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K Mallikarjunarao
Assistant Professor, Department of Horticulture, MSSSOA, Centurion University of Technology and Management, Paralakhemundi, Odisha, India

Meenakshi Badu
Assistant Professor, Faculty of Agriculture, Sri Sri University, Godi Sahi, Bidyadharpur, Cuttack, Odisha, India

Hari Ram Kumar Bandi
Assistant Professor, Department of Genetics and Plant Breeding and Seed Science and Technology, MSSSOA, Centurion University of Technology and Management, Paralakhemundi, Odisha, India

Barsha Tripathy
Assistant Professor, Department of Horticulture, MSSSOA, Centurion University of Technology and Management, Paralakhemundi, Odisha, India

Corresponding Author:
K Mallikarjunarao
Assistant Professor, Department of Horticulture, MSSSOA, Centurion University of Technology and Management, Paralakhemundi, Odisha, India

Heterosis breeding in Bitter Gourd (*Momordica charantia* L.): A review

K Mallikarjunarao, Meenakshi Badu, Hari Ram Kumar Bandi and Barsha Tripathy

Abstract

Bitter gourd (syn. Bitter cucumber; *Momordica charantia* L.) is an important Cucurbitaceae vegetable crop. Bitter gourd particularly originated from the Indo Burma region. Bitter gourd fruits and seeds are eaten together at an immature stage, and both have medicinal properties. Poor genetic potential of improved varieties, poor crop management, lack of good quality seeds, and high yielding early hybrids, biotic and abiotic stresses are maximum constraints to bitter gourd productivity. Heterosis has been widely studied and used by plant breeders to improve yield rates in bitter gourd (cross-pollinated crop). The degree to which hybrid vigour can be manipulated depends on the path and magnitude of heterosis and biological utility. Hence, for varied characters, a significant degree of heterosis has been reported in bitter gourd reviewed here.

Keywords: Bitter gourd, Heterosis

Introduction

Cucurbitaceous crops that are familiar in India and are the largest family of vegetable crops need to be careful to replace the huge number of unrecognized inferior varieties most of that are low-yielding, fruitless and highly susceptible to pests as well as diseases. To some extent, these problems can be overcome by using certain crop improvement programmes. Heterosis breeding has been increasingly used to improve the yield and quality of various crops. The term heterosis is broadly utilized in numerous vegetable crops. Heterosis could be a composite/complex genetical phenomenon showed within the predominance of F_1 hybrids over upon its parents in terms of yield (or) some other traits. The usage of hybrid vigour as a synonym for heterosis. It is widely accepted that hybrid vigour represents only hybrids superiority over upon parents, whereas heterosis also represents certain other conditions. However, the dominance of the hybrids upon parents are the maximum cases of heterosis. Negative direction hybrid vigour is desirable in a few cases like plant toxic substances and maturity period. The term heterosis was coined by Shull, 1914 [24].

Heterosis in bitter gourd

Mishra *et al.* (1994) [17] evaluated thirty-six F_1 hybrids together with their nine parents of bitter gourd for yield as well as yield attributing characteristics, and recorded maximum heterosis percentage 139.95 for fruit yield vine^{-1} followed by 124.39% for fruit weight, 119.28% for number of fruits vine^{-1}, 35.24% for fruit length & 8.35% for fruit girth. The hybrid combination Coimbatore Long x Gadabheta had recorded the maximum heterosis for fruit length, a number of fruits plant^{-1} & fruit yield vine^{-1}. Kennedy *et al.* (1995) [10] evaluated sixty hybrids of bitter gourd obtained from four lines and fifteen testers to study heterosis and reported an appreciable amount of heterosis for all the characteristics studied. The top-performing hybrid Pusa Vishesh x MC 13 showed 65.74 and 49.00% heterosis over standard parent and better parent, respectively. Ram *et al.* (1997) [22] experimented with 11 parents and 24 F_1 to study the heterosis in bitter gourd. The negative heterosis which is enviable in maximum crosses for earliness (days to 1st male flower and female flower anthesis). The cross, IC-50516 x VRBT-46 exhibited maximum significant positive heterobeltiosis 98.17 per cent for fruit yield plant^{-1}. Rajeswari and Natarajan (1999) [21] studied heterosis in bitter gourd using six divergent parental lines along with their 30 hybrids in a full diallel fashion and they observed that cross combinations, Preethi x MDU-1; Preethi x CO-1 & Arka Harit x Preethi had the highest heterosis for fruit weight as well as fruit yield^{-1}. Singh *et al.* (2000) [9] noted in their research on heterosis in a bitter gourd that the three hybrids *viz.*, BG-11 × BG-25, BG-11 × BG-29 & BG-5 × BG-25 were the most excellent performing hybrids for fruit yield vine^{-1}

and showed significant standard heterosis of 100.00, 94.96 and 85.61 per cent respectively. The hybrid BG-25 x BG-29 shows the higher heterobeltiosis and economic heterosis negative direction which is desirable for days to 1st fruit harvest.

Panda (2001) [20] evaluated six parental lines and their 15 F_1's of bitter gourd in half diallel fashion. Standard parent heterosis extended between -58.89 and 82.86% for a yield of fruits plant^{-1}. The superior cross combinations identified them in order of merit were PBIG-2 × PBIG-1, PBIG-2 × Priya White & PBIG-1 × Kalyanpur Sona recorded 82.86, 77.57, 50.02% standard heterosis for fruit yield plant^{-1}, respectively. Tewari *et al.* (2001) [29] examined 15 F_1's obtained from six diverse genotypes of bitter gourd. They found that eight crosses recorded highly significant better parent heterosis in summer and rainy season for fruit yield vine^{-1} and Kalyanpur Sona × Kalyanpur Baramasi, PBLG-2 × Priya White, Kalyanpur Baramasi × Priya White, PBIG-2 × Kalyanpur Sona & PBIG-4 × Kalyanpur Sona were superior hybrids in order of merit. They suggested heterosis breeding in bitter gourd as an important breeding method for yield improvement. Chaubey and Ram (2004) [7] studied commercial heterosis for fruit yield vine^{-1} and its components by using eight promising lines of bitter gourd and observed heterosis in a positive direction for maximum yield-related characters. The F_1 hybrids Kalyanpur Sona × Kalyanpur Barahmasi, PBIG-68 × Kalyanpur Sona and PBIG × Kalyanpur Barahmasi showed the highest positive significant standard heterosis of 41.90, 19.30 and 10.00 per cent respectively for a yield of fruits vine^{-1}. Mohan (2005) [18] studied heterosis for 25 F_1 hybrids along with 10 parents in bitter gourd. Among these 25 F_1 hybrids and identified topmost hybrid for fruit yield vine^{-1} was Green long x PRD-5 and it also recorded significant heterobeltiosis for vine length at 90 DAS (23.60%), number of primary branches (44.87%), days for 1st male & female flower appearance (-19.13 & -20.65%), days to 1st fruit harvesting (-2.91%), fruit length (28.18%), rind thickness (65.43%), average fruit weight (24.15%) and number of fruits vine^{-1}(35.57%). Sundaram (2006) evaluated eight genetically diverse parents of bitter gourd along with fifty-six F_1's collected through full diallel mating of the parents under saline soil for yield as well as yield contributing characters. He observed the significant positive heterbeltiosis and standard heterosis for yield and its related characters, and negative heterosis for earliness traits in bitter gourd. The hybrids, *viz.*, IC85643 × Bikaneer 1, IC85643 × Bikaneer 3 and IC85643 × BOS 1 were found to show heterotic vigour over standard variety for 12 of the 15 characters studied. Singh *et al.* (2007) [26] examined heterosis in bitter gourd through Line × Tester found negative heterosis for three characters days to 1stmale flower and female flower anthesis and days to 1st fruit harvesting. The highest positive heterosis was noted for a number of fruits vine^{-1} (131.62 & 156.59%) and yield vine^{-1} (91.75 & 16.88%) over a better and mid parent. Sundaram (2008) [27] reported that heterosis for yield and attributing characters in the bitter gourd is due to the presence of heterotic vigour for the majority of traits. Two-hybrid combinations Bikaneer -1 × CO-1 and Bikaneer -3 × Paravai local were found to express the maximum heterosis for fruit yield.

Jadhav *et al.* (2009) [9] assessed 8 parental lines along with their 28 F_1's of bitter gourd to examine the amount of heterosis for yield and its relating characteristics. Top three parents for fruit yield plant^{-1} were P_7 (Hirkani), P_6 (DVBTG-7) & P_1 (Phule Green Gold). The cross combinations Phule Green Gold × DVBTG-5; MC-84 × Co. White Long & Phule Green Gold × MC-84 have noticed to-be superior hybrids for fruit yield plant^{-1} in order of merit. The best performing F_1's over the better parents for different characters included P_4 (DVBTG-5) x P_7 (Hirkani) for days to 1st female flower (-17.00%) and days to 1st harvest (-16.39%), P_3 (MC-84) x P_7 (Hirkani) for number of node bearing 1st female flower (-20.08%), P_2 (Delhi Local) × P_8 (NDBT-12) for the length of fruit (13.17%), P_4 (DVBTG-7) x P_5 (Co. White Long) for a diameter of fruit (11.08%), P_2 (Delhi Local) × P_5 (Co. White Long) for fruit flesh thickness (38.27%) and for length of vine (10.81%), P_3 (MC-84) x P_6 (DVBTG-7) for average fruit weight (16.46%), P_1 (Phule Green Gold) × P_4 (DVBTG-5) for number of fruit vine^{-1} (63.72%) & for an average yield of fruit plant^{-1} (63.14%) and P_5 (Co. White Long) x P_8 (NDBT-12) for number of primary branches vine^{-1} (23.76%). The best performing F_1 are P_1 (Phule Green Gold) × P_4 (DVBTG-5) which recorded 41.48% higher yield over best parent can be exploited for economic cultivation. Maurya *et al*. (2009) [16] evaluated six parental lines and their 15 F_1's of bitter gourd in both *kharif* and summer season & they observed that out of fifteen hybrids, eight hybrids registered significantly positive heterobeltiosis in *kharif* season & twelve hybrids in summer season for fruit yield plant^{-1}. In *kharif* season BIG-1 x Kalyanpur Sona; BIG-4 × BIG-56; BIG-11 × BIG-56; BIG-4 × Kalyanpur Sona and BIG-2 × Kalyanpur Sona were maximum yielders with the yielding ability of 1892.3, 1754.8, 1640.6, 1375.9 and 1205.9 g fruits per plant, respectively, with heterosis of 42.8, 22.1, 0.5, 106.2 and 7.1% over better parent. For summer season BIG-4 x BIG-56; BIG-1 x Kalyanpur Sona; BIG-11 x Kalyanpur Sona; BIG-11 x BIG-56 and BIG-4 x Kalyanpur Sona were maximum yielders with the yielding potentialities of 2496.2, 2487.2, 2026.4, 1954.1 and 1905.6 g fruit yield per plant, respectively, with heterosis of 138.8, 41.6, 15.4, 86.9 and 85.0% over better parent. Yadav *et al.* (2009) [32] estimated mid parent and better parent heterosis varied from -8.31 to 29.81% & -25.51 to 2.20% respectively for vine length; -30.46 to 251.77% and -11.21 to 293.65% respectively for primary branches per vine; -37.57 to 4.87% and -30.95 to 20.76% respectively for fruit length; -24.19 to 23.88% and -22.39 to 39.53% respectively for fruit width, -14.81 to 7.42% and -0.83 to 88.57% respectively for fruit weight, -38.14 to 1.94% and -22.37 to 69.77% respectively for number of fruit vine^{-1} and -34.75 to 23.10% & -10.29 to 58.51% respectively for fruit yield per vine.

Kumara *et al.* (2011) [11] assessed ten parental lines and 24 F_1's of bitter gourd obtained from Line x Tester mating design by using 6 lines [VRBT-100 (L_1), Arka Harit (L_2), White Long (L_3), Coimbatore Long (L_4), Green Long (L_5), and Panurthy (L_6)] and four testers [IC-42261 (T_1), Chidambaram Small (T_2), Nanjangood Local (T_3), and Panurthy (T_4)] to examine the degree of heterosis for yield & yield-related characters. The heterobeltiosis ranged from -16.56 (L_2 x T_4) to 17.53 per cent (L_2 x T_2) for vine length at 90 DAS, -8.79 (L_4 x T_4) to 4.31 per cent (L_1 x T_3) for days to 1st staminate flower appearance, -18.60 (L_6 x T_2) to 11.48 per cent (L_3 x T_4) for days to 1st pistillate flower appearance, -36.39 (L_5 x T_4) to 20.93 per cent (L_5 x T_3) for node at 1st pistillate flower appearas, -15.31 (L_6 x T_2) to 12.26 per cent (L_3 x T_4) for days to 1st fruit harvest, -49.07 (L_2 x T_3) to 4.72 (L_3 x T_4) per cent for number of primary branches vine^{-1}, -35.73 (L_4 x T_2) to 40.86 (L_5 x T_4) per cent for fruit length, -34.61 (L_2 x T_2) to 19.90 (L_5 x T_3) per cent for fruit weight, -55.01 (L_2 x T_2) to 34.61 (L_2 x T_3) per cent for number of fruit vine^{-1} & -35.06 (L_6 x T_4) to 56.90 (L_5 x T_3) per cent for fruit yield vine^{-1} & -

43.61 (L_5 x T_2) to 26.51 (L_1 x T_4) per cent for number of seeds fruit^{-1}. Kushwaha and Karnwal (2011) [12] noted that cross BBIG-3 × Pusa Do Mausami registered significantly higher heterobeltiosis for fruit weight, number of fruits plant^{-1} and fruit yield plant^{-1}, while BBIG-2 × Pusa Vishesh for fruit length.

Dey *et al.* (2012) evaluated 36 cross combinations along with their 9 parents in half diallel fashion. The highest values of standard heterosis for days to 1st staminate flower appearance and node to 1st pistillate flower appearance were recorded by DBGY-201 × Pusa Vishesh (-42.69%) & Pusa Vishesh × NDBT-12 (-49.20%). Only one cross combinations NDBT-12 × Priya (-15.93%) recorded significantly negative values for days to 1st fruit harvest. Sixteen crosses registered positively significantly standard heterosis for fruit yield vine^{-1} with a maximum percentage of 126.41 noticed in DBGY-201 x Priya. Laxuman *et al.* (2012) evaluated eight germplasm lines and their 28 F_1's of bitter gourd in half diallel fashion along with a commercial hybrid check (MBTH-101). Among 28 F_1 hybrids, significant positive heterobeltiosis was observed in 11 hybrids which varied from -58.27 per cent in PRD-2 × White long to 73.51 per cent in Gadag Local × Pusa Vishesh for fruit yield vine^{-1}. Only three hybrids, Gadag Local × Com Green Long; Gadag Local × Pusa Vishesh & Gadag Local × IC-68310 exhibited significant positive standard heterosis 23.16, 17.51 and 23.16 per cent with a yield of 3.26, 3.11 and 3.07 kg, respectively. Muttineni (2013) crossed five bitter gourd inbreds in a half diallel fashion design and obtained 10 F_1 hybrids. He studied ten F_1 hybrids along with their 5 parents and 2 commercial checks (Palee & Maya). He found that RNMC-53 × RNMC-55; RNMC-52 × RNMC-55; RNMC-54 × RNMC-55 and RNMC-51 × RNMC-53 were maximum yielders with the yielding potentialities of 1.60, 1.54, 1.46 and 1.35kg fruits vine^{-1}, respectively, with an heterosis of 18.84, 14.09, 7.88 and 42.83 per cent over better parent, 52.72, 46.61, 38.64 and 28.01 per cent over commercial check (Maya) and 31.14, 25.90, 19.05 and 9.92 per cent over commercial check (Palee). The cross combination RNMC-52 x RNMC-53 showed maximum negatively significant heterosis of -11.46% over better parent, -4.81 & -7.31% over the commercial check (Maya and Palee) for days to 1st pistillate flower appearance and -13.84% over better parent and -14.12 and -15.96% over the commercial check (Maya and Palee) for node of 1st pistillate flower appearance. Singh *et al.* (2013) [25] studied 21 hybrids in 7 x 7 half diallel and observed that the cross HABG-24 x HABG-30 had highest positive heterosis for yield per plant 79.58 percent over better parent followed on HABG-23 x HABG-34 (73.39%). Out of 21 cross combinations, only four crosses *viz.*, HABG-28 × HABG-29 (62.50%), HABG-31 × HABG-34 (53.85%), HABG-24 × HABG-30 (40.09%) and HABG-24 × HABG-31 (35.71%) exhibited positive significant heterosis for fruit weight. For fruit length, HABG-28 x HABG-29 (30.15%), HABG-24 x HABG-30 (30.03%) and HABG-24 x HABG-34 (14.51%); for fruit breadth, HABG-28 x HABG-29 (4.37%), HABG-23 x HABG-30 (4.02%), HABG-30 x HABG-34 (2.28%) and HABG-28 x HABG-30 (1.34%) recorded positive significant heterobeltosis. For number of fruits plant^{-1}, out of 21 crosses, twenty crosses recorded significantly positive heterobeltiosis which varied from 48.75 (HABG-23 × HABG-28) to 2.51 percent (HABG-24 × HABG-34). Talekar *et al.* (2013) evaluated eleven lines, four testers and their 28 F_1's of bitter gourd collected from a Line × Tester fashion. Heterosis was estimated over better parent and Priya (standard variety) and they reported that out of 28 hybrids, 18 and 16 hybrids recorded significantly (+ve) heterobeltiosis and standard heterosis values, respectively. Degree of heterobeltiosis and standard heterosis varied from -19.34 to 14.47% and -17.51 to 2.82% respectively for days to open 1st pistillate flower; -21.13 to 20.00% and -38.60 to -4.76% respectively for intermodal length; -34.60 to 30.72% and -19.30 to 36.96% respectively for vine length; -26.23 to 13.70% and -22.64 to 18.91% respectively for number of primary branches vine^{-1}, -32.23 to 22.99% and 5.49 to 100.40% respectively for number of fruits vine^{-1}; -17.41 to 17.92% and -12.69 to 27.31% respectively for average fruit weight; -38.08 to 39.11% and -22.76 to 40.92% respectively for fruit length; -15.61 to 18.29% and -11.12 to 22.52% respectively for fruit girth and -58.96 to 51.14% and -55.65 to 73.79% respectively for fruit yield vine^{-1}. The Topmost significantly positive standard heterosis was recorded in the hybrids Preethi x HABG-22 (73.79%) followed by Ujjwala × HABG-22 (63.10%), Hirkani × CO-4 (57.26%), Kalyanpur Baramasi × HABG-21 (55.22%) and Hirkani × HABG-22 (53.83%).

Thangamani and Pugalendhi (2013) reported that out of ninety hybrids studied, forty-six hybrids recorded significantly negative heterobeltiosis for days to 1st pistillate flower appearance & the cross combination CO-1 × GL (-20.17%) showed highest values for this character. The F_1 CO-1 × MC-105 had noted maximum negatively significant relative heterosis (-53.47%), heterobeltiosis (-58.24%) & standard heterosis (-58.24%) for node of 1st female flower appearance. Significantly maximum relative heterosis and heterobeltiosis for fruit length were also noticed in KR x UB (95.28%, and 33.29%) and for standard heterosis recorded in CO-1 x MC-105 (22.46%). The highest significantly average heterosis and heterobeltiosis for fruit girth were recorded on USL x UB (77.16% and 48.25%), respectively and the maximum estimate of economic heterosis was observed in the cross CO-1 x MC-105 (38.45%). Twelve hybrids noted positively & significant heterobeltiosis for fruit weight, and it was the maximum in KR x USL (36.13%). Thirteen F_1's had recorded positively & significant heterobeltiosis, as well as standard heterosis values for number of fruits vine^{-1}. The F_1 MC-105 x MC-10 had positively significant relative heterosis (48.30%) and heterobeltiosis (6.98%) values for iron content in fruits. For ascorbic acid content in fruits significantly & positively heterobeltiosis was noted for eight F_1's which were the maximum in the cross KR x USL (20.68%). The uppermost values of positive heterobeltiosis & standard heterosis for fruit yield vine^{-1} were observed in Preethi x MC-30 (68.89% and 72.73%), respectively. By considering mean, *sca* and significant standard heterosis values the hybrids *viz*., Preethi x MC-30, KR x USL and MC-105 x MC-10 were chosen as the topmost performing F_1's concerning yield, earliness & quality traits.

Angadi (2015) [5] calculated heterosis for yield & its components in 45 F_1's obtained by using 15 BGA lines and 3 testers (Arka Harit (AH), CO-1 and Coimbatore Long (CL)) in bitter gourd. The degree of heterosis over BP (better parent) and commercial check (Swetha) varied from -21.95 (BGA-15 x AH) to 11.67 per cent (BGA-5 x CL) and -5.93 (BGA-8 x CL) to 21.61 per cent (BGA-5 x CL) for vine length 90 DAS; -27.88 (BGA-4 x AH) to 24.18 per cent (BGA-3 x CO-1) and -23.11 (BGA-4 x AH) to 13.68 per cent (BGA-14 x CO-1) for number of primary branches at 90 DAS; -7.69 (BGA-11 x CO) to 10.33 per cent (BGA-13 x AH) and -0.25 (BGA-2 x AH) to 15.72 per cent (BGA-8 x CO-1) for days to first male flowering; -4.79 (BGA-1 x CL) to 14.02 per cent (BGA-15 x CO-1) and -4.81 (BGA-5 x CO-1) to 12.75 per cent (BGA-14 x CO-1) for days to first female flowering; -25.61 (BGA-12 x CL) to 30.14 per cent (BGA-4 x CL) and -25.00 (BGA-4 x CO-1) to 14.92 per cent (BGA-4 x CL) for nodes up to first female flowering; -12.85 (BGA-1 x CL) to 8.10 per cent (BGA-14 x AH) and 1.15 (BGA-5 x CO-1) to 16.78 per cent (BGA-7 x CL) for days to first harvesting; -34.26 (BGA-2 x CL) to 42.14 per cent (BGA-2 x CO-1) and -42.97 (BGA-2 x CL) to 16.47 per cent (BGA-14 x AH) for number of fruits per vine; -27.61 (BGA-1 x CL) to 24.90 per cent (BGA-7 x CO-1) and -22.87 (BGA-1 x CL) to 12.20 per cent (BGA-5 x CO-1) for average fruit weight; -29.87 (BGA-13 × CO-1) to 50.59 percent (BGA-1 × CO-1) & -36.36 (BGA-1 x AH) to 31.40 per cent (BGA-14 x CO-1) for fruit length; -41.61 (BGA-3 x AH) to 17.25 per cent (BGA-4 x CO-1) and -33.57 (BGA-3 x AH) to 32.86 per cent (BGA-5 x AH) for fruit girth; -58.97 (BGA-5 × CO-1) to 107.21 percent (BGA-14 × AH) & -55.88 (BGA-4 x AH) to 17.63 per cent (BGA-14 x CO-1) for fruit yield per vine; - 63.11 (BGA-3 x AH) to 52.02 per cent (BGA-1 x CL) and -69.37 (BGA-3 x AH) to 8.84 per cent (BGA-15 x CL) for flesh thickness; -20.20 (BGA-4 x CL) to 14.74 per cent (BGA-15 x CO-1) and -12.22 (BGA-4 x CL) to 23.33 per cent (BGA-8 x CO-1) for ascorbic acid, respectively.

Kandasamy (2015) [4] evaluated 20 F_1's of bitter gourd and observed herobeltosis varied from 1.43 to 39.79% for fruit length, 1.07 to 25.34% for fruit diameter, 1.66 to 24.56% for fruit girth, 2.79 to 38.10% for number of fruits vine^{-1}, 1.13 to 49.44% for single fruit weight, 0.38 to 60.38% for yield per vine. The $P_5 \times P_3$ (Panruti local × VK-1 Priya) & $P_4 \times P_2$ (MC -13 × Arka Harit) were topmost performing cross combinations for yield & they recorded 46.21 & 29.31 percent heterosis, respectively over top parent Arka Harit (P_2) need to be exploited on a commercial scale through the production of hybrid seeds of these crosses. Bhatt (2016) evaluated 36 F_1 hybrids along with the 9 parents and observed that Punjab-14 x Arka Harit, Arka Harit x Panipat Local, Punjab-14 x Kalyanpur Barahmasi, Phule Green × Pusa Do Mausami & Punjab-14 × Pusa Do Mausami were topmost yielders with the yielding potentialities of 1.36, 1.28, 1.24, 1.20 and 1.20 kg fruit yield vine-^{1}, respectively, with heterosis of 21.43, 14.29, 10.71, 7.14 and 7.14 per cent over commercial check (Pusa Hybrid-1). The hybrid Punjab-14 x Arka Harit (9.68%) recorded maximum heterobeltiosis for fruit yield per vine. High positive heterosis over CC (commercial check) was noticed in hybrid Phule Green × Pusa Do Mausami (27.59%) with a fruit length of 22.20 cm. Maruti (2016) reported that crosses Phule Green Gold x Preethi, Co-White long x DVBTG-7, Preethi x Co-White Long and Preethi x DVBTG-7 were found promising for growth, yield and yield contributing characters. These crosses produce higher fruit yield vine^{-1} over better parent, standard check and also positive *sca* effects. The good general combiners for growth & yield-related characters was parent Phule Green Gold. Mishra (2016) [17] observed that maximum crosses noted significant heterobeltiosis and standard heterosis regarding earliness, vegetative traits and yield characters. The crosses PDM x VNR 28 (-23.95%), VNR 28 x MC 84 (-21.95%) and VNR 28 x US 33 (-19.77%) showed maximum negatively significant standard heterosis for days to 1st female flower in pooled seasons. The crosses VNR 28 x MC 84 (-36.72%) and VNR 28 x US 33 (-36.51%) and VNR 28 x PBIG 2 (-29.44%) expressed significantly negative standard heterosis for node number to 1st female flower in pooled seasons. For vegetative characters such as vine length, internode length, a number of primary branches vine^{-1} & leaf area crosses showing maximum standard heterosis were MC 84 x Pant Karela 3 (49.54%), VNR 28 x VNR 22 (26.95%), Pant Karela 3 x PBIG 2 (40.00%) and VNR 28 x Pant Karela 1(360.25%), respectively. The maximum amount of standard heterosis for number of fruits plant^{-1} was noted in cross combinations VNR 28 x Pant Karela 3 (160.55%), VNR 22 x MC 84 (130.26%) and VNR 28 x MC 84 (127.27%) in pooled seasons. The cross combinations US33 x Pant Karela 3 (29.34%), MC 84 x US 33 (21.97%) and PDM x US 33 (21.17%) showed topmost significantly positive standard heterosis for fruit yield/plant in pooled seasons.

Verma *et al.* (2016) [31] observed heterotic effects in 36 crosses resulted from crossing 12 lines and 3 testers. The hybrids NDBT-5 x Kalyanpur Sona (15.71%) for fruit length, NDBT-3 x Pusa Do Mausami (41.04%) for fruit diameter, NDBT-3 x Kalyanpur Sona (9.38%) for average fruit weight, NDBT-13 x NDBT-12 (32.43%) for number of fruits/plant and (35.23%) for fruit yield/plant possessed maximum heterobeltiosis in summer season whereas the hybrids NDBT-13 x Kalyanpur Sona (17.40%) for fruit length, NDBT-5 x Kalyanpur Sona (49.13%) for fruit diameter, NDBT-3 x Kalyanpur Sona (12.79%) for average fruit weight, NDBT-7 x Kalyanpur Sona (15.85%) for number of fruits/plant & NDBT-10 × Pusa Do Mausami (24.20%) for fruit yield/plant noted maximum heterobeltiosis in the rainy season. Rao (2017) [23] studied heterosis in a bitter gourd for 11 quantitative traits in 21 F_1's developed from 7 x 7 half diallel cross. High heterotic values over better parent were observed in DBGS-2 x DBGS-57 (-6.67 and -8.62%) for node at 1st pistillate flower & days to 1st pistillate flower appearance, Pusa Vishesh x DBGS-57 (-8.29%) for days to 1st harvesting, DBGS-2 x DBGS-57 (45.57%) for fruit length, Pusa Aushadhi x DBGS-57 (37.47%) for fruit diameter, DBGS-54 x DBGS-2 (24.56 and 31.78%) for number of fruit/plant and average fruit weight and DBGS-54 × Pusa Vishesh (31.07%) for yield/plant.

Adarsh *et al*. (2018) [2] studied heterobeltiosis & standard heterosis for quantitative & qualitative traits in six parents and their six F_1 random crosses and observed that BRBTL x Pusa Aushadhi and BRBTL x Gangajalee Small were found to be topmost performing F_1's for morphological & biochemical traits. Alhariri *et al.* (2018) [3] examined heterosis on yield & yield related characters in eight parental lines of bitter gourd including gynoecious line (PDMGy-201) along with their 28 F_1's obtained from 8 × 8 half diallel cross. The highest negative standard heterosis was noted in S-54 × Pusa Aushadhi (-51.34%) for node number of 1st pistillate flower, PDMGy-201 x S-2 (-35.96%) for days to 1st female flower appearance, PDMGy-201 x S-2 (-28.24%) for days to 1st fruit harvest, and PDMGy-201 × Pusa Aushadhi (-99.07%). Higher heterotic values in a positive direction over standard parent (Pusa Vishesh) was observed in S-32 x S-57 (47.62%) for fruit length, S-54 x S-57 (15.12%) for fruit diameter, S-54 x S-57 (29.07%) for flesh thickness, PDMGy-201 x Pusa Vishesh (18.92%) for number of fruits plant^{-1}, S-2 x Pusa Do Masusami (60.67%) for average fruit weight and S-2 x Pusa Aushadhi (68.33%) for yield plant^{-1}. Mallikarjunarao *et al.* (2018) [14] calculated heterosis on yield & quality characters in eight parental lines of bitter gourd along with their 28 F_1's obtained from 8 × 8 half diallel cross. The highest heterobeltosis was reported in Phule Green Gold × Pusa Do Mausami (26.87% & 24.75%) for flesh thickness & vitamin C respectively, Hirkani x Nakhara Local (20.18%) for TSS, Phule Green Gold x Preethi (36.97%) for iron content, Thusi x Pusa Do Mausami (98.75%) for fruit yield vine^{-1}. Acharya *et al.* (2019) [1] studied heterosis & combining ability for fruit yield & its component traits in 45F_1 hybrids derived from a 10 × 10 half diallel cross under four environments. Significantly higher positive heterobeltosis was recorded in IC-85605 × IC-45346 (43.85%) and MDU-1 x IC-85605 (41.38%) for yield vine^{-1}, IC-85605 x Solan Collection (24.72%) and MDU-1 x IC-68237 (23.58%) for fruit length, IC-85605 × IC-45346 (38.94%) & MDU-1 × IC-85605 (34.98%) for fruit weight over the environments.

Conclusion: Heterosis plays a major role in the development of hybrids to improve in bitter gourd and other cucurbitaceous vegetables. Broad experimental evidence suggests that heterosis is exploited only to some degree, but still, there is lots of scope to exploit heterosis as bitter gourd and other cucurbits have a wide range of genetic variation.

References

1. Acharya SK, Kaushik RA, Ameta KD, Dubey RB and Upadhyay B. Heterosis and combining ability in bitter gourd (*Momordica charantia* L.). International Journal of Bioassays. 2019; 8(1):5692-5711.
2. Adarsh A, Kumar R, Singh HK, Bhardwaj A. Heterosis Study in Bitter Gourd for Earliness and Qualitative Traits. International Journal of Current Microbiology and Applied Sciences. 2018; 7:4239-4245.
3. Alhariri A, Behera TK, Munshi AD, Bharadwaj C and Jat GS. Exploiting Gynoecious Line for Earliness and Yield Traits in Bitter Gourd (*Momordica charantia* L.). International Journal of Current Microbiology and Applied Sciences. 2018; 7(11):922-928.
4. Kandasamy R. Heterosis in bitter gourd (*Momordica charantia* L.). The Asian Journal of Horticulture. 2015; 10(1):158-160.
5. Angadi A. Divergence heterosis and genetic studies in bitter gourd (*Momordica charantia* L.). Ph.D. (Hort.) Thesis, Department of Horticulture, Kittur Rani Channamma College of Horticulture, University of Horticultural Sciences, Bagalkot, 2015.
6. Bhatt L. Combining ability and heterosis studies in bitter gourd (*Momordica charantia* L.), M.Sc. Agri. (Horticulture), Thesis, 2016; SKN College of Agriculture, Jobner SKN Agricultural University, Jobner.
7. Chaubey AK and Ram HH. Heterosis for fruit yield and its components in bitter gourd (*Momordica charantia* L.). Vegetable Science. 2004; 31(1):51-53.
8. Dey SS, Behera TK, Munshi AD, Rakshit S, Bhatia R. Utility of gynoecious sex form in heterosis breeding of bitter gourd and genetics of associated vegetative and flowering traits. Indian Journal of Horticuture. 2012; 69(4):523-529.
9. Jadhav KA, Garad BV, Dahmal SS, Kashirsagar DB, Patil BT, Shinde KG. Heterosis in bitter gourd (*Momordica charantia* L.). Agricultural Science Digest. 2009; 29(1):7-11.
10. Kennedy RR, Arumugam R, Kandasamy G, Suresh S. Heterosis studies in bitter gourd (*Momordica charantia* L). Madras Agriculture Journal. 1995; 82(2):121-123.
11. Kumara B, Puttaraju TB, Hongal S, Rakash, K, Jaing K, Sudeesh NK. Heterosis studies in bitter gourd (*Momordica charantia* L.) for yield and yield related attributes. International Journal of Plant Sciences. 2011; 6(1):199-204.
12. Kushwaha ML, Karnwal MK. Combining ability studies in bitter gourd (*Momordica charantia* L.) under dry temperate condition. Pantnagar Journal of Research. 2011; 9(1):41-45.
13. Laxuman Patil SA, Salimath PM, Dharmatti PR, Byadgi AS, Nirmalayenagi. Heterosis and combining ability analysis for productivity traits in bitter gourd (*Momordica charantia* L.). Karnataka Journal Agricultural Science. 2012; 25(1):9-13.
14. Mallikarjunarao K, Das AK, Nandi A, Baisakh B, Tripathy P. and Sahu G. Heterosis and combining ability of quality and yield of bitter gourd (*Momordica charantia* L.). Journal of Pharmacognosy and Phytochemistry. 2018; 7(3):05-09.
15. Maruti MG. Studies on heterosis and combining ability in bitter gourd (*Momordica charantia* L.), M.Sc. (Hort.) in Vegetable science Thesis, College of Agriculture, Latur Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani, 2016.
16. Maurya M, Mohan J, L Kushwaha. Studies on heterobeltiosis and combining ability in bitter gourd (*Momordica charantia* L.). Pantnagar Journal of Research. 2009; 7(2):177-179.
17. Mishra HN, Mishra RS, Mishra SN, Parhi G. Heterosis and combining ability in bitter gourd, Indian Journal of Agricultural Science. 1994; 64:310-313.
18. Mohan L. Heterosis and combining ability studies in bitter gourd (*Momordica charantia* L.), M.Sc. Agri. (Horticulture), Thesis, Department of Horticulture, College of Agriculture, Dharwad University of Agricultural Sciences, Dharwad, 2005.
19. Muttineni M. Exploitation of Heterosis in Bitter gourd (*Momordica charantia* L.), MSc, Thesis, Dr. YSR Horticultural University VR. Gudem, West Godavari (Dst.), Andhra Pradesh, 2013.
20. Panda A. Diallel cross analysis and protein profile study in bitter gourd (*Momordica charantia* L.), M.Sc. (Ag.), Thesis, GBPUA & T, Pantnagar, 2001, 99-102.
21. Rajeswari KS, Natarajan S. Studies on heterosis for growth, yield and quality parameters in bitter gourd (*Momordica charantia* L.), South Indian Horticulture. 1999; 47(1-6):208-209.
22. Ram D, Kalloo D and Singh M. Heterosis in bittergourd (*Momordica charantia* L.). Vegetable Science. 1997; 24(2):99-102.
23. Rao PG. Genetics and mapping of economic traits in bitter gourd. Ph.D. (Vegatable Science) Thesis, 2017; Indian Agricultural research Institute, New Delhi.
24. Shull GH. Duplicate genes for capsule form in *Bursabursa pastoris*, Zeit. Induk Abstamm. Vererbungal. 1914; 12:97-149
25. Singh AK, Pan RS, Bhavana P. Heterosis and combining ability analysis in bitter gourd (*Momordica charantia* L.), The Bioscan. 2013; 8(4):1533-1536.
26. Singh SK, Singh B, Uttam K, Rai M. Heterosis analysis in bitter gourd through Line x Tester design. Vegetable Science. 2007; 34(1):95.
27. Sundaram V. Studies on genetics of yield and yield components in bitter gourd (*Momordica charantia* L.) under salinity. Ph. D (Hort.) Thesis,; Tamil Nadu Agricultural University, Coimbatore, 2006.
28. Talekar NS, Vaddoria MA, Kulkarani GU. Heterosis studies for quantitative traits in bitter gourd (*Momordica charantia* L.). Progressive Research. 2013; 8:650-653.

29. Tewari D, Ram HH, Jaiswal HR. Studies on heterosis and combining ability in indigenous bitter gourd (*Momordica charantia* L.) for fruit yield. Vegetable Science. 2001; 28(2):106-108.
30. Thangamani, Pugalendhi. Development of heterotic hybrids in bitter gourd (*Momordica charantia* L.) for earliness, high yield and quality traits. The Asian Journal of Horticulture. 2013; 8(1):195-201.
31. Verma RS, Pratap N, Shekhar R, Singh RP, Vishnoi RK. Exploitation of heterosis for yield and its components in bitter gourd (*Momordica charantia* L.). Plant Archives. 2016; 16(1):403-412.
32. Yadav M, Chaudhary R, Singh DB. Heterosis in bitter gourd (*Momordica charantia* L.), Journal of Horticulture Science. 2009; 4(2):170-173.