L
	NDBG-1x Arka Harit	201.08	NDBG-1x Arka Harit	9.18	NDBG-6 x Jounpuri	13.81**	H x L
	NDBG-7 x Jounpuri	199.60	NDBG-7 x Jounpuri	8.37	NDBG-1 x Arka Harit	12.40**	H x L
Fruit length (cm)	NDBG-1x Arka Harit	17.70	NDBG-1xArka Harit	51.97	NDBG-17 x Local bitter gourd	3.61**	L x L
	NDBG-4 x Arka Harit	17.25	NDBG-4 x Arka Harit	50.72	NDBG-12 x Jounpuri	2.50**	L x M
	NDBG-7 x Jounpuri	17.10	NDBG-7 x Jounpuri	50.27	NDBG-7 x Jounpuri	2.49**	H x M
	NDBG-1 x Jounpuri	16.45	NDBG-1 x Jounpuri	48.32	Pant karela-1x ArkaHarit	1.63**	H x L
	Pant karela-1 x Arka Harit	16.42	Pant Karela-1x Arka Harit	47.94	NDBG-4 x Arka Harit	1.58**	H x L
Fruit diameter (cm)	Pant Karela-1 x Arka Harit	5.07			NDBG-1 x Local bitter gourd	0.75**	L x L
	NDBG-4 x Arka Harit	4.86	NDBG-4 x Jounpuri	16.86	Pant Karela-1x Arka Harit	0.74**	H x L
	NDBG-6 x Local bitter gourd	4.28	Pant Karela-1x Arka Harit	16.48	NDBG-4 x Arka Harit,	0.68**	H x L
	NDBG-1 x Local bitter gourd	4.27	NDBG-4 x Arka Harit	11.72	NDBG-7x Local bitter gourd	0.49**	L x L
	Pant Karela-1 x Jounpuri	4.08			NDBG-6 x Local bitter gourd	0.45**	H x L
Number of fruits plant^{-1}	NDBG-1x Arka Harit	13.85	NDBG-1 x Arka Harit	46.21	NDBG-1x Arka Harit	2.98**	H x M
	NDBG-5 x Jounpuri	11.48	NDBG-5 x Jounpuri	35.10	NDBG-17 x Jounpuri	1.26**	H x L
	NDBG-5 x Local bitter gourd	11.43	NDBG-5 x LBG	34.82	NDBG-4 x Local bitter gourd	1.17**	L x L
	PBTH-52 x Local bitter gourd	11.42	PBTH-52 x LBG	34.76	NDBG-3 x Jounpuri	1.05**	H x L
	NDBG-5 x Arka Harit	11.28	NDBG-5 x Arka Harit	33.95	Pant karela-1 x Local bitter gourd	0.91**	L x L

Table -7 contd…

Trait	Cross combinations	*Per se* performance	Cross combinations	Standard Heterosis (%)	Cross combinations	Sca Effect	Gca effect of parents
Average fruit weight (g)	Pant Karela-1 x Arka Harit	183.13	Pant Karela-1x Arka Harit	52.21	Pant Karela-1x Arka Harit	44.70**	H x L
	NDBG- 4 x Arka Harit	166.50	NDBG-4 x Arka Harit	47.44	NDBG-4 x Arka Harit	37.53**	H x L
	Pant Karela-1 x Jounpuri	130.52	Pant Karela-1 x Jounpuri	32.96	NDBG-6 x Local bitter gourd	29.05**	L x L
	NDBG-4 x Local bitter gourd	116.67	NDBG-4 x LBG	25.33	NDBG-7 x Jounpuri	20.82**	L x M
	NDBG-7 x Jounpuri	111.12	NDBG-7 x Jounpuri	21.25	NDBG-1 x Local bitter gourd	18.51**	L x L
Fruit yield plant^{-1}(kg)	NDBG-4 x Arka Harit	1.42	NDBG-4 x Arka Harit	52.11	Pant Karela-1x Arka Harit	0.27**	H x M
	Pant Karela-1 x Arka Harit	1.31	NDBG-4 x LBG	48.38	NDBG-5 x Jounpuri	0.22**	L x M
	NDBG-4 x Local bitter gourd	1.24	Pant Karela-1x Arka Harit	48.09	NDBG-4 x Arka Harit	0.19**	H x M
	NDBG-1x Arka Harit	1.01	NDBG-1x Arka Harit	32.67	NDBG-6 x Local bitter gourd	0.19**	L x L
	NDBG-4 x Jounpuri	1.00	NDBG-4 x Jounpuri	32.10	NDBG-3 x Jounpuri	0.18**	L x M
Fruit yield hectare^{-1}(q)	NDBG-4 x Arka Harit	284.15	Pant Karela-1x Arka Harit	59.09	Pant Karela-1x Arka Harit	53.27**	H x M
	Pant Karela-1 x Arka Harit	263.05	NDBG-4 x Arka Harit	51.57	NDBG-5 x Jounpuri	43.35**	L x M
	NDBG-4 x Local bitter gourd	248.78	NDBG-4 x LBG	44.69	NDBG-4 x Arka Harit	37.78**	H x M
	NDBG-1x Arka Harit	202.79	NDBG-1x Arka Harit	33.14	NDBG-6 x Local bitter gourd	38.07**	L x L
	NDBG-4 x Jounpuri	200.98	NDBG-4 x Jounpuri	31.53	NDBG-3 x Jounpuri	37.36**	L x M
Number of seeds fruit^{-1}	NDBG-4 x Arka Harit	17.65	NDBG-4 x Arka Harit	66.25	PBTH- 52 x Jounpuri	4.20**	L x M
	NDBG-4 x Local bitter gourd	16.73	NDBG-4 x LBG	57.61	NDBG-1 x Arka Harit	2.82**	H x L
	NDBG-1x Arka Harit	15.36	NDBG-1x Arka Harit	44.68	NDBG-6 x Local bitter gourd	2.78**	H x L
	NDBG-4 x Jounpuri	14.85	NDBG-4 x Jounpuri	39.87	NDBG-17 x Local bitter gourd	2.98**	L x L
	PBTH-52 x Jounpuri	14.83	PBTH- 52 x Jounpuri	39.72	NDBG-7 x Jounpuri	2.64**	L x H

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