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Heterosis in bitter gourd (*Momordica charantia* L.) for yield and yield related traits

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Abstract
The experiment was conducted to study the heterosis in bitter gourd (*Momordica charantia* L.) at Sabour Farm, Department of Horticulture (Vegetable and Floriculture), Bihar Agricultural University, Sabour, Bhagalpur during summer season, 2017. The investigation comprised of seven diverse parents *viz.*, Thailong(P_1), Konkon Tara (P_2), Pusa Aushadhi (P_3), Pirpaiti Local (P_4), Karela Safed (P_5), Gangajali Small (P_6), and Pusa Rasdar (P_7) and a for all characters indicated presence of genetic variability. The cross combinations Gangajali Small × Pusa diallel diallel mating design was used to evaluate 21 hybrids to increase yield by identification of a unique cross combination with desirable heterosis in bitter gourd. Significant differences Rasdar, Karela Safed × Pusa Rasdar and Konkon Tara × Gangajali Small showed highest heterosis with 45.65%, 39.13% and 35.65% respectively for fruit yield per plant over check parent Pusa Rasdar. Based on *per se* performance and high magnitude of heterosis for yield and yield contributing characters, the hybrids Gangajali Small × Pusa Rasdar ($P_6 \times P_7$), Karela Safed × Pusa Rasdar ($P_5 \times P_7$) and Konkon Tara × Gangajali Small ($P_2 \times P_6$) were identified as ideal cross combinations and can be used for development of improved commercial lines. Conclusively, it has been suggested that heterosis breeding could be useful breeding approach for developing of early and high yielding genotypes from potent breeding material suggested in the present experiment and further amelioration of fruit yield and quality can be achieved in bittergourd.

Keywords: Bitter gourd, yield, standard heterosis

Introduction
Bitter gourd (*Momordica charantia* L.) is an important commercial cucurbit of family Cucurbitaceae. The origin of this crop is probably in India with secondary centre of diversity in China (Grubben 1977) [4]. The Latin name '*Momordica*' means 'to bite' and refers to the leaves of the bitter melon plants, which have jagged edges and look like they have been bitten. It is locally known as Karela and also as Balsam pear or bitter cucumber in English. The role of bitter melon traditionally, has been as a food and medicine. Bitter gourd possesses comparatively high concentrations of ascorbic acid and iron as compared to other cucurbits (Behera 2005) [1]. The immature fruits and tender vine tips are used in a variety of culinary preparations. The fruits and shoots are soaked in salt water to remove some of their bitterness and then boiled, fried or pickled. The medicinal value of this gourd in the treatment of infectious diseases and diabetes is attracting the attention of scientists worldwide. Fruits have hermicidal effect and are laxative and easily digestible, good for curing blood diseases, diabetes and asthma.

Bitter gourd is monoecious vine having unisexual flowers, highly cross pollinated and bears male and female flowers separately on the same plant, which renders considerable amount of variability. However, there is a prime need for its improvement to develop varieties or hybrids suited to specific conditions. In bitter gourd full exploitation of heterosis through development of hybrids has not been successfully commercialized due to one or the other reason. Variability found in shape, size and colour of fruits in most conspicuous which offers tremendous scope for heterosis breeding for yield enhancement. Crossing nature and heterosis in cross pollinated crops has been known to offer good potentialities for increased yield.

Yield potential of bitter gourd needs to be improved and one of the best way to improve yield and quality is heterosis breeding. Heterosis breeding has been a recognized practical tool providing the breeder a means of increasing yield and other economic traits. The F_1 hybrids offer several advantages like earliness, high yield, uniformity, wider adaptability and also help in development of dominant genes for resistance to diseases and pests (Riggs, 1988) [13]. The commercial exploitation of hybrid vigour depends on the ease with which the technique

employed and cost of seed production. Bitter gourd being monoecious can be profitably utilized for the production of F_1 hybrid seeds at cheaper price. High number of hybrid seeds per cross makes it more economical. Further, the crop being cultivated at wider spacing, the seed requirement per hectare for commercial cultivation would be low and cost effective. Therefore, bitter gourd offers greater scope for exploitation of hybrid vigour on commercial scale to increase the productivity and production.

Materials and methods

The present investigation was conducted with seven diverse genotypes/cultivars of bitter gourd. The crosses were made in half diallel mating design to generate 21 F_1 hybrids. The 21 F_1 hybrids along with their seven parents were evaluated during summer season, 2017 in a Randomized block design with three replications at Sabour Farm, Bihar Agricultural University, Sabour (Bhagalpur). The plot size was 9.0 m2 with a spacing of 1.5 cm x 1 cm. Recommended cultural practices were followed to raise a good crop. Observation were recorded on five randomly selected tagged plants from each treatment for yield and yield attributing traits *viz*. days to 50%flowering, vine length (cm), days to first fruit harvest, number of fruits per plant, yield of marketable fruits per plant (kg), average fruit weight (g), fruit length (cm), were recorded from five randomly selected plants from each replication, while days to 50% flowering were recorded on plot basis. Heterosis over better parents and commercial check, were computed following standard statistical procedure Fonseca and Patterson (1968) was applied to compute heterosis estimates.

Result and Discussion

The analysis of variance revealed the existence of adequate genetic variability in experimental material for all traits under study. Variance due to parents Vs F_1'swere significant for all yield and yield attributing traits, thereby indicating the presence of overall average heterosis for all characters. Heterosis was computed as percent increase or decrease in F_1 valves over mid parent, the better parents and over the best standard check variety Pusa Rasdar (Table -1). In the present investigation the relative magnitude of heterosis over the mid parent, better parents and standard variety (Pusa Rasdar) was studied for seven characters. Days to 50% flowering is a desirable character in favour of early yielding genotypes. In case of days to 50% flowering, eight crosses exhibited significant and negative heterosis over mid parent, sixteen over better parent and eleven crosses over the check parent. The hybrids viz., Thailong × Pusa Aushadhi followed by Pusa Aushadhi × Gangajali Small and Pirpaiti Local × Pusa Rasdar showed significant and negative heterosis for earliness over the standard check variety, Pusa Rasdar. Heterosis for earliness were also reported by Ranpise *et al*. (1992) [11], Yadav *et al*. (2012) and Ray *et al*. (2015) [12] in bitter gourd.

Table 1: Estimates of heterosis over mid, better and standard check for yield and yield attributing traits in bitter gourd

Crosses (F_1)	Days to 50% flowering Heterosis over			Vine Length (cm) Heterosis over		
	MP	BP	CP	MP	BP	CP
Thailong × Konkon Tara	1.34	0.68	-0.82	4.72**	-6.43**	-27.10**
Thailong × Pusa Aushadhi	-6.17**	-23.10**	-24.25**	7.10**	0.00	-16.77**
Thailong × Pirpaiti Local	-1.00	-3.40**	0.00	0.00	0.00	-16.77**
Thailong × Karela Safed	-1.94	-3.80**	-5.24**	-18.80**	-23.67**	-38.06**
Thailong × Gangajali Small	-5.73*	-10.84**	-1.50	-4.96**	-9.45**	-16.77**
Thailong × PusaRasdar	-2.41*	-3.14**	-3.14**	72.77**	40.16**	47.74**
Konkon Tara × Pusa Aushadhi	16.36**	-4.16**	-6.81**	20.87**	15.28**	-16.77**
Konkon Tara × Pirpaiti Local	-6.79**	-9.62**	-6.44**	-2.92**	-13.25**	-38.06**
Konkon Tara × Karela Safed	4.67**	3.34**	0.48	3.97**	-12.01**	-16.77**
Konkon Tara × Gangajali Small	-3.78**	-9.55**	-0.07	20.17**	2.91**	5.16**
Konkon Tara × Pusa Rasdar	7.40**	5.91**	5.91**	65.81**	48.47**	10.32**
Pusa Aushadhi × Pirpaiti Local	10.97**	-10.77**	-7.63**	0.22	-6.43**	-27.10**
Pusa Aushadhi × Karela Safed	18.56**	-1.34	-6.51**	-0.20	-12.01**	-16.77**
Pusa Aushadhi × Gangajali Smsall	5.48**	-17.21**	-8.53**	-12.02**	-21.45**	-38.06**
Pusa Aushadhi × Pusa Rasdar	13.55**	-7.49**	-7.49**	13.21**	-2.78**	-41.94**
Pirpaiti Local × Karela Safed	7.59**	3.04**	6.66**	-43.98**	-47.35**	-81.29**
Pirpaiti Local × Gangajali Small	-2.27*	-5.35**	4.57**	-4.96**	-9.45**	-16.77**
Pirpaiti Local × Pusa Rasdar	-9.30**	-10.85**	-7.71**	6.93**	-13.25**	-38.06**
Karela Safed × Gangajali Small	-1.90	-8.88**	0.67	-10.75**	-12.01**	-16.77**
Karela Safed × Pusa Rasdar	-3.54**	-6.06**	-6.06**	-31.96**	-47.35**	-81.29**
Gangajali Smsall × Pusa Rasdar	-2.20	-6.84**	2.92**	-46.05**	-57.82**	102.58**

Mid Parent, Better Parent and Check Parent

*, **- Significant at 5 percent and 1 percent probability level, respectively.

In the present study, out of 21 crosses, nine, four and four crosses exhibited significant negative heterosis over mid parent, better parent and check parent for vine length. The mid parent heterosis for vine length ranged from -46.05 percent (Gangajali Small × Pusa Rasdar) to 72.77 percent (Thailong × Pusa Rasdar) and heterosis over better parent ranged from -57.82 percent (Gangajali Small × Pusa Rasdar) to 48.47 percent (Konkon Tara × Pusa Rasdar). Standard heterosis ranged from -81.29 percent (Pirpaiti Local × Karela Safed) to 102.58 percent (Gangajali Small × Pusa Rasdar). Standard heterosis for internodal length was also reported by Maurya *et al*. (2004) [8] in bitter gourd. Heterosis for growth parameters is an indication of earliness, high vigour and yield as growth and yield parameters are strongly associated. The hybrid Gangajali Small × Pusa Rasdar showed longest vine length among all the hybrids under study. In earlier studies also, heterosis was reported for vine length (Behera *et al.* 2009, Yadav *et al.* 2012 and Singh *et al.* 2013) [14]. The ideal plant type should have longer vine length and branching to support higher yield (Sirohi and Choudhury, 1978) [15].

For fruit yield per vine, out of 21 crosses, 11 crosses over mid parent, 11 crosses over the better parent and 16 crosses over the commercial check exhibited positive and significant heterosis. The hybrid which exhibited maximum heterosis over better parent was Konkon Tara × Gangajali Small (31.56%), 30.97% over mid parent and 7.64% over standard check. The magnitude of heterosis for fruit yield over commercial check was low as compared to earlier reports, where Celine and Sirohi (1996) [2] reported 55.80 percent and Mishra *et al.* (1994) [9] reported 46.70 percent standard heterosis.

For average fruit weight, out of twentyone cross combinations ten, eight and six cross combinations exhibited significant positive heterosis over mid parent, better parent and standard check variety. The mid parent heterosis for average fruit weight ranged from -12.42 (Pusa Aushadhi × Karela Safed) to 172.71 percent (Konkon Tara × Gangajali Small) and heterobeltiosis ranged from -16.46 percent (Pusa Aushadhi × Gangajali Small) to 142.06 percent (Konkon Tara × Gangajali Small). Standard heterosis for average fruit ranged from -3.14 (Thailong × Gangajali Small) to 65.79 percent (Konkon Tara × Gangajali Small). Out of 21 crosses, six crosses exhibited significant positive heterosis over check parent. The hybrids viz., Konkon Tara × Gangajali Small, Konkon Tara × Pusa Aushadhi, Konkon Tara × Pirpaiti Local and Konkon tara × Karela Safed showed high degree of standard heterosis for average fruit weight. The cross Konkon Tara × Gangajali Small showed significant and positive heterosis of 172.71 percent over mid parent, 142.09 percent over better parent and 65.79 percent showed positive and significant heterosis of over the commercial check. In earlier studies, 13.95 percent heterosis over commercial check has been reported by Ranpise *et al.* (1992) [11] and Verma and Singh (2014) [16] in bitter gourd.

For number of fruits per plant, significant and positive heterosis were observed by 6 cross over mid parent, 5 cross over better parent and 21 cross over standard check variety.The mid parent heterosis ranged from -12.30 (Thailong × Konkon Tara) to 19.74 percent (Pusa Aushadhi × Pusa Rasdar) and heterobeltiosis ranged from -24.39 percent (Thailong × Konkan Tara) to 15.55 percent (Pusa Aushadhi × Pusa Rasdar). Standard heterosis ranged from 8.24 (Thailong × Konkon Tara) to 32.17 percent (Thailong × Gangajali Small). The highest standard heterosis were exhibited by Thailong × Gangajali Small followed by Konkon Tara × Pusa Rasdar and Konkon Tara × Gangajali Small for number of fruits per plant was recorded. Conformity evidence for above mentioned characters has also been given by Mangal *et al.*, 1984 [7] and Khattra *et al.*, 2000 [6].

For days to first fruit harvest, 8 hybrids, 11 hybrids and five hybrids showed significant negative heterosis over mid parent, better parent and standard check variety. The crosses viz., Pusa Aushadhi × Karela Safed, Pusa Aushadhi × Pirpaiti Local and Pusa Aushadhi × Gangajali Smsall showed significant negative standard heterosis for days tofirst fruit harvest. Yield components greatly influence the yield and expression of heterosis for fruit length, fruit diameter, fruit weight and number of fruits per vine can greatly contribute for total fruit yield per plant. For all these traits, positive heterosis is desirable. For fruit length, out of 21 crosses, 15 cross over mid parent, five crosses over the better parent and five crosses over the commercial check exhibited positive and significant heterosis. The cross Konkon Tara × Gangajali Small showed maximum positive and significant heterosis of 137.99 percent over the mid parent, 131.16 percent over the better parent and 10.94 percent over the commercial check. These findings are in accordance with the result of significant heterosis by Talekar *et al.*, (2013) and Naliyadhara *et al.*, (2010) [10]. Number of fruits per vine was influenced by the size of the fruit, that is fruit length and fruit girth (Ranpise *et al.*, 1992) [11].

For total fruit yield per plant, 10 hybrids, 11 hybrids and 16 hybrids showed positive and significant heterosis over better parent, mid parent and standard check variety, respectively. The mid parent heterosis for yield of marketable fruit per plant ranged from -18.11 percent (Pirpaiti Local × Pusa Rasdar) to 58.77 percent (Gangajali Small × Pusa Rasdar) and heterobeltiosis ranged from -39.34 percent (Pusa Aushadhi × Pirpaiti Local) to 45.65 percent (Gangajali Small × Pusa Rasdar) and standard heterosis ranged from -14.35 (Thailong × Karela Safed) to 45.65 percent (Gangajali Small × Pusa Rasdar).Total fruit yield per plant is dependent mainly on the number of fruits per plant and average fruit weight. Number of fruits per vine was influenced by the size of the fruit, that is fruit length and fruit girth (Ranpise *et al.*, 1992) [11]. Number of fruits per plant, out of 21 crosses, 11 over the mid parent, six over the better parent and all crosses over the commercial check exhibited positive and significant heterosis. The cross Pusa Aushadhi × Pusa Rasdar showed maximum and positive heterosis of 15.55 percent over better parent, cross Pusa Aushadhi × Pusa Rasdar of 19.74 percent positive heterosis over mid parent and the cross Thailong × Gangajali small showed maximumand positive heterosis of 32.17 percent over the commercial check. Standard heterosis for number of fruits per vine was also reported to the extent of 32.70 percent by Ranpise *et al.* (1992) [11], 9.0 percent by Mishra *et al.* (1994) [9]. The promising hybrids were Thailong × Gangajali Small, Konkon Tara × Gangajali Small and Konkon Tara × Pusa Rasdar.

Based on yield contributing characters and heterotic performance hybrids from crosses Small × Pusa Rasdar, Karela Safed × Pusa Rasdar and Konkon Tara × Gangajali Small can be used development of improved commercial lines. Conclusively, it has been suggested that heterosis breeding could be useful breeding approach for developing of early and high yielding genotypes from potent breeding material suggested in the present experiment and further amelioration of fruit yield can be achieved in bitter gourd. It is concluded that there is tremendous scope for the development of F_1 hybrids in bitter gourd. Hybrids with significant heterosis in desirable direction for yield, its attributing traits viz., number of fruits per plant, fruit weight and fruit length should be utilized for further evaluations and can be exploited for commercial cultivation.

Table 2: Estimates of heterosis over mid, better and standard check for yield and yield attributing traits in bitter gourd

Crosses (F_1)	Fruit yield per plant (kg) Heterosis over			Fruit weight (gm) Heterosis over		
	MP	BP	CP	MP	BP	CP
Thailong × Konkon Tara	9.28**	1.92**	15.22**	36.47**	1.03	11.62*
Thailong × Pusa Aushadhi	1.65	-16.45**	26.96**	-7.78	-11.60*	6.48
Thailong × Pirpaiti Local	18.50**	11.33**	23.91**	12.62	-2.06	8.20

Thailong × Karela Safed	-10.66**	-12.44**	-14.35**	-3.30	-3.42	6.70
Thailong × Gangajali Small	7.43**	-0.44*	-2.61**	8.24	-12.32*	-3.14
Thailong × Pusa Rasdar	-2.42**	-3.48**	-3.48**	-0.91	-5.61	4.28
Konkon Tara × Pusa Aushadhi	-6.48**	-18.45**	23.91**	76.62**	27.24**	53.26**
Konkon Tara × Pirpaiti Local	12.02**	12.89**	25.65**	122.90**	83.92**	50.20**
Konkon Tara × Karela Safed	12.18**	18.67**	16.09**	72.01**	27.45**	40.44**
Konkon Tara × Gangajali Small	38.05**	38.67**	35.65**	172.71**	142.06**	65.79**
Konkon Tara × Pusa Rasdar	-4.08**	2.17**	2.17**	37.24**	5.06	5.06
Pusa Aushadhi × Pirpaiti Local	-29.98**	-39.34**	-7.83**	-0.44	-16.46**	0.62
Pusa Aushadhi × Karela Safed	-13.35**	-29.90**	6.52**	-12.42	23.67**	1.00
PusaAushadhi × GangajaliSmsall	-5.45**	-26.75**	11.30**	8.62	-6.88	2.62
Pusaaushadhi × PusaRasdar	-4.75**	-21.03**	20.00**	-2.68	56.63**	7.28
Pirpaiti Local × KarelaSafed	8.90**	0.39*	11.74**	5.60	-8.07	1.30
Pirpaiti Local × Gangajali Small	19.64**	4.69**	16.52**	34.58**	23.72**	1.04
Pirpaiti Local × PusaRasdar	-18.11**	-13.48**	-13.48**	14.16*	3.70	3.70
KarelaSafed × Gangajali Small	24.02**	17.13**	10.00**	17.07*	-5.08	4.60
KarelaSafed × PusaRasdar	43.50**	39.13**	39.13**	0.02	-4.61	5.12
GangajaliSmsall × PusaRasdar	58.77**	45.65**	45.65**	32.11**	11.30*	11.30*

Mid Parent, Better Parent and Check Parent

*, **- Significant at 5 percent and 1 percent probability level, respectively.

Table 3: Estimates of heterosis over mid, better and standard check for Number of fruits per plant and Fruit length (cm)

Crosses (F1)	Number of fruits per plant Heterosis over			Fruit length (cm) Heterosis over		
	MP	BP	CP	MP	BP	CP
Thailong × Konkon Tara	-12.30**	-24.39**	17.37**	-11.16**	-17.04**	8.24**
Thailong × PusaAushadhi	2.78	0.95	-7.43**	-13.24**	-7.37**	8.55**
Thailong × Pirpaiti Local	2.49	-0.71	5.67**	4.70**	-2.23*	9.81**
Thailong × Karela Safed	6.71*	5.34*	-2.14	-4.27**	-6.55**	9.23**
Thailong × Gangajali Small	19.47**	12.42**	12.18**	-16.73**	-22.25**	32.17**
Thailong × Pusa Rasdar	10.04**	8.08**	-1.81	-5.06**	-5.06**	12.07**
Konkon Tara × Pusa Aushadhi	1.55	-11.08**	21.83**	-11.71**	-5.73**	27.28**
Konkon Tara × Pirpaiti Local	-4.18	-15.07**	55.14**	18.18**	8.33**	21.57**
Konkon tara × Karela Safed	-2.88	-17.17**	29.48**	-3.43**	-5.73**	18.56**
Konkon Tara × Gangajali Small	-0.94	-9.79**	137.99**	131.16**	10.94**	29.13**
Konkon Tara × Pusa Rasdar	7.56*	-8.65**	34.04**	-0.82	-0.82	30.77**
Pusa Aushadhi × Pirpaiti Local	4.29	2.84	7.46**	-0.14	6.62**	13.74**
Pusa Aushadhi × Karela Safed	5.51	2.32	7.97**	3.34**	10.34**	10.02**
Pusa Aushadhi × Gangajali Smsall	6.99*	2.41	11.31**	-20.77**	-15.40**	20.41**
Pusa aushadhi × Pusa Rasdar	19.74**	15.55**	-3.92**	-6.97**	-0.67	24.24**
Pirpaiti Local × Karela Safed	18.06**	12.95**	9.04**	5.72**	3.20**	24.92**
Pirpaiti Local × Gangajali Small	5.24	2.12	35.33**	1.06	-7.37**	20.07**
Pirpaiti Local × Pusa Rasdar	9.03**	3.80	-2.56*	-6.62**	-6.62**	14.80**
Karela Safed × Gangajali Small	7.04*	-0.49	22.40**	-10.44**	-12.57**	16.99**
Karela Safed × Pusa Rasdar	15.14**	14.55**	-3.77**	-4.91**	-4.91**	15.73**
Gangajali Smsall × Pusa Rasdar	7.95*	-0.12	26.54**	-8.11**	-8.11**	17.44**

Mid Parent, Better Parent and Check Parent

*, **- Significant at 5 percent and 1 percent probability level, respectively.

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