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Estimation of Heterosis on infestation of fruit fly and other quality traits in bitter gourd (*Momordica charantia* L.)

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Abstract
The experimental material comprised 28 F_1 crosses, developed by crossing 8 genotypes and one standard check during summer 2020 and *kharif* 2020. Parents and the 28 hybrids, along with standard check, were planted in a randomized block design for screening against different fruit fly under natural field conditions. The crosses combination 3 x 7, 2 x 7, 4 x 7 and 6 x 7 exhibited maximum negative heterosis over standard check for fruit fly infestation, days to 50 per cent flowering and days to first harvest. Therefore, these parents and hybrid combinations can be utilized for the development of hybrids/varieties having resistance to these biotic stresses in bitter gourd. Further, gene action revealed predominant role of non-additive gene action for the control of different insect infestation under study, hence heterosis breeding can be exploited commercially for insect resistant hybrid development in bitter gourd.

Keywords: Heterosis, fruit fly infestation, bitter gourd and genotypes

Introduction
Vegetables are one of the most crucial components of Indian gardening. India recently made great progress, which allowed it to surpass. China is the second-largest vegetable producer in the world (Panday *et al.*, 2009) [13]. In terms of vegetable production, India is only surpassed by China. In India, there are around 245 g of vegetables available per person every day compared to a daily requirement of 300 g. On the Indian subcontinent, cucurbitaceous vegetables, which include bitter gourd, cucumber, melons, pumpkins, and many other varieties of gourds, are among the most significant vegetable crops, producing the majority of the summer and rainy season vegetables. One of the most well-liked vegetables in Southeast Asia is the bitter gourd (*Momordica charantia*). In terms of nutritional value, bitter gourd tops all other cucurbits due to its high levels of ascorbic acid, phosphorus, and iron. It is advised for diabetics to eat bitter gourd fruits because they contain a substance that is clinically comparable to insulin. With an expected annual production of 34.97 MT from an area of approximately 3.58 hectares in Maharashtra and 1330.21 MT from an estimated 108.8 ha across India (Anon., 2021) [2]. A number of insect pests, notably the fruit fly, one of the most destructive pest insects, attack bitter gourds (Panday *et al*., 2008) [12]. Melon fruit flies, also known as Tephritidae or Dacinae flies, are tropical and subtropical cucurbit pests that are significant economically. Losses may range from 30 to 100 per cent depending on the species of cucurbit and the season. (Panday *et al.*, 2009) [13].
Heterosis breeding has come to play a pivot role in crop improvement for yield and quality attributes (Singh *et al*., 2014) [19]. But, before the exploitation of heterosis, nature and magnitude of gene action involved in the expression of trait of interest and choice of suitable parental lines is of utmost importance. The ability to choose an effective breeding strategy and suitable parental lines for the genetic improvement of any crop is facilitated by knowledge of the nature and magnitude of gene action controlling the inheritance of various traits, along with the proportional contribution of parental lines in the expression of traits in F1 hybrids (Rattan and Chadha, 2009) [14]. The degree and kind of gene action involved in the production of quantitative traits is also indicated by combining capacity. However, there is currently very little information in the literature about heterosis, gene activity, proportional contribution of lines, tester and their interactions for fruit fly resistance in bitter gourd. The most significant factor in breeding for fruit fly resistance in the bitter gourd is identifying promising parents.

Similarly, a thorough understanding of the nature of fruit fly resistance inheritance, as well as its component traits and their relationships, is required to put such breeding programs on solid ground. As a result, research encompassing a larger range of bitter gourd genotypes was conducted to identify superior combiners based on morphological features that have shown a strong positive link with fruit fly resistance. Therefore this experiment was conducted to draw the results about heterosis for fruit fly infestation and other quality traits.

Material and Method

The studies on Inheritance of fruit fly resistance in relation to component characters were carried out on RHRBG, variety during two season of the year 2020 at PGI MPKV, Rahuri, and the details of experiments are as under. The twenty eight hybrids obtained from the diallel cross mating. The present investigation was carried at All India Coordinated Research Project on Vegetable Crops, MPKV, Rahuri. The 8 parents 28 F_1 hybrids and one standard check were sown in randomize block design, replicated twice during 2020. The observation was recorded in F_1 hybrids and parents on 5 randomly selected plants per genotype in each replication for following plant characters.

Observations recorded

The observations of fruit fly infestation were recorded from five tagged plants of each genotype, as described below. Eight genotypes along with 28 F_1 hybrids were evaluated for their relative susceptibility against fruits fly under natural infestation conditions. The marketable size fruits irrespective of healthy and infested were picked at weekly intervals. At each picking, the total number of fruits and number of fruits infested were documented and per cent infestation was worked out. The per cent of fruit infestation were worked out by following formula.

$$\% \text{ Pest infestation} = \frac{\text{No. of damaged fruits}}{\text{Total no. of fruits}} \text{ X } 100$$

Observed the growth characteristics like days to 50 per cent flowering and days to first harvest. The values of F_1 averaged over replications were used for estimating heterosis. The magnitude of heterosis was calculated as percentage increase or decrease of F_1 mean over the mean of mid parent (MP) (Turner, 1953 and Hays *et al.* 1955) [22, 3]. Similarly per cent superiority over the better parent (BP) and standard hybrid check (SC).

Result and Discussion

Heterosis

The hybrids produced from the crossed seeds are typically more robust, vigorous, and productive than the parents when two homozygous individual inbreeds are mixed together. Heterosis is the ability to outperform parents in terms of production. Additionally, it is known by the name hybrid vigour. Due to the bitter gourd monoecious nature, large amount of seeds per fruit and many other beneficial characteristics, heterosis breeding presents an opportunity. Bitter gourd heterosis can be used for high production, early ripening, longer harvesting times and fruit fly resistance. Performance in comparison to the commercial variety of a crop is the main factor determining the commercial usefulness of hybrids. In this study, heterosis of several crosses obtained from the diallel method was evaluated over mid parent, better parent, and standard check (excluding reciprocals). For the evaluation of hybrids, standard heterosis and heterobeltiosis are important. When choosing possible hybrid combinations for further use in plant breeding and exploitation of heterosis, it is crucial to take both the performance of the parent and hybrids into account in addition to the per cent heterosis.

Fruit infestation (%)

The least amount of fruit infestation caused by larval feeding is preferred. Therefore, the cross combination with negative heterosis is quite valuable for fruit infestation. In the current investigation, the range of heterosis during summer 2020 for these characters over mid parent, better parent and standard check respectively, was -62.60 to 17.63 per cent, 72.03 to 10.99 per cent and -80.69 to 37.85 per cent. The cross RHR BG-10 x RHR BG-29 (3 x 7) has the highest percentage (-72.03) of negative heterobeltosis. The range of heterosis over MP, BP and Standard check during the 2020 *kharif* season was, respectively, -67.88 to 32.23 per cent, -78.46 to 18.16 per cent and -28.88 to 62.32 per cent. The cross RHR BG-10 x RHR BG-29 (3 x 7) had the highest percentage of negative heterobeltosis (-78.46).

The resistance of watermelon to the fruit fly was controlled by a single dominant gene. The symbol *Fwr* has been proposed to denote the resistant gene (Khandelwal & Nath 2011). These results were in correspondence with findings, Kumar A. (2006) [5], Sharma, M. (2010) [15], Kuma S. (2013) [7], Kumari, R. (2015) [8] and Kumar *et al.* (2018) [6].

Days to 50 per cent flowering

For the least amount of fruit infestation, earliest is a desirable trait. Out of all the crosses, during the summer seasons, 4 cross combinations showed negative heterosis above mid parent, 11 cross combinations over better parents and 8 cross combinations over standard check. During the *kharif* seasons, 8 cross combinations showed negative heterosis above mid parent, 17 cross combinations over better parents and 1 cross combinations over standard check. While the cross combinations over better parents 3 x 7 (-14.52, -10.94), 2 x 7 (-6.50, -6.40), 4 x 7 (-5.69, -7.02), 1 x 7 (-4.87, -5.60), and 5 x 7 (-4.06, -7.20) recorded negative heterosis in the summer and *kharif* seasons, respectively. Singh and Kumar (2002) [18], Laxuman *et al.* (2012) [10], Singh *et al.* (2013) [16] and Acharya *et al.* (2019) [1] in bitter gourd.

Days required for first harvest

Out of all the crosses, during the summer seasons, 16 cross combinations showed negative heterosis over mid parent, 22 cross combinations over better parents and 22 cross combinations over standard check. The cross combinations RHR BG-10 x RHR BG-29 (3 x 7) (-7.88, -8.61 and -9.54) over the mid parent, better parent and standard check in summer 2020. Similar results observed by Tiwari *et al.* (2001) Singh and Kumar (2002) [18], Laxuman *et al.* (2012) [10], Singh *et al.* (2013) [16] and Acharya *et al.* (2019) [1] in bitter gourd.

Table 1: Heterosis (%) over mid parent, better parent and standard hybrid check in 8×8 half diallel of fruit infestation in bitter gourd.

Sr. No.	Crosses	Fruit fly infestation (%)					
		summer			*kharif*		
		M.P.	B.P.	S.C.	M.P.	B.P.	S.C.
1.	1×2	-34.20**	-35.72**	-18.10	-45.93**	-46.60**	-26.85*
2.	1×3	-19.60**	-20.88**	-3.85	-43.20**	-43.28**	-22.08*
3.	1×4	-45.98**	-63.55**	26.81**	-41.97**	-61.03**	55.62**
4.	1×5	-48.47**	-60.22**	-11.13	-61.08**	-71.85**	-13.70
5.	1×6	-44.69**	-58.72**	1.83	-42.59**	-57.50**	21.15*
6.	1×7	-11.47	-22.16**	-5.41	-32.72**	-42.54**	-21.29
7.	1×8	-27.43**	-32.55**	-15.04	-9.45	-26.42**	0.79
8.	2×3	-19.64**	-22.72**	-1.53	19.82**	18.16*	62.32**
9.	2×4	-57.77**	-71.15**	0.37	-54.66**	-69.75**	20.81*
10.	2×5	-33.48**	-47.77**	16.69	-31.32**	-50.69**	51.14**
11.	2×6	-26.49**	-44.26**	37.51**	-23.43**	-43.77**	60.28**
12.	2×7	-34.12**	-43.23**	-27.67**	-38.31**	-46.76**	-13.98
13.	2×8	-17.94**	-25.36**	-4.89	-15.25	-30.46**	-7.11
14.	3×4	-40.78**	-60.38**	37.85**	-39.65**	-59.44**	61.97**
15.	3×5	-24.27**	-42.20**	29.13**	-26.21**	-46.57**	63.77**
16.	3×6	-27.96**	-46.80**	31.24**	-26.25**	-45.36**	55.76**
17.	3×7	-62.60**	-72.03**	-80.69**	-67.88**	-78.46**	-12.88**
18.	3×8	17.63	10.99	30.57**	32.23**	7.33	47.45**
19.	4×5	-55.78**	-69.29**	6.85	-65.34**	-71.62**	13.35
20.	4×6	5.00	-10.27**	12.20**	3.98	-10.90**	55.83**
21.	4×7	-36.85**	-43.69**	-33.75**	-3.27	-17.48**	-13.98
22.	4×8	-41.98**	-62.29**	31.21**	-40.38**	-63.80**	44.58**
23.	5×6	-57.55**	-59.55**	-0.21	-62.79**	-64.09**	10.08
24.	5×7	-47.55**	-62.96**	-17.24	-37.10**	-58.60**	26.92*
25.	5×8	-44.06**	-58.96**	-8.32	-32.28**	-56.68**	32.78**
26.	6×7	-26.10**	-49.24**	25.22**	-22.16**	-47.84**	48.69**
27.	6×8	-29.05**	-49.52**	24.55	-19.97**	-47.96**	48.34**
28.	7×8	-22.85**	-27.36**	-24.18*	2.32	3.66	-6.56
S.E.±		1.29	1.49	1.49	1.24	1.43	1.43
C.D. @ 5%		2.62	3.02	3.02	2.51	2.90	2.90
C.D. @ 1%		3.52	4.06	4.06	3.37	3.90	3.90

* and ** significant at 5% and 1% level.

Table 2: Heterosis (%) over mid parent, better parent and standard hybrid check in 8×8 half diallel of 50 per cent flowering in bitter gourd

Sr. No.	Crosses	Days to 50 per cent flowering					
		summer			*kharif*		
		M.P	B.P.	S.C.	M.P	B.P.	S.C.
1.	1×2	0.81	0.00	1.64	-3.13	-3.13	3.33
2.	1×3	-1.63	-2.42	-0.82	0.81	-2.34	4.17
3.	1×4	-2.44	-3.23	-1.64	-4.88 *	-8.59 **	-2.50
4.	1×5	-0.81	-1.61	0.00	-0.83	-7.03 **	-0.83
5.	1×6	-6.50 **	-7.26 **	-5.74 **	0.83	-5.47 *	0.83
6.	1×7	-4.09	-4.87	-4.16	-4.83	-5.6	-1.86
7.	1×8	0.81	0.00	1.64	-1.63	-5.47 *	0.83
8.	2×3	0.00	-3.23	-1.64	-4.69 *	-4.69 *	1.67
9.	2×4	5.31 *	-4.03 *	-2.46	-4.69 *	-4.69 *	1.67
10.	2×5	3.54	-5.65 **	-4.10 *	-7.81 **	-7.81 **	-1.67
11.	2×6	-0.88	-9.68 **	-8.20 **	-5.47 *	-5.47 *	0.83
12.	2×7	-5.73	-6.50	-5.79	-5.64	-6.4	-2.69
13.	2×8	0.83	-2.42	-0.82	-7.03 **	-7.03 **	-0.83
14.	3×4	-6.14 **	-12.10 **	-10.66 **	2.42	-0.78	5.83 *
15.	3×5	-1.67	-4.84 *	-3.28	-4.03	-7.03 **	-0.83
16.	3×6	-3.33	-6.45 **	-4.92 *	0.81	-2.34	4.17
17.	3×7	-9.17 **	-14.52 **	-13.11 **	-7.89 **	-10.94 **	-5.00 *
18.	3×8	1.67	-1.61	0.00	0.00	-3.13	3.33
19.	4×5	-1.77	-10.48 **	-9.02 **	-4.07	-7.81 **	-1.67
20.	4×6	-6.19 **	-6.55 **	-7.31**	-7.32 **	-4.03	-4.08
21.	4×7	-4.91	-5.69	-4.98	-6.45	-7.02	-3.52
22.	4×8	-1.67	-4.84 *	-3.28	-2.44	-6.25 **	0.00
23.	5×6	-0.88	-9.68 **	-8.20 **	-0.85	-8.59 **	-2.50
24.	5×7	-3.27	-4.06	-3.34	-6.45	-7.2	-3.52
25.	5×8	5.00 *	1.61	3.28	-5.69 *	-9.38 **	-3.33

26.	6×7	0.81	0.81	2.46	-0.82	-5.47 *	0.83
27.	6×8	3.33	0.00	1.64	-2.44	-6.25 **	0.00
28.	7×8	0.00	0.00	1.64	0.00	-3.91	2.50
S.E.±		1.165	1.165	1.165	1.311	1.311	1.311
C.D. @ 5%		2.365	2.365	2.365	2.661	2.661	2.661
C.D. @ 1%		3.137	3.137	3.137	3.571	3.571	3.571

* and ** significant at 5% and 1% level

Table 3: Heterosis (%) over mid parent, better parent and standard hybrid check in 8×8 half diallel of days to first harvest in bitter gourd

Sr. No.	Crosses	Day to first harvest					
		summer			*kharif*		
		M.P.	B.P.	S.C.	M.P.	B.P.	S.C.
1.	1×2	-2.14	-2.99*	-4.11**	1.04	-0.48	2.15
2.	1×3	-3.55**	-4.33**	-5.55**	5.56**	5.18**	3.41
3.	1×4	-1.16	-2.57	-2.57	2.94	2.00	3.92
4.	1×5	-4.45**	-5.56**	-6.09**	3.64*	2.94	4.96*
5.	1×6	-6.88**	-4.12**	-7.81**	5.30**	4.34*	1.55
6.	1×7	-0.68	-3.39*	-6.16**	8.13**	6.64**	0.10
7.	1×8	-2.53*	-4.69**	-7.42**	3.50*	1.49	4.51*
8.	2×3	-5.58**	-5.64**	-6.72**	1.51	0.33	-0.65
9.	2×4	-7.44**	-7.97**	-7.97**	2.33	-0.13	-2.88
10.	2×5	-6.60**	-6.88**	-7.40**	-0.88	-1.72	6.63**
11.	2×6	-6.83**	-7.76**	-6.96**	3.42*	0.94	-0.39
12.	2×7	-2.15	-5.62**	-6.70**	4.70**	4.56**	-2.44
13.	2×8	-3.68**	-6.61**	-7.68**	-1.04	-1.49	-0.22
14.	3×4	-0.61	-1.24	-1.24	5.16**	3.83*	3.67
15.	3×5	-0.41	-0.76	-1.32	3.27*	2.93	4.45*
16.	3×6	-2.54*	-3.57**	-2.74*	5.70**	4.36*	1.93
17.	3×7	-7.88**	-8.61**	-9.54**	2.24	1.18	-1.54
18.	3×8	1.76	-1.28	-2.53	0.71	-0.91	2.51
19.	4×5	-6.99**	-7.25**	-7.25**	6.84**	5.15**	2.37
20.	4×6	-2.69*	-3.11*	-2.27	6.00**	6.00**	-0.03
21.	4×7	-3.21**	-7.16**	-7.16**	6.10**	3.96*	-1.24
22.	4×8	0.05	-3.53**	-3.53**	2.87	-0.04	4.89*
23.	5×6	-6.95**	-7.60**	-6.80**	3.11*	1.48	-0.01
24.	5×7	-2.48*	-6.21**	-6.73**	1.63	0.90	1.96
25.	5×8	-4.07**	-7.26**	-7.78**	-0.74	-2.03	2.61
26.	6×7	2.15	-2.42	-1.58	3.89*	1.53	5.17*
27.	6×8	0.34	-3.65**	-2.82*	3.90*	0.96	4.27*
28.	7×8	-1.60	-2.12	-9.13**	4.18**	3.57*	-0.16
S.E.±		0.77	0.89	0.89	1.14	1.31	1.31
C.D.@ 5%		1.56	1.80	1.80	2.31	2.67	2.67
C.D. @ 1%		2.10	2.42	2.42	3.10	3.58	3.58

* and ** significant at 5% and 1% level

Conclusions

In the present study it can be concluded that the cross combinations 3 × 7, 4 × 7, 2 × 7, 1 × 7 displayed the significant heterosis for most of the traits. Significant negative heterosis for fruit fly infestation, Days to 50 per cent flowering and days to first harvest.

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