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Exploitation of heterosis in bottle gourd (*Lagenaria siceraria* (Mol.) Standl.) for earliness, yield and yield contributing traits

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Abstract
The present investigation entitled "Exploitation of heterosis in bottle gourd (*Lagenaria siceraria* (Mol.) Standl.) for earliness, yield and yield contributing traits" was carried out in Randomized Block Design (RBD) with two replications having each investigated unit of single row with spacing 3.0 m x 1.0 m (*Kniffen* system). Investigation carried out at All India Coordinated Research Project on Vegetable Crops, Department of Horticulture, Mahatma Phule Krishi Vidyapeeth, Rahuri with the objectives for enlightening information on magnitude and nature of heterosis in bottle gourd for quantitative and qualitative characters. Parents and hybrids along with commercial check were evaluated for quantitative traits *viz*., length of vine, number of primary branches/ vine, days required for first male flower, days required for first female flower, number of male and female flowers/ vine, node at which first female flower appeared, days required for first harvest of fruit, length of fruit, diameter of fruit at pedicel, center and styler end, average weight of fruit, number of fruits/ vine, yield/ vine, fruit yield (t/ha) and qualitative traits *viz*., TSS (^{0}Brix), shape of fruit, colour of fruit, presence of pubescence on fruits, percent incidence of diseases and pest.

Keywords: Bottle gourd, *kniffen* system, heterosis, TSS, yield, qualitative traits.

Introduction
Bottle gourd (*Lagenaria siceraria* (Mol.) Standl.) is one of the most popular vine vegetable crops having diploid chromosome no (2n = 2x = 22) mainly grown for its fruits and seeds which are good source of oil and protein. Bottle gourd originated in Africa (Singh, 1990) [43] and from there by floating on the seas, it travelled to India, where it has evolved into numerous local varieties and has spread to China, Indonesia and far to New Zealand. The family Cucurbitaceae comprises of 120 genera and 825 species out of which 36 genera and 100 species are available in India which are largely cultivated in the tropics and subtropics even in temperate zone for its edible fruits. Approximately 38 species of this family are economically important (Yadav and Kumar, 2012) [54]. This delicious vegetable is also known by names of bottle squash, calabash gourd, white flowered gourd, doodhi and lowki (Anon., 2010) [2]. It is highly cross-pollinated crop due to its monoecious and andromonoecious nature (Swiander *et al.*, 1994) [51]. The name "*Lagenaria*" and "*Siceraria*" are derived from Latin words "Lagena" for bottle and "Sicera" for drinking utensil.

It is very popular among a large section of people. It is easily digestible and is used extensively as vegetable. Due to its delicate and nutty flavour, bottle gourd is widely used for preparing many delectable recipes. Fruits are used in sweets, pickles, kofta, petha, halwa, kapoorkand, paratha and rayata especially in the hills. Bottle gourd is a rich source of minerals and vitamins. It contains higher concentrations of dietary fiber, vitamin A, vitamin C, vitamin E, vitamin K, vitamin B_6, folate, potassium, manganese, protein, thiamine, rioboflavin, panthothenic acid, calcium, iron, magnesium, phosphorus and selenium. It also contains many nutritional properties are calories- 22 Kcal, carbohydrates- 5.4 g, protein- 0.9 g, sodium- 347 mg (Anon., 2018) [3]. It is found to be the one mentioned in the scriptures as a healer for mental health disorder for its highest content of choline than any other vegetables known to man till date and the vitamins, minerals and amino acids that are present in it for the synthesis of neurotransmitters. Instead of consuming vitamin pills or tonics, a slice of gourd, a slice of melon and a handful of pumpkin seeds are enough to maintaining our health (Habibur, 2003) [12]. Genetic variability and diversity is of prime interest to the plant breeders as it has a key role in designed successful breeding programme. Genetically dissimilar and diverse genotypes are always able to produced high heterotic effects (Chetariya and Vaddoria, 2017) [4].

In bottle gourd, increasing attention is being paid to breeding of superior cultivars, with greater focus on development of hybrid seed (Dubey and Ram, 2007) [8]. Exploitation of hybrid vigour could increase yield in bottle gourd, if the genetic architecture of the crop is explained, a hybrid with high yield and quality can be developed. Due to its high seed content and easy seed extraction techniques commercialization of hybrids will be easy in bottle gourd. In recent, bottle gourd improvement programme is focused on heterosis breeding. Heterosis refers to the superiority of F_1 hybrid in one or more characters over its parents. In other words, heterosis refers to increase of F_1 in fitness and vigour over the parental values. Heterosis leads to superiority in adaptation, yield, quality, disease resistance, maturity and general vigour over its parents. Generally, positive heterosis is considered as desirable, but in some cases negative heterosis is also desirable, for example, negative heterosis for flowering, maturity duration and toxic substances is desirable in many cases because it shows superiority over the parents.

Exploitation of Heterosis

Heterosis is the superiority of F_1 hybrids over its both the parent for yield and other contributing traits. In the history of breeding heterosis play an important role specially in cross pollinated crops. Heterosis known since the art of hybridization came into existence. Hybrid vigour is synonym of heterosis. The heterosis/ hybrid vigour was first recognized by Koelreuter (1763) [19] in the hybrids of tobacco and Datura. The term heterosis first coined by Shull (1914) [42] while discussing the work on maize during delivering lecture at Gottingen (West Germany). He proposed the term heterosis in heteros means different and osis = condition. Many scientist work for manifested heterosis. Fonseca and Peterson (1968) coined new term named "heterobeltiosis" to describe heterosis relation with better parent. Theories for heterosis proposed by Davenport (1908) [5], Bruce (1910) and Keeble and Pellew (1910) [17] on dominance. Hull (1945) [14] explained phenomenon on over dominance. First report on heterosis in cucurbits proposed by Hays and Jones (1916) [13].

Kumar *et al*., (1998) [44] studied heterosis in bottle gourd using Line x Tester method of analysis and revealed that, the cross PSPL x NDBG-1 (106.85%) recorded highest heterobeltiosis, while F_1 hybrids L12 x T2 (27.07%) and L9 x T1 (20.68%) manifested highest heterosis over the standard variety, Pusa Naveen for yield per vine.

Twenty-eight F_1 hybrids along with eight parents studied to tested heterosis in bottle gourd. The crosses ARBGH-7 x Pusa Naveen for yield/vine, yield per hectare and number of fruits per vine. ARBGH-7 x LC2-1 for weight of fruit and days to first female flowering. PBOG-61 x NDBG-56 for fruit length, girth and vine length while cross PSPL x ARBGH-7 for days to first fruit harvest were showing significant heterosis over the better parent. ARBGH -7 x LC2-1 showed a significant increase over the commercial hybrid-204 for yield and related characters (Singh *et al*., 1998) [20].

Moumita (2001) [28] investigated the heterosis using half diallel set of 45 F_1 hybrids along with 10 parents to studied 13 characters of bottle gourd. The analysis of variance revealed significant differences among the parents and hybrids for all the traits except days to first open female flower for which hybrids did not differ significantly whereas for first female flowering node, main vine length and moisture content the parents did not differ significantly. Several hybrids exhibited heterobeltiosis and economic heterosis for fruit yield and other characters. The hybrid worth commercial exploitation of heterosis on the basis of both *per se* performance and estimates of heterosis is PSPL x Pusa Naveen.

An experiment conducted by Samadia and Khandelwal (2002) [37] to study heterosis in 36 F_1 hybrids along with 9 cultivars (Banswara Local-1 (BL-1), Long White Prolific, Pusa Naveen, Raichur Local-1, Udaipur Local-1, IC 92352A, IC 92374, IC 42361 and PSPL), including *cv*. Varad as the control cultivar. The hybrids BL-1 × IC 92374, BL-1 × Pusa Naveen, and IC 92374 × PSPL were superior and exhibited significant economic heterosis for fruit yield per vine and yield components such as number of fruits and female flowers per vine. Most of the heterotic crosses were also heterobeltiotic.

Sets of 20 F_1 hybrids along with their 10 lines and 2 testers of bottle gourd were studied to estimate the magnitude of heterosis for yield and their components. They examined the heterosis for almost all the characters and found significant heterosis for yield and its components. The cross-combination Punjab BOG-22 x Punjab Komal showed significant heterosis (80.50%) for fruit yield followed by Punjab BOG-62 x Punjab Komal (73.17%) whereas hybrid Punjab BOG-62 x Punjab Komal exhibited highest heterosis (86.7%) for number of fruits per vine (Singh and Kumar, 2002) [45].

Sit and Sirohi (2002) [50] evaluated 45 F_1 crosses obtained from 10 diverse cultivars of bottle gourd *viz*., Pusa Naveen, Pusa Sandesh, S.41, Pusa Summer Prolific Long, S.6-1 S.6-2 S.8 S.1, NDBG-56 and NDBG-58 through 10 x 10 diallel method of analysis without reciprocals to study the magnitude of heterosis for yield, yield components like vine length, days to first male flower opening, days to first female flower opening, days to first fruit harvest, and number of fruits per vine and fruit quality (fruit weight, length, and girth). They revealed that the, S.6-2, Pusa Sandesh, and S.1 produced the highest yields. The F_1 hybrid Pusa Sandesh x S.1 showed maximum heterosis for yield and yield components over the top parent.

Dubey and Maurya (2003) [6] estimated nine parental lines of bottle gourd along with their 36 F1 hybrids obtained from half diallel method of analysis to extent the heterosis in bottle gourd for yield and yield attributing characters. They revealed that, the cross-combination UL-2 x UL-4 recorded the highest economic heterosis (89.47%) for total yield and other characters *viz.*, average weight marketable fruit, number of branches/plants, vine length with earliness.

Maurya *et al*., (2003) [6] carried out experiment to estimate the heterosis using ten parental lines and three testers. The F_1 cross Pusa Naveen x PBOG-61 showed highest economic heterosis for early yield (59.93%) followed by PBOG-40 x PBOG-91 (20.47%). Punjab Komal x PBOG 61 (24.01%) and PBOG-40 x PBOG-61 (13.65%) crosses showed positive standard heterosis for fruit diameter in bottle gourd.

Padma *et al*., (2003) [30] evaluated 18 hybrids of bottle gourd along with their parents and two commercial hybrids (Indam-204 and Warad) to study the magnitude of heterosis for yield and yield contributing traits *viz*. number of fruits per vine, node to first flowering. The F_1 hybrid LS-34 x Arka Bahar showed positive heterosis for yield 76.83% and number of fruits per vine was 61.0%.

Pandey *et al*., (2003) [32] studied the magnitude of heterosis and observed the cross combination Sel 16 x Pusa Summer Prolific Long showed significant heterosis over better parent and two standard varieties. Heterosis for number of primary branches per vine were 147.39, 28.40 and for length of lateral shoot were 6.34, 6.94, 6.34 respectively, whereas crosses Pusa Naveen x Pusa Summer Prolific Long, KLG x Pusa Naveen,

9503 x Pusa Naveen and KLG x Pusa Summer Prolific Long showed 43.82 percent, 31.33 percent, 16.30 percent and 10.52 percent significant heterosis respectively for yield over better parent.

Pandey *et al.,* (2004) [33] carried out experiment to study the heterosis and inbreeding depression in fifteen F_1 hybrids along with their six parent lines. Cross 9503 x Pusa Summer Prolific Long had significant positive heterosis for fruit length (22.44%) over better parent and also found significant over standard varieties Pusa Summer Prolific long (22.48%) and Pusa Naveen (102.72%) respectively. Cross KLG x Pusa Naveen had significant heterosis 31.37, 31.33, 50.07 over better parent and two standard varieties respectively for fruit diameter.

Pal *et al.,* (2005) [31] conducted experiment with 30 F_1 hybrids along with 10 lines and 3 testers under line x tester analysis to estimate the extent of heterosis over mid and better parents for yield and its contributing traits in bottle gourd. Analysis of variance indicated highly significant differences for almost all characters except vine length. The results of present investigation revealed that the crosses IC-92362 x Pusa Naveen showed higher heterosis 97.47 percent over better parent whereas IC-92462 x Pusa Naveen recorded significant heterosis (89.85%) over mid parents for fruit yields. Both crosses can be considered as superior among all.

Sharma *et al.,* (2004) [40] studied the set of thirty F_1 hybrids generated by crossing of 10 lines and 3 testers of long-fruited bottle gourd to assess the extent of heterosis over better parent. GH-9 × PSPL (6.29%) for days to first female flower; GH-13 × G-2 for days to first picking (10.59%), fruit diameter (22.71%) and early yield per vine (63.34%), KBG-16 × G-2 for fruit length; G-22 × PSPL for average fruit weight; KBG-16 × Pusa Naveen for total yield per vine; and GH-16 × Pusa Naveen for fruits per vine. This cross were showing the highest significant heterosis over better parent. An appreciable amount of heterobeltiosis for early yield, fruit number and total yield per vine was observed in the crosses KGB-16 × Pusa Naveen and GH-16 × Pusa Naveen.

Singh *et al.,* (2006) [46] evaluated 21 F_1 hybrids involving sets of 7 parents with diallel method (excluding reciprocals) to assess the extent of heterosis for yield and yield components of bottle gourd. They resulted the crosses, Rajendra Chamatkar x Pusa Naveen showed the highest values for most of the characters, followed by Rajendra Chamatkar x Faizabadi. Thus, the feasibility of capitalizing hybrid vigour was evident in the two cross combinations.

The investigation carried out with the sets of 28 F_1 hybrids along with their 8 parents of bottle gourd to study the extent of heterosis. The crosses showing significant heterosis over better parent were Pusa Santushti x Arka Bahar for vine length, Pusa Santushti x Pusa Samrudhi for days to first male flower opening. Pusa Sandesh x Pusa Summer Prolific Long for days to first female flower opening, Pusa Sandesh x Punjab Komal for days to first fruit harvest, Pusa Summer Prolific Long x Samrat Long for fruit length, Pusa Naveen x Samrat Long for fruit diameter, Samrat Long x Pusa Samridhi for total yield per vine respectively. (Sirohi and Rana, 2007) [49].

Mourya *et al.,* (2009) studied extent of heterosis using sets of 28 F_1 hybrids from a diallel method of analysis involving 8 parents (excluding reciprocals) of bottle gourd for fruit yield and its components. Recorded significant heterosis over standard check Pusa Naveen for 14 traits in both the season. Crosses PBOG-61 × Pusa Naveen, PBOG-61 × PBOG-88, PBOG-81 × PBOG-88, PBOG-88 × Pusa Naveen and PBOG-40 × Pusa Naveen proved the best and recorded 51.3, 43.8, 39.5, 36.6 and 36.2% heterosis over the check for fruit yield. The high fruit yield recorded in these five crosses has been directly attributed to increased number of fruits per vine. The F_1 hybrid PBOG-61× Pusa Naveen produced long type fruits and identified best for the number of fruits and fruit yield.

Quamruzzaman *et al.,* (2009) [35] was studied heterosis in bottle gourd in a set of 13 F_1 with 26 parents and observed highly significant differences for all the characters. Heterosis was higher for yield per vine, number of fruits per vine and individual fruit weight, medium in fruit length and fruit diameter, and lower in days to 1st harvest. F_1 hybrids BGN 10 x BGN 17 manifested highest heterosis over mid parent (73.1%) however BGN 19 x BGN 26 showed heterosis (61.8%) over better parent for yield per vine.

An experiment conducted by Kumar *et al.,* (2011) [21] to find out the exploitation of hybrid vigour for yield and its components in bottle gourd. The yield and yield contributing parameters *i.e.* days to fruit setting, fruit length (cm), fruit diameter (cm), number of branches per vine, vine length (m), number of seeds per fruit, number of fruits per vine, days to maturity, fruit yield per vine were worked out through line x tester analysis involving eight lines *viz.* C-29, C-37, C-74, C-78, C-4, C-55, C-34, C-26 and three testers *viz.* Azad Harit, PSPL and KLG. On the basis of facts, three crosses namely C-4 x PSPL, C-34 x PSPL and C-29 x PSPL, revealed significant desirable heterosis for yield and many other traits, which were showed more than 40% heterosis over better parent.

Shaikh *et al.,* (2011) [39] carried out experiment using 50 F_1 hybrids along with their 10 parental lines and 3 testers through Line × Tester for estimated the extent of heterosis in bottle gourd. They resulted that the cross Punjab Long × Thar Samruddhi, Punjab Long × PSPL and Arka Bahar × Panjab Komal exhibited significant positive heterosis over better parent for fruit yield per vine in E_1, E_2 and E_3, respectively. The cross combinations ABG-1 × NDBG-517, NDBG-104 × Thar Samruddhi and Pusa Naveen × PSPL showed significant standard heterosis and high heterotic effect in desirable positive directions over three define environments.

Sets of 28 F_1 hybrids from eight different genotypes of bottle gourd evaluated to study the assess of heterosis over better parent and standard check INDAM 204. The F_1 hybrids Pusa Naveen x NDBG 104, Pusa Naveen x UL-6 and Pusa Naveen x NDBG 140 were found to be most promising and manifested heterobeltiosis of 84.95%, 76.02% and 51.26% and standard heterosis of 37.33%, 20.16% and 31.34%, respectively, for fruit yield per vine (Sharma *et al.,* 2012) [41].

Singh *et al.,* (2012) [47] carried out experiment to tested the heterosis using thirteen parents of bottle gourd and resulted the highest heterobeltiosis showed in cross DVBG-1 x NDBG-58 for fruit yield per vine whereas, the highest yielding F_1 was PBOG-40 x PSPL. The cross PBOG-62 x PSPL was showed significant negative heterosis for first female flower anthesis and first harvesting.

Singh *et al.,* (2012) [47] estimated 36 genotypes (8 parents and 28 F_1 hybrids) of bottle gourd and reported significant heterosis over better parents for various characters. Crosses PBOG-40 x DVBG-2 for pedicel length, average fruit weight and fruit yield per vine, F_1 hybrid NDBG-58 x PBOG-62 for number of primary branches, days of first female flower anthesis and day of first fruit harvesting, NDBG-58 x Pusa Naveen for vine length, PBOG-40 x Pusa Naveen for days of first male flower anthesis, DVBG-1 x NDBG-58 for number of fruit per vine, PBOG-61 x PBOG-62 for fruit length,

PBOG-61 x DVBG-1 for fruit diameter, PBOG-61 x NDBG-58 for number of seeds per fruit and DVBG-2 x PBOG-62 for hundred seed weight showed significant heterosis over better parents.

36 F_1 hybrids of bottle gourd with fifteen parental lines evaluated by Yadav and Kumar (2012) [54] to assess the extent of standard heterosis over standard variety *i.e.* Pusa Meghdoot and resulted that, the positive and significant heterosis is desirable for vine length, number of nodes per vine, number of primary branches per vine, length of fruit, weight per fruit, number of fruits per vine and fruit yield per vine. The negative and significant heterosis is desirable for days to fifty percent germination, days to first male flower anthesis, days to first female flower anthesis, node number to first male flower, node number to first female flower. Most of the crosses showed positive and significant heterosis over standard variety. The cross combinations DK x NDBG-104 and PBOG-22 x Pusa Naveen for days to fifty percent germination, VRBG-18 x NDBG-104 for days to first male flower anthesis, VRBG-105 x PSPL and VRBG-18 x NDBG-104 for days to first female flower anthesis and DK x PSPL for node number to first male flower, PBOG- 22 x NDBG-104 for node number to first female flower, AD-1 x NDBG-104 showed negative and significant heterosis over standard variety. As negative heterosis is desirable for these characters. The cross combinations AD-1 x NDBG-104 for vine length, VRBG- 1 x PSPL and DK x PSPL for number of nodes per vine, VRBG-1 x PSPL and AD-1 x Pusa Naveen for number of primary branches per vine, VRBG-44 x NDBG-104 and VRBG-112 x PSPL for length of fruit, VRBG-148 x NDBG-104 for weight per fruit, DK x Pusa Naveen for number of fruits yield per vine and VRBG-44 x Pusa Naveen for fruit yield per vine showed highly positive and significant heterosis over standard variety.

An extent of heterosis estimated by Gaykawad (2014) using thirty-six crosses developed by crossing 12 lines with each of three testers subjected to line × tester method of analysis in bottle gourd. The magnitude of heterosis over the commercial check (Warad) was very high in the desirable direction and it ranged from -58.00 to 71.40, -42.66 to 44.08 percent for vine length at 45 and 75 days after sowing (DAS), -29.49 to 8.12 percent for number of branches at 75 DAS, -29.78 to 21.35% percent for sex ratio (M:F), -33.33 to 26.67 percent for number of fruits per vine, -25.57 to 24.42 percent for fruit length, -23.58 to 94.13 percent for fruit diameter, -37.50 to 150.00 percent for average fruit weight, -56.40 to 57.00 percent for fruit yield per vine and -24.83 to 176.96 percent for fruit yield per plot. The cross NBBL-12 x Pusa Sandesh exhibited maximum heterosis over the commercial check (Warad) for yield per hectare (174.97%) followed by IC421962 x Pusa Summer Prolific Long (161.84%) and IC308564 A x Pusa Summer Prolific Long (158.89%).

An experiment carried out to evaluate 45 F_1 hybrids along with their 10 parental lines of bottle gourd derived from half diallel method of analysis to investigated the extent of heterosis for yield and its related traits. The parents NDBG-603, NDBG-517 and NDBG-601 were observed to be three top performing parents for fruit yield per vine. The negative heterosis, which is desirable for days to first pistillate flower anthesis, node number of first pistillate flower anthesis and days to first fruit harvest was common in most of the crosses. Significant heterosis was recorded over better parent in order of merit, F_1 hybrids $P_8 \times P_9$ (NDBG-625 × NDBG-749-2), $P_5 \times P_9$ (NDBG-601 × NDBG-749-2), $P_6 \times P_9$ (NDBG-603 × NDBG-749-2), $P_1 \times P_4$ (Pusa Naveen × NDBG-517) and $P_4 \times P_6$ (NDBG-517 × NDBG-603) were recorded to be five best performing hybrids for fruit yield per vine. The highest yield recorded by these hybrids could be due to increased number of fruits per vine. The best performing F_1 hybrid was $P_8 \times P_9$ (NDBG-625 × NDBG-749-2) which recorded 7.73 kg fruit yield per vine (Kumar *et al.*, 2014) [22].

Ray *et al.*, (2015) [36] studied the magnitude of exploitation of heterosis in 45 F_1 hybrids derived by crossing ten diverse bottle gourd parents for earliness and yield components through half diallel analysis for twelve quantitative traits including 5 maturity traits for earliness. The best performing F_1 hybrids for standard heterosis found in Pusa Naveen x NDBG-603, NDBG-707-2 x NDBG-603 and NDBG-707-2 x NDBG-624. Based on earliness, desirable fruit shape and high fruit yield, elite hybrids were NDBG-707-2 x NDBG-624, NDBG-51 x NDBG-601 and NDBG-517 x NDBG-751.

Adarsh *et al.*, (2016) [1] carried out an experiment to estimate exploitation of hybrid vigor to assess the heterosis in bottle gourd through half diallel mating design consisting 9 parents and their 36 F_1 hybrids. Analysis of variance showed mean squares due to parents and hybrids were almost significant for all the characters except for days to first pistillate flower anthesis and fruit weight. It indicates the significant differences in sources of variations among parent's *vs* hybrids for most of the traits. The heterosis for days to first pistillate flower anthesis was -22.74% (SBBG-32 × HZP-RC-1) over better parent while standard heterosis was -31.52% (Pusa Naveen × SBBG-31-1). The cross SBBG-31 × HZP-RC-1 showed the significant heterosis over better parent for days to first fruit harvest was -16.95% while standard heterosis was showed in Pusa Naveen × SBBG-31-1 (-21.12%) and these characters are suitable for earliness. The cross HZP-RC-1 × SBBG-11 (47.79%) showed heterosis over better parent for fruit yield/vine while F_1 Pusa Santushti × Pusa Naveen (21.32%) over standard variety.

Ghuge *et al.*, (2016) [11] estimated 28 F_1s of bottle gourd and recorded eleven hybrids among them showed significant heterosis in favourable direction over standard check for vine length, percentage for primary branches per vine, days to anthesis of first staminate flower, days to pistillate flower anthesis, node number of first pistillate flower and days to first fruit harvest. Highly significant heterosis for vine length (35.7%) was expressed by PSPL x VRBG 100 followed by Samrat x VRBG 100 (23.5%) over standard check Samrat in desirable direction. Percentage for primary branches per vine (53.6%) was expressed by TC 092372 x VRBG 444 followed by PSPL x IC 093236 (37.9%) over standard variety. TC 092372 x VRBG 444 (-12.6%) showed highly significant heterosis in desirable direction for days to anthesis of first staminate flower over mid parent. TC 092372 x VRBG VAR-45 and TC 092372 x VRBG 444 showed highly significant heterosis (-13.5%) over standard check for days to first male flower. TC 092372 x VRBG VAR-45 showed maximum heterosis (-11.3%) which was highly significant over mid parent while PSPL x VRBG 100 showed maximum significant heterosis (-12.8%) over standard check in desirable direction for days to pistillate flower anthesis. Maximum significant heterosis (-18.5%) was recorded in F_1, Aditi x VRBG VAR-45 whereas minimum heterosis (-0.97%) was observed in hybrid Samrat x VRBG 444 over standard check for node number of first pistillate flower. Maximum significant heterosis (-14.7%) was recorded in F_1, PSPL x VRBG VAR-45 over standard check, in case of days to first fruit harvest. They also concluded that, the highly significant heterosis over standard variety in desirable direction for

average fruit weight, fruit length, number of fruits per vine, fruit yield per vine. The IC 093236 x VRBG 444 showed highly significant heterosis (44.6) over standard variety in desirable direction for average fruit weight, highly significant heterosis percentage for fruit length (48.9%) was expressed by IC 093236 x TC 092372 followed by Samrat x IC 093236 (23.9%) over standard variety Samrat. The number of fruits per vine ranged from -28.2 to 17.9% over mid parent and -17.6 to 53.3% over standard check. Aditi x PSPL showed maximum heterosis for fruits per vine (17.9%) and fruit yield per vine ranged from -35.2 to 23.9% over mid parent and -17.6 to 68.5% over standard check.

An experiment conducted by Janaranjani *et al.*, (2016) [15] to study the usefulness of heterosis breeding to develop F_1 hybrids for commercial cultivation. Nine lines and four testers were crossed to produce 36 hybrid combinations of bottle gourd under Line × Tester analysis method and resulted that there were differences among hybrids and parents for all characters. Variance associated with lines indicated significant differences for all characters except days to first male flower anthesis, number of seeds per fruit and 100 seed weight. For testers, variances exhibited significant differences among genotypes except for vine length, days to first male flower anthesis, days to first female flower anthesis, sex ratio, fruit width, fruit flesh thickness, number of seed per fruit, 100 seed weight and yield per vine. The variance due to the interaction between lines and testers was significant for all characters except node at first female flower anthesis. Hybrids from the crosses Pusa Naveen × NDBG- 164, Pusa Naveen × Punjab Komal and NDBG-121 × Samrat could be promising for commercial exploitation of fruit yield in F_1 hybrids. Number of fruit per vine and fruit flesh thickness were significantly and positively correlated with yield. When selecting the best hybrids for yield in bottle gourd, more emphasis should be given to number of fruit per vine, fruit flesh thickness, days to first male flower anthesis, fruit cavity size, fruit weight, days to first fruit harvest and TSS.

45 crosses along with their 10 parental lines evaluated through diallel mating design during *kharif* and rabi season to assess the extent of heterobeltiosis and standard heterosis in bottle gourd. The heterosis range from -3.84% (P_2 x P_7) to 64.49% (P_5 x P_8) in pooled over better parent for yield/vine. The best five crosses *viz.*, P_3 x P_9 (67.26%), P_5 x P_8 (64.49%), P_6 x P_9 (63.58%), P_4 x P_5 (60.66%) and P_2 x P_4 (58.76%) were showed positive and significant heterosis over better parent. The range of standard heterosis from P_4 x P_8 (9.80%) to (69.17%) P_3 x P_9 in pooled, the best five crosses which showed significantly positive heterosis over standard check were P_3 x P_9 (69.17%), P_6 x P_9 (65.45%), P_5 x P_8 (64.49%), P_4 x P_5 (60.66%) and P_7 x P_9 (56.80%) for fruit yield/ vine in pooled analysis. These crosses indicated that there was a great scope of heterosis breeding for higher yield in bottle gourd. It was suggested by Gautam *et al*., (2017) [9].

Khot (2017) [18] developed thirty crosses by crossing 10 lines with each of three testers under line × tester analysis to investigated the magnitude of heterosis over the commercial check Warad ranged from -44.06 to 68.34%, -57.84 to 38.67%, for vine length at 30 and 60 DAS respectively. Heterosis for number of branches at 60 DAS ranged from -40.00 to 76.00%, -20.88 to 22.59 percent for sex ratio, -4.64 to 25.83 percent for number of fruits per vine, -13.43 to 42.56 percent for fruit length, -18.37 to 32.17 percent for fruit diameter, for average fruit weight ranged from -18.56 to 5.78 percent, -10.00 to 22.93 percent for fruit yield per vine and -6.03 to 29.92 percent for fruit yield per plot. The crosses Kolkotta Collection x Samrat (29.93%) followed by Bot.G-6 x Samrat (26.93%) and Bot.G-7 x Arka Bahar (25.98%) showed significant heterosis over the commercial check for fruit yield per hectare.

Thakur (2017) [53] estimated the 20 F_1 hybrids of bottle gourd to study the relative heterosis, heterobeltiosis and standard heterosis obtained for fruit yield and its components using 5 lines and 4 testers under line x tester analysis method. A high degree of heterosis was observed for most of the characters. The highest standard heterosis shown by the crosses IBG-Local x Pusa Naveen, IBG-69 x NBBL-12 for yield and IBG-66 x Pusa Naveen, IBG-66 x Pusa Samridhi for earliness, however, a high degree of heterosis for other traits was also observed.

Niva *et al.*, (2018) [29] studied 45 F_1 hybrids using diallel set involving ten parents (excluding reciprocals) of bottle gourd to extent the heterosis over better parent and standard check NDBGH 4 and recorded that the presence of considerable variability among genotypes for all the characters under study. The cross combinations ABGS 11-23 x DBG 5, ABG 1 x Arka Bahar and DBG 6 x DBG 5 showed highly positive significant heterosis over standard check for fruit yield per vine. While, crosses ABGS 11-22 x Punjab Komal and DBG 6 x Punjab Komal showed significant negative heterosis over standard check for earliness.

Mishra *et al.*, (2019) [26] investigated extent of heterosis using 36 F_1s developed by 9 different parents of bottle gourd through diallel method of analysis (excluding reciprocals) for different 12 characters *viz*., days to first male and female flower anthesis, node number to first male and female flower appearance, days to first fruit harvest, vine length (m), number of primary branches per vine, fruit length (cm), fruit circumference (cm), fruit weight (kg), number of fruits and fruit yield per vine (kg) and revealed that the, heterosis for fruit yield per vine ranged from -42.02% to 47.92% over better parent and -44.85% to 54.74% over standard parent Pusa Naveen. Fruit yield, number of fruits per vine, vine length and primary branches per vine observed as top heterotic trait. P_7 x P_9 (54.74%), P_1 x P_7 (47.43%) and P_3 x P_7 (46.55%) were the top heterotic F_1 for fruit yield and also possessed high estimates of significant heterosis for number of fruits per vine along with attractive fruit shape.

Jayanth *et al*., (2019) [16] estimated heterosis to evaluate earliness and vegetative traits using 6 x 6 half diallel mating system and revealed that the genotypes showed significant differences for all the characters. The hybrid from the cross Pusa Naveen x Punjab Komal showed significantly higher negative standard heterosis for earliness and the hybrid from the cross KBG-16 x Pusa Samridhi showed highly significant heterosis for vegetative traits.

Other cucurbits

Pandey *et al*., (2005) [34] assessed the magnitude of heterosis in ash gourd through diallel method without reciprocals using eight parents and their 28 F_1s and revealed that, maximum heterosis for yield was exhibited by IVAG-90 x IVAG-114. The selection should be made for improvement of traits like number of fruits per vine, polar and equatorial circumference of fruit and yield. While number of branches, vine length and individual fruit weight may be improved through hybridization.

Sarkar *et al.*, (2015) [38] investigated eight different parental lines to developed 28 F_1 hybrids of ridge gourd through diallel method of analysis (excluding reciprocals) to assess the heterosis for earliness and vegetative characters. They

resulted the appreciable heterosis in desirable direction was found over better parent and check parent for the characters *viz*. days to first female flower, node number to first female flower, vine length (m), number of primary branches and days taken to first fruit harvesting. Crosses PCPGR 7256 x PRG 142, PRG 117 x PRG 142, PRG 117 x PRG 131, PRG 117 x PRG 132 and PRG 117 x PRG 120 were found promising for earliness. Crosses PCPGR 7256 x PRG 117, PCPGR 7256 x PRG 131 and PRG 132 x PRG 120 were recorded promising for vegetative traits.

Tamilselvi *et al*., (2015) [52] studied standard heterosis for earliness and yield contributing characters in pumpkin using 15 diverse genotypes including 12 lines and 3 testers to obtained 36 F_1 hybrids through Line x Testers method. They resulted the parents Kasi Harit, Vadhalagundu Local and CO2 identified as best genotypes for earliness and yield characters based on *per se* performance and the hybrids Kasi Harit x Avinashi Local and Vadhalagundu Local x CO 2 considered best on standard heterosis for earliness and yield characters.

Mahamud *et al*., (2016) [23] estimated extent of heterosis in bitter gourd to increase yield and quality by identification of unique cross combination using five parents along with their 16 hybrids through partial diallel mating design. They resulted heterotic vigour was present for earliness, yield and quality characters among hybrids. Significant differences for all characters indicated presence of genetic variability. The heterosis was negative for days to first harvest, fruit length, diameter and single fruit weight and positive for number of fruits/vine and fruit yield/vine. Average fruit weight ranged from 115 to 249 g, the heaviest fruit were from the crosses $P_1 \times P_3$, $P_2 \times P_3$, $P_3 \times P_1$, $P_3 \times P_5$, and $P_5 \times P_2$. The crosses were $P_3 \times P_4$, $P_4 \times P_3$ and $P_5 \times P_4$ had the smallest fruit. The hybrids from the crosses P_3 x P_1, P_2 x P_3 and P_1 x P_3 were had longest fruit and the crosses P_4 x P_3, P_4 x P_2 and P_3 x P_4 had the shortest fruit length. The cross combination P_3 x P_5 had highest yield followed by the crosses P_4 x P_1 and P_4 x P_3. The crosses P_5 x P_4 (102%), P_3 x P_5 (82.6%) and P_2 x P_5 (82.4%) recorded highest higher heterosis percent over better parent for fruit yield/vine. Hybrids from the crosses P_5 x P_4, P_3 x P_5 and P_2 x P_5 can be used to developed commercial lines based on the yield attributes and heterotic performance.

Sets of 28 F_1s crosses developed by using 8 diverse parents of ridge gourd by Muthaiah *et al*., (2017) [27] through half diallel analysis method to estimated heterosis for growth and yield of ridge gourd and resulted, the analysis of variance indicated highly significant differences for growth and yield characters, which suggesting presence of wide genetic variability, which provided the opportunity to exploit heterosis in ridge gourd. The positive heterosis exhibited for most of growth and yield characters *viz.*, vine length, number of leaves, fruit yield per vine and fruit yield per hectare. The crosses DMRG-36 × DMRG-25, DMRG-25 × Arka Sumeet and DMRG-25 × DMRG-22 exhibited high heterosis for yield characters.

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