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Estimation of heterosis in ridge gourd [*Luffa acutangula* (L.) Roxb.]

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Abstract
The present investigation was carried out to investigate the magnitude of heterosis in 21 F_1 hybrids of Ridge gourd for earliness, growth, yield attributing and quality traits during 2021-22. These 21 hybrids are obtained by crossing seven diverse lines in diallel mating design excluding reciprocal. The best heterotic cross for fruit yield per plant was GLC-1 × GLC-3. The high magnitude of heterosis observed in this hybrid for fruit yield can be attributed to significant standard heterosis and heterobeltiosis in desirable direction for yield attributing traits *viz.*, vine length, fruit weight and fruits per plant. This cross also exhibited significant heterosis for days to first female flower, days to marketable maturity, 100 seed weight and crude fibre. The second-best hybrid GLC-1 × GLC-6 for fruit yield per plant also showed significant heterosis in the desirable direction for fruit weight, fruits per plant, Days to marketable maturity and crude fibre.

Keywords: Ridge gourd, Heterosis, fruit yield per plant, Diallel

Introduction
Ridge gourd [*Luffa acutangula* (L.) Roxb.] is a popular spring, summer and rainy season vegetable crop which belongs to the genus *Luffa* of the *Cucurbitaceae* family and has chromosome number 2n = 26 the genus derived its name from the product "loofah" meaning the sponge. It may have originated from Asian subtropical areas, probably from India. It is popularly known as Kalitori, angled loofah, angled gourd, ribbed gourd, Chinese okra, silky gourd and "Turia" in Gujarati.

It is cultivated in the tropics for its tender edible fruits both on a commercial scale and small scale for household consumption throughout India. Fruit is club-shaped, angled with prominent ridges and multiple seeded. It becomes hard, rigid and inedible on maturity. Seeds are generally black, flattened and wrinkled. One thousand seeds weigh about 150 to 170 g (Doijode, 2002) [2].

The crop is economically and medicinally important and has immense potential for improvement. Being predominantly monoecious, ridge gourd is a cross-pollinated crop and thus provides ample scope for exploitation of the hybrid vigour. Single fruit gives many seeds and the cost of production of F_1 seeds is not high in comparison to the other vegetables. Hence, speedy improvement can be brought about by assessing and exploiting the genetic variability. To make an effective improvement in the characteristics related to earliness and yield-related traits, F_1 hybrid breeding is prominent among the methods used in the improvement of ridge gourd. Hybrids under optimum crop production and protection management give economically more yield than that of improved varieties. In ridge gourd, there are fewer F_1 hybrids available in the public sector to date for commercial cultivation. Owing to the existence of large variability, it is considered worthwhile to take up the present investigation to make heterosis with the variable germplasm by adopting the half diallel method.

Materials and Methods
This investigation was carried out at Navsari Agricultural University, Navsari in *late Kharif* 2021-22. The experimental material was composed of seven diverse parental lines *viz.*, GLC-5, GLC-1, GLC-3, GLC-6, Jaipuri, JL-7 and JVRS -2 which crossed in diallel mating design to develop 21 hybrids. The resulting hybrids along with their parents and one check GARG-1 (total 29) were grown under randomized block design (RBD) with three replications. The spacing of 2.0 m between rows and 0.6 m between plants was maintained.

Observations were recorded from five randomly selected plants in each replication on fifteen characters *viz*., days to the first female flower, days to first male flower, node number of first female flower, node number of first male flower, vine length (m), fruit length (cm), fruit girth (cm), fruit weight (gm), fruits per plant, fruit yield per plant (kg), days to marketable maturity, 100 seed weight (g), crude fibre (g/100g), moisture content (%) and total soluble sugar (g/100g). These characters were subjected to statistical analysis to derive information on Heterobeltiosis (HB) and standard heterosis (SH). The analysis of variance was carried out for randomized block design as per the procedure described by Panse and Sukhatme (1967) [6]. Heterobeltiosis and economic heterosis were calculated according to the method suggested by Shull (1908) [9] and Fonseca and Patterson (1968) [3], respectively.

Results and Discussion

The analysis of variance for experimental design revealed that the mean squares due to genotypes, due to various genotypes were highly significant for all the characters in the study while highly significant differences were observed among parents for all characters except for node number of first male flower, fruits per plant, fruit yield per plant (kg) and among hybrids except for moisture (%) this indicating higher genetic diversity present in the genotype studied.

Earliness is a useful character in ridge gourd for realizing the potential economic yield in a short time. The characters like days to anthesis of first female and male flower, node to first female and male flower and days to first harvest are considered as criteria for earliness and for these traits heterosis is desirable in the negative direction. In this study, the cross JL-7 × JVRS-12 (-17.01%) for days to first female flower, GLC-5 × JVRS-12 and JL-7 × JVRS-12 (-15.32%) for days to first male flower showed highest significant negative heterosis. Significant negative heterosis was shown by six and two hybrids for these two characters, respectively. Similar results were also reported by Narasannavar *et al.* (2014) [4] and Chittora *et al.* (2018) [1] in ridge gourd. For node number of the first female flower GLC-3 × Jaipuri (-15.32%) and node number of the first male flower GLC-1 × Jaipuri (-24.14) exhibited the highest significant negative heterosis, for this trait two hybrids showed significant negative standard heterosis. In the case of days to marketable maturity, cross GLC-5 × JL-7 (-17.26%) exhibited maximum significant negative heterosis. At the same time, ten hybrids showed significant standard heterosis for this trait. In comparison, cross JL-7 × JVRS-12 (-7.50%) exhibited the highest significant heterobeltiosis these results agree with Sarkar *et al.* (2015) [15] and Chittora *et al.* (2018) [1] in ridge gourd.

In this study out of 21 crosses, three crosses showed significant positive heterosis over the standard check for vine length (m) and the best cross was GLC-1 × GLC-3 (36.51. For fruit length (cm) GLC-6 × Jaipuri (23.326) showed maximum heterosis, two hybrids showed significant heterosis over the standard check, while none of the hybrids showed significant heterobeltiosis for this trait. For fruit girth (cm) from 21 hybrids, 3 hybrids expressed significant and positive standard heterosis, the best cross was GLC-3 × JVRS-12 (18.82%), while two crosses exhibited significant positive heterobeltiosis and the best cross was JL-7 × JVRS-12 (10.00%). The highest value of significant standard heterosis and heterobeltiosis for fruit weight (g) was showed by GLC-3 × JVRS-12 (27.23%) and GLC-3 × Jaipuri (34.28%), respectively. While, 4 crosses over the standard check and 5 crosses over better parent exhibited significant estimates of heterosis in a positive direction (Table 2). Similar findings were reported by Narasannavar *et al.* (2018) [5] and Chittora *et al.* (2018) [1] in ridge gourd.

In this study, positive significant heterosis for the number of fruits per plant was depicted by 3 crosses over the better parent and seven crosses over the standard check. Maximum positive standard heterosis and heterobeltiosis for this trait were observed in GLC-1 × GLC-3 (33.32% and 58.26%, respectively). Similar findings were reported by Narasannnavar *et al.* (2018) [5] and Varalakhsmi *et al.* (2019) [10]. For 100 seed weight (g), five and seven crosses showed positive significant heterosis over better parent and standard check, respectively. The best cross was GLC-3 × GLC-6 (39.93%) and GLC-5 × GLC-6 (40.04%), respectively.

Higher yield is the ultimate goal of any plant breeding programme. In this study significant standard heterosis and heterobeltiosis were manifested by only one hybrid GLC-1 × GLC-3 (84.74% and 52.63%, respectively), significant amount of heterosis for this trait was also reported by Sarkar and Singh (2017) [7] and Chittora *et al.* (2018) [1].

Crude fiber (g/100g), total soluble sugar (g/100g) and moisture content (%) are the important quality parameters of fruits and except for crude fibre positive direction of heterosis would be desirable. In the case of crude fibre negative heterosis was desirable, negative significant heterosis was observed in 19 hybrids over the standard check and 8 hybrids over the better parent. The highest negative values were shown by GLC-3 × GLC-6 (-80.28%) and GLC-3 × Jaipuri. For total soluble sugar, significant standard heterosis and heterobeltiosis were expressed by six crosses, best cross was JL-7 × JVRS-12 (140.77%) for heterobeltiosis and GLC-5 × GLC-6 (64.70%) for standard heterosis. None of the hybrids showed positive significant heterobeltiosis for moisture content.

Among all crosses, for earliness traits, JL-7 × JVRS-12 had the lowest standard heterosis for days to first female flower, days to first male flower and node number of first female flower and GLC-5 × JL-7 had the lowest heterosis for days to marketable maturity. Hybrid GLC-3 × Jaipuri manifested the lowest heterosis for crude fibre while, GLC-6 × Jaipuri had maximum heterosis for fruit length, GLC-3 × JVRS-12 for fruit weight, GLC-5 × GLC-6 had the highest heterosis for 100 seed weight and total soluble sugar. These cross combinations could be recommended to be utilized in the heterosis breeding programme of ridge gourd for their commercial exploitation as hybrids.

Table 1: Estimates of heterobeltiosis and standard heterosis for various traits in ridge gourd

Sr. No.	Crosses	Days to first female flower		Days to first male flower		Node number of first female flower		Node number of first male flower		Vine length (m)	
		HB (%)	SH (%)	HB (%)	SH (%)	HB (%)	SH (%)	HB (%)	SH (%)	HB (%)	SH (%)
1.	GLC-5 × GLC-1	44.23**	2.04	44.44**	25.81**	44.44**	25.81**	-7.84	-18.97	-71.95**	-48.01*
2.	GLC-5 × GLC-3	19.23	-15.65*	0.86	-5.65	0.86	-5.65	-11.76	-22.41	-19.92*	6.87
3.	GLC-5 × GLC-6	29.81**	-8.16	-4.96	-7.26	-4.96	-7.26	4.55	-20.69	-29.52*	-22.44
4.	GLC-5 × Jaipuri	49.04**	5.44	17.36**	14.52*	17.36**	14.52*	-1.89	-10.34	-1.69	0.18
5.	GLC-5 × JL-7	23.08*	-12.93	-0.86	-7.26	-0.86	-7.26	4.59	-1.72	36.45*	6.42
6.	GLC-5 × JVRS-12	20.19*	-14.97*	-13.22*	-15.32*	-13.22*	-15.32*	39.22	22.41	15.56	21.97
7.	GLC-1 × GLC-3	5.04	-14.97*	2.78	-10.48	2.78	-10.48	25.49	10.34	-26.35**	36.51**
8.	GLC-1 × GLC-6	11.76	-9.52	10.19	-4.03	10.19	-4.03	18.18	-10.34	-57.72**	-21.63
9.	GLC-1 × Jaipuri	22.69*	-0.68	24.07**	8.06	24.07**	8.06	-13.73	-24.14	-45.25**	1.48
10.	GLC-1 × JL-7	9.24	-11.56	2.78	-10.48	2.78	-10.48	-5.88	-17.24	-43.21**	5.26
11.	GLC-1 × JVRS-12	12.61	-8.84	13.89	-0.81	13.89	-0.81	9.80	-3.45	-54.60**	-15.86
12.	GLC-3 × GLC-6	-3.88	-15.65*	-3.45	-9.68	-3.45	-9.68	31.82	0.00	-36.36**	-15.06
13.	GLC-3 × Jaipuri	-3.10	-14.97*	5.17	-1.61	5.17	-1.61	5.88	-6.90	0.49	34.10**
14.	GLC-3 × JL-7	-0.78	-12.93	-0.86	-7.26	-0.86	-7.26	19.61	5.17	-17.45	10.16
15.	GLC-3 × JVRS-12	-1.55	-13.61	0.00	-6.45	0.00	-6.45	15.69	1.72	-1.22	31.83*
16.	GLC-6 × Jaipuri	-0.69	-2.72	5.79	3.23	5.79	3.23	29.55	-1.72	-19.36	-11.27
17.	GLC-6 × JL-7	15.33*	7.48	19.83**	12.10	19.83**	12.10	31.82	0.00	-30.47**	-23.49
18.	GLC-6 × JVRS-12	3.47	1.36	2.48	0.00	2.48	0.00	34.09	1.72	-3.89	5.75
19.	Jaipuri × JL-7	7.30	0.00	16.38*	8.87	16.38*	8.87	9.43	0.00	-20.89	-19.39
20.	Jaipuri × JVRS-12	-8.44	-4.08	-11.68	-2.42	-11.68*	-2.42	5.88	-6.90	-29.40*	-25.48*
21.	JL-7 × JVRS-12	-10.95	-17.01*	-9.48	-15.32*	-9.48	-15.32*	37.25	20.69	-21.62	-17.27
S.Ed.		3.53	3.53	2.65	2.65	2.65	2.65	0.41	0.41	0.41	0.48
CD 5%		7.08	7.08	5.31	5.31	5.31	5.31	0.83	0.83	0.83	0.96
CD 1%		9.42	9.42	7.07	7.07	7.07	7.07	1.10	1.10	1.10	1.28
Range		-10.95 to 49.04	-17.01 to 7.48	-13.22 to 44.44	-15.32 to 25.81	-13.22 to 44.44	-15.32 to 25.81	-13.73 to 39.22	-24.14 to 22.41	-71.95 to 36.45	-48.01 to 36.51

*, ** Significant at 5% and 1% levels, respectively. HB- Heterobeltiosis, SH- Standard Heterosis

Table 2: Estimates of heterobeltiosis and standard heterosis for various traits in ridge gourd

Sr. No.	Crosses	Fruit length (cm)		Fruit girth (cm)		Fruit weight (g)		Fruits per plant		Fruit yield per plant (kg)	
		HB (%)	SH (%)	HB (%)	SH (%)	HB (%)	SH (%)	HB (%)	SH (%)	HB (%)	SH (%)
1.	GLC-5 × GLC-1	-26.82**	-8.86	-14.67**	-13.98**	-45.04**	-41.16**	1.26	18.22	-32.52*	-18.32
2.	GLC-5 × GLC-3	-3.12	20.67	-3.93	6.99*	18.84**	27.23**	-31.25**	-18.45	5.09	15.15
3.	GLC-5 × GLC-6	-4.11	19.43	3.47	12.37**	11.03*	18.87**	-43.63**	-24.65	-17.99	-10.44
4.	GLC-5 × Jaipuri	-27.76**	-10.03	1.60	2.69	-53.15**	-49.85**	5.68	26.08*	-23.92	-16.91
5.	GLC-5 × JL-7	-38.34**	-23.20*	3.47	4.30	-29.01**	-24.00**	8.33	10.33	2.97	12.45
6.	GLC-5 × JVRS-12	-28.48**	-10.93	-6.32	-4.30	-28.57**	-23.53**	26.01*	36.17**	5.77	15.51
7.	GLC-1 × GLC-3	-7.33	7.57	-14.07**	-4.30	-21.09**	-18.79**	33.42**	58.26**	52.62**	84.74**
8.	GLC-1 × GLC-6	-3.23	12.32	-13.86**	-6.45	-17.94**	-15.55**	-4.16	28.11**	1.99	23.46
9.	GLC-1 × Jaipuri	4.11	20.84	-8.51**	-7.53*	4.26	7.30	-14.88	1.54	-3.69	16.59
10.	GLC-1 × JL-7	5.72	22.72*	-3.93	-5.38	-16.34**	-13.90*	8.68	26.89*	-0.36	20.61
11.	GLC-1 × JVRS-12	-3.17	12.40	0.53	2.69	-22.35**	-20.09**	24.19*	45.00**	-3.51	16.80
12.	GLC-3 × GLC-6	15.64	18.53	-6.35*	4.30	-4.40	-12.40*	-1.26	31.99*	4.57	14.58
13.	GLC-3 × Jaipuri	9.80	4.24	-4.90	5.91	34.28**	23.03**	-21.36	-6.19	5.80	15.92
14.	GLC-3 × JL-7	-13.01	-6.51	-5.38	5.38	-5.62	-7.64	4.17	23.57	4.56	14.57
15.	GLC-3 × JVRS-12	22.85	16.62	6.69*	18.82**	31.52**	20.51**	-26.48*	-12.78	3.02	12.88
16.	GLC-6 × Jaipuri	20.35	23.36*	-4.46	3.76	14.74*	-7.38	-15.27	13.25	-1.83	6.30
17.	GLC-6 × JL-7	5.12	12.97	-1.98	6.45	-8.67	-10.62	-9.72	20.67	6.55	15.37
18.	GLC-6 × JVRS-12	11.74	14.54	-3.47	4.84	4.27	-8.70	-23.61*	2.11	-7.21	0.47
19.	Jaipuri × JL-7	2.34	9.98	2.13	3.23	-1.71	-3.81	-17.66	-1.76	7.23	5.61
20.	Jaipuri × JVRS-12	6.15	-1.38	-8.42**	-6.45	0.34	-12.13*	-9.41	8.08	-1.45	-4.93
21.	JL-7 × JVRS-12	-16.54	-10.32	10.00**	12.37**	2.40	0.21	-0.51	7.52	9.62	7.97
S.Ed.		2.36	2.36	0.44	0.44	5.92	5.92	1.15	1.15	0.17	0.17
CD 5%		4.72	4.72	0.88	0.88	11.85	11.85	2.30	2.30	0.33	0.33
CD 1%		6.28	6.28	1.17	1.17	15.78	15.78	3.06	3.06	0.44	0.44
Range		-38.34 to 22.85	-23.20 to 23.36	-14.67 to 10.00	-13.98 to 18.82	-53.15 to 34.28	-49.85 to 27.23	-43.63 to 33.42	-24.65 to 58.26	-32.52 to 52.62	-18.32 to 84.74

*, ** Significant at 5% and 1% levels, respectively. HB- Heterobeltiosis, SH- Standard Heterosis

Table 3: Estimates of heterobeltiosis and standard heterosis for various traits in ridge gourd

Sr. No.	Crosses	Days to marketable maturity		100 seed weight (g)		Crude fibre (g/100g)		Moisture (%)		Total soluble sugar	
		HB (%)	SH (%)	HB (%)	SH (%)	HB (%)	SH (%)	HB (%)	SH (%)	HB (%)	SH (%)
1.	GLC-5 × GLC-1	30.53**	1.79	-16.17**	9.26	-12.41	-28.81**	-1.53	-1.96*	-54.87**	-56.94**
2.	GLC-5 × GLC-3	9.92	-14.29**	-12.81**	13.63**	-53.54**	-51.71**	0.56	-1.31	27.50**	30.98**
3.	GLC-5 × GLC-6	18.32**	-7.74	7.45*	40.04**	-6.41	-1.52	0.62	-1.25	6.15	64.70**
4.	GLC-5 × Jaipuri	33.59**	4.17	-30.37**	-9.25	-16.44*	-34.87**	0.56	-0.29	-41.30**	-44.00**
5.	GLC-5 × JL-7	6.11	-17.26**	-2.18	27.48**	-61.48**	-69.98**	-0.82	-0.85	0.56	-4.06
6.	GLC-5 × JVRS-12	7.63	-16.07**	-21.41**	2.43	-24.12**	-40.86**	1.32	-0.56	34.64**	28.45**
7.	GLC-1 × GLC-3	-2.78	-16.67**	33.17**	26.13**	-44.71**	-42.53**	0.01	-0.43	-42.41**	-40.84**
8.	GLC-1 × GLC-6	3.42	-10.12*	3.69	-1.80	-28.60**	-24.87**	0.39	-0.05	-55.57**	-31.07**
9.	GLC-1 × Jaipuri	16.44**	1.19	-13.06**	-11.31*	-62.87**	-69.83**	1.06	0.62	8.09	-4.64
10.	GLC-1 × JL-7	0.68	-12.50**	-14.50**	-7.90	-25.75**	-39.65**	-0.02	-0.05	34.89**	13.77**
11.	GLC-1 × JVRS-12	5.48	-8.33	-13.37**	-17.95**	8.40	-11.90*	-1.26	-1.70	-41.91**	-51.01**
12.	GLC-3 × GLC-6	-2.08	-16.07**	39.93**	21.40**	-81.05**	-80.06**	-0.56	-2.54**	-56.07**	-31.83**
13.	GLC-3 × Jaipuri	-1.39	-15.48**	-20.14**	-18.52**	-83.88**	-83.24**	0.28	-0.57	-46.29**	-44.82**
14.	GLC-3 × JL-7	3.47	-11.31*	-4.89	2.44	-77.32**	-76.42**	-0.35	-0.38	-25.35**	-23.31**
15.	GLC-3 × JVRS-12	0.69	-13.69**	9.07	-5.38	-66.45**	-65.13**	1.76	-0.44	-46.13**	-44.66**
16.	GLC-6 × Jaipuri	0.61	-1.19	-29.01**	-27.57**	-39.34**	-36.16**	-0.69	-1.52	-78.32**	-66.36**
17.	GLC-6 × JL-7	7.50	2.38	8.89*	17.28**	-36.02**	-32.68**	0.31	0.28	-85.02**	-76.76**
18.	GLC-6 × JVRS-12	5.45	3.57	34.25**	8.37	-74.71**	-73.39**	1.61	-0.41	-68.87**	-51.70**
19.	Jaipuri × JL-7	7.50	2.38	-3.93	3.48	-32.73**	-54.66**	-0.87	-0.90	15.21*	1.64
20.	Jaipuri × JVRS-12	-6.94	-4.17	8.15	10.33*	-4.39	-35.56**	0.14	-0.70	42.29**	25.53**
21.	JL-7 × JVRS-12	-7.50	-11.90*	1.15	8.95	128.42**	13.95**	0.05	0.02	140.77**	35.31**
S.Ed.		2.64	2.64	0.64	0.64	0.13	0.13	0.87	0.87	0.11	0.11
CD 5%		5.29	5.29	1.27	1.27	0.26	0.26	1.75	1.75	0.23	0.23
CD 1%		7.05	7.05	1.70	1.70	0.35	0.35	2.33	2.33	0.30	0.30
Range		-7.50 to 33.59	-17.50 to 4.17	-30.37 to 39.93	-27.57 to 40.04	-83.88 to 128.42	-83.24 to 13.95	-1.53 to 1.76	-2.54 to 0.62	-85.02 to 140.77	-76.76 to 64.70

*, ** Significant at 5% and 1% levels, respectively. HB- Heterobeltiosis, SH- Standard Heterosis

Conclusion

The best heterotic cross for fruit yield per plant was GLC-1 × GLC-3 High magnitude of heterosis observed in this hybrid for fruit yield can be attributed to significant standard heterosis and heterobeltiosis in desirable direction for yield attributing traits *viz.*, vine length, fruit weight and fruits per plant. This cross also exhibited significant heterosis for days to first female flower, days to marketable maturity, 100 seed weight and crude fiber. Second-best hybrid GLC-1 × GLC-6 for fruit yield per plant also shows significant heterosis in desirable direction for fruit weight, fruits per plant, days to marketable maturity, crude fiber and total soluble sugar.

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