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Patel AN
Department of Horticulture, College of Agriculture Junagadh Agricultural University, Junagadh, Gujarat, India

Vaddoria MA
Department of Horticulture, College of Agriculture Junagadh Agricultural University, Junagadh, Gujarat, India

Mehta DR
Department of Horticulture, College of Agriculture Junagadh Agricultural University, Junagadh, Gujarat, India

Corresponding Author:
Patel AN
Department of Horticulture, College of Agriculture Junagadh Agricultural University, Junagadh, Gujarat, India

Exploitation of hybrid vigour for fruit yield and its components in okra [*Abelmoschus esculentus* (L.) Moench]

Patel AN, Vaddoria MA and Mehta DR

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Abstract
The present investigation on “Exploitation of hybrid vigour for fruit yield and its components in okra [*Abelmoschus esculentus* (L.) Moench]” was conducted at the Vegetable Research Station, Junagadh Agricultural University, Junagadh during summer 2018. The experimental material comprised of 16 parents (12 lines and 4 testers) to develop 48 hybrids using line x tester mating design. The final evaluation trial was conducted with 16 patents, their 48 F_1 hybrids along with one commercial check (GJOH-4) in a randomized block design (RBD) with three replications. On considering the performance of hybrids in respect of fruit yield per plant, 4 and 3 hybrids exhibited significant and positive heterosis over better parent and standard check, respectively. Significant and positive estimates of heterobeltiosis and standard heterosis for fruit yield per plant were exhibited by the crosses IC-282248 x GAO-5 (33.77%, 24.67%), IC-282248 x Pusa Sawani (22.84%, 14.30%) and IC-31398 x GO-2 (17.30%, 13.14%), respectively and could be utilized for commercial exploitation of heterosis after large scale multilocation testing. The heterosis for fruit yield per plant was also associated with the heterosis expressed by its component characters.

Keywords: Okra, heterobeltiosis and standard heterosis

Introduction
Vegetables are increasingly becoming important as produce for domestic and export markets. Okra is an important vegetable crop grown for its green tender fruits in tropical and sub-tropical regions. It is more remunerative than the leafy vegetables. Its green tender fruits are used as vegetable and generally marketed in fresh form. It is also available in dehydrated and canned forms.

Exploitation of heterosis in okra has been recognized as a practical tool for improving fruit yield and other important traits. For developing promising varieties through hybridization, the choice of parents is a matter of great concern to the plant breeders. Several reports on heterosis for fruit yield and its attributes have enhanced the scope for commercial utilization of heterosis in okra as emasculation and pollination events are easier due to large flower and Monadelphous stamens (Sprague and Tatum, 1942) [12]. Today hybrids are gaining popularity due to their high productivity, better quality, uniform product and adaptation in to varying environmental condition. In okra, several researchers have already reported the presence of significant and high heterosis for fruit yield and its components. Heterosis of small amount for individual yield contributing traits may have an additive or synergistic effect on the end product. Hence, the present study was undertaken with a view to find out heterotic combinations for fruit yield and its components in okra.

Materials and Methods
The experimental material comprised of 16 parents (12 lines + 4 testers) to develop 48 F_1 crosses through line x tester mating design. The field experiment was carried out at Vegetable Research Station, Junagadh Agricultural University, Junagadh during summer 2018 in a randomized block design with three replications involving 16 parents (12 lines + 4 testers) and their 48 cross combinations along with one standard check (GJOH-4). Each entry was accommodated with two rows/plot of twenty plants, spaced at 45 x 20 cm. The recommended plant protections and other cultural practices were followed to maintain uniform experimental

conditions. The observations were recorded on fruit weight (g), fruit length (cm), fruit girth (cm), number of fruits per plant, number of marketable fruits per plant and fruit yield per plant (g). The mean values were used for estimation of heterosis over better parent and standard check as per the standard procedure.

Results and Discussion

The analysis of variance was performed to test the differences among parents and their hybrids for all the six characters is presented in Table 1. The results revealed that the mean squares due to genotypes were significant for all the characters indicating the considerable amount of genetic variability present among genotypes for various characters. The mean squares due to genotypes were further partitioned into parents, hybrids and parent *vs*. hybrid. The differences among parents were significant for all the characters. The mean squares due to hybrids were found significant for all the characters. Parents *vs*. hybrids comparison was found significant for fruit weight (g), fruit girth (cm) and fruit yield per plant (g) indicated that the performance of hybrids was different from that of parents, thereby supporting the presence of substantial amount of heterosis for these traits.

The details on range of heterobeltiosis and standard heterosis as well as number of hybrids having significant heterosis are presented in Table 2.

Heterobeltiosis and standard heterosis for fruit weight varied from -31.35 (EC-305623 x GJO-3) to 47.08% (IC-282248 x GAO-5) and -19.91 (EC-305623 x GJO-3) to 53.24% (IC-90117 x GJO-3), respectively. Among 48 hybrids, 10 and 21 hybrids recorded significant and positive heterosis over better parent and standard check, respectively.

The spectrum of variation for heterobeltiosis and standard heterosis for fruit length ranged from -31.65 (EC-30563 x GAO-5) to 10.10% (IC-052273 x GAO-5) and -28.46 (IC-2911B x GO-2) to 9.31% (IC-052273 x GO-2), respectively.

The range of heterobeltiosis and standard heterosis for fruit girth was noted from -15.53 (IC-31398 x GAO-5) to 19.29% (IC-282248 x GO-2) and -17.88 (IC-2911B x GO-2 and IC-89819 x Pusa Sawani) to 3.03% (EC-305623 x Pusa Sawani), respectively. Among 48 hybrids, only one hybrid showed significant and positive heterosis over better parent.

The quantum of heterobeltiosis for number of fruits per plant and number of marketable fruits per plant ranged from -55.14 (IC-90117 x GJO-3) to 31.70% (IC-282248 x Pusa Sawani) and -55.82 (IC-90117 x GJO-3) to 33.81% (IC-282248 x Pusa Sawani), respectively. While the estimate of standard heterosis for number of fruits per plant and number of marketable fruits per plant varied from -63.55 (EC-305623 x GO-2) to -8.16% (IC-90117 x GO-2) and -64.10 (IC-90117 x GJO-3) to -7.94% (IC-90117 x GO-2), respectively. Out of 48 crosses, 9 and 10 hybrids recorded significant and positive heterosis over better parent for number of fruits per plant and number of marketable fruits per plant, respectively. While none of the cross combinations was found significant and positive over standard check for number of fruits per plant and number of marketable fruits per plant.

The fruit yield per plant is an attribute of economic importance which the plant breeders attempt to improve by evolving new high yielding hybrids. The heterobeltiosis and standard heterosis ranged from -39.08 (IC-111493 x GJO-3) to 33.77% (IC-282248 x GAO-5) and -37.80 (IC-111493 x GJO-3) to 24.67% (IC-282248 x GAO-5), respectively. Out of 48 crosses, 4 and 3 hybrids recorded significant and positive heterosis over better parent and standard check, respectively. High heterosis for fruit yield per plant in okra has been reported by several workers (Reddy *et al*. 2012a, Gajera and Vaddoria 2014, Nagesh *et al*. 2014, Tiwari *et al*. 2015, Bhatt *et al*. 2016, Kumar and Reddy *et al*. 2016, Paul *et al*. 2017a, Punia *et al*. 2017, Gavint *et al*. 2018 and Prakash *et al*. 2019) [9, 2, 5, 13, 1, 4, 6, 8, 3].

The results indicated that in different crosses, pathway for releasing heterotic effects varied from cross to cross. It also revealed that number of fruits per plant, fruit weight, fruit length and fruit girth were the main contributors towards increased fruit yield. The similar results have been reported in okra by Reddy *et al.* (2012a) [9], Reddy *et al.* (2013b) [10], Solankey *et al.* (2013) [11], Gajera and Vaddoria (2014) [2], Nagesh *et al.* (2014) [5], Tiwari *et al.* (2015) [13], Bhatt *et al.* (2016) [1], Kumar and Reddy *et al.* (2016) [4], Paul *et al.* (2017a) [6], Punia *et al.* (2017) [8], Gavint *et al.* (2018) [3] and Prakash *et al.* (2019).

Table 1: Analysis of variance for experimental design in okra

Source of variation	d.f.	Fruit weight (g)	Fruit length (cm)	Fruit girth (cm)	Number of fruits per plant	Number of marketable fruits per plant	Fruit yield per plant
Replications	2	2.20**	2.02*	0.04	46.08**	45.45**	492.04*
Genotypes	63	5.00**	1.53**	0.20**	36.01**	32.80**	795.80**
Parents	15	1.20**	2.56**	0.32**	36.13**	35.20**	1278.78**
Hybrids	47	6.29**	1.22**	0.15**	36.56**	32.59**	637.91**
Parent *vs*. Hybrid	1	1.09*	0.59	1.00**	8.39	6.44	972.14*
Error	126	0.26	0.54	0.04	3.98	3.25	142.51

*, ** Significant at P=0.01 and P=0.05, respectively

Table 2: Estimation of heterobeltiosis (H_1) and standard heterosis (H_2) percentage for fruit weight (g), fruit length (cm), fruit girth (cm), number of fruits per plant, number of marketable fruits per plant and fruit yield per plant (g) in okra

Hybrids	Fruit weight (g)		Fruit length (cm)		Fruit girth(cm)		Number of fruits per plant		Number of marketable fruits per plant		Fruit yield per plant (g)	
	H_1	H_2	H_1	H_2	H_1	H_2	H_1	H_2	H_1	H_2	H_1	H_2
1	2	3	4	5	6	7	8	9	10	11	12	13
IC-99716 x GO-2	6.59	34.72**	-7.81	-3.69	3.87	-6.36	-16.84**	-52.08**	-14.98*	-51.34**	4.11	0.42
IC-99716 x GJO-3	15.75**	46.30**	-0.40	-4.23	3.16	-1.06	-5.10	-53.90**	-2.81	-52.99**	6.77	5.62
IC-99716 x GAO-5	-29.67**	-11.11	-3.31	-5.77	-10.81	-11.21	-16.96**	-35.48**	-19.09**	-34.71**	-4.03	-10.56
IC-99716 x Pusa Sawani	-13.57**	12.04	-9.19	-6.54	-6.73	-9.70	15.42*	-45.43**	16.83*	-45.03**	0.23	-6.74
IC-2911B x GO-2	-23.65**	-14.81*	-31.52**	-28.46**	-4.07	-17.88**	28.21**	-24.57**	31.48**	-24.67**	1.91	-1.71
IC-2911B x GJO-3	-13.69*	-3.70	-5.00	-7.92	1.74	-2.42	11.01	-34.70**	13.69*	-34.86**	-2.42	-3.48
IC-2911B x GAO-5	-12.45*	-2.31	-1.58	-4.08	-3.04	-3.48	-2.27	-24.06**	-4.53	-22.96**	0.33	-5.85

IC-2911B x Pusa Sawani	-5.71	22.22**	2.24	5.23	-6.57	-9.55	-25.01**	-55.89**	-21.86**	-55.23**	-10.52	-16.03*
IC-31398 x GO-2	-10.97	-2.31	0.15	4.62	2.30	-5.45	20.24**	-30.71**	24.74**	-28.6**	17.30*	13.14*
IC-31398 x GJO-3	7.17	10.65	0.40	-3.46	-5.85	-9.70	14.71*	-44.28**	16.33*	-43.74**	-3.91	-4.95
IC-31398 x GAO-5	43.05**	47.69**	-12.55*	-14.77*	-15.53*	-15.91*	-36.51**	-50.66**	-39.58**	-51.25**	1.56	-5.35
IC-31398 x Pusa Sawani	-3.93	24.54**	-10.91	-8.31	-9.70	-12.58*	-10.95	-57.90**	-11.85	-58.52**	-16.16*	-21.99**
IC-89819 x GO-2	10.13	20.83**	0.37	4.85	10.62	-5.30	0.14	-42.29**	4.28	-40.32**	7.87	4.04
IC-89819 x GJO-3	-9.57	-3.70	-0.40	-4.23	-8.06	-11.82	24.93**	-39.31**	21.2**	-41.38**	-13.57*	-14.50*
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**
IC-89819 x GAO-5	-6.96	-0.93	2.05	-0.54	-13.39*	-13.79*	6.63	-17.14**	5.41	-14.94**	19.65**	11.51
IC-89819 x Pusa Sawani	-5.36	22.69**	-12.48*	-9.92	-15.18*	-17.88**	-12.22	-58.49**	-15.61*	-60.29**	-20.44**	-25.97**
IC-282248 x GO-2	-11.39*	-2.78	-2.28	2.08	19.29**	2.12	17.43**	-32.33**	20.47**	-31.05**	0.02	-3.53
IC-282248 x GJO-3	18.83**	22.69**	-7.67	-11.08	1.74	-2.42	-23.16**	-60.84**	-25.75**	-61.19**	-26.49**	-27.28**
IC-282248 x GAO-5	47.09**	51.85**	2.05	-0.54	-14.61*	-15.00*	-25.42**	-42.05**	-25.34**	-39.76**	33.77**	24.67**
IC-282248 x Pusa Sawani	-4.29	24.07**	3.29	6.31	-2.50	-5.61	31.70**	-32.88**	33.81**	-30.05**	22.84**	14.30*
IC-111443 x GO-2	13.03*	36.57**	-6.65	-0.69	2.76	-9.85	-3.65	-40.02**	-2.03	-38.88**	-13.46*	-8.59
IC-111443 x GJO-3	11.88*	35.19**	-5.93	0.08	2.84	-1.36	-32.45**	-57.95**	-31.17**	-57.06**	-16.17*	-11.46
IC-111443 x GAO-5	2.68	24.07**	-5.28	0.77	-6.85	-7.27	-8.05	-28.55**	-8.44	-26.11**	-0.72	4.86
IC-111443 x Pusa Sawani	-30.36**	-9.72	-12*	-6.38	-3.29	-6.36	8.21	-32.63**	6.07	-33.83**	-14.43*	-9.62
IC-90117 x GO-2	-18.68**	-3.24	-8.03	-3.08	-2.79	-4.85	12.31**	-8.16*	13.29**	-7.94*	-11.94*	7.90
IC-90117 x GJO-3	28.79**	53.24**	-11.09	-6.31	-6.97	-8.94	-55.14**	-63.32**	-55.82**	-64.1**	-31.87**	-16.51*
IC-90117 x GAO-5	-18.29**	-2.78	-12.92*	-8.23	-8.68	-9.09	-20.53**	-35.02**	-19.04**	-34.21**	-20.28**	-2.31
IC-90117 x Pusa Sawani	-27.14**	-5.56	-6.93	-1.92	-0.77	-2.88	-8.46*	-25.14**	-4.33	-22.26**	-11.84*	8.03
EC-30563 x GO-2	-2.85	10.65	-9.43	3.46	-5.69	-9.55	0.90	-33.19**	1.92	-31.86**	-17.23**	-3.46
EC-30563 x GJO-3	-2.03	11.57	-14.41**	-2.23	-5.69	-9.55	-2.65	-35.54**	-3.63	-35.57**	-17.04**	-3.24
EC-30563 x GAO-5	8.13	23.15**	-31.65**	-21.92**	-5.78	-6.21	-40.72**	-53.93**	-47.1**	-57.31**	-31.14**	-19.69**
EC-30563 x Pusa Sawani	-15.36**	9.72	-16.77**	-4.92	1.72	-1.52	-26.67**	-51.45**	-28.57**	-52.25**	-33.82**	-22.81**
EC-305623 x GO-2	25.4**	46.3**	-3.46	0.85	4.78	-10.30	-53.91**	-63.55**	-54.23**	-63.09**	-28.26**	-17.9**
EC-305623 x GJO-3	-31.35**	-19.91**	-0.48	-4.31	-11.06	-14.70*	-21.07**	-37.57**	-25.24**	-39.71**	-35.54**	-26.22**
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**
EC-305623 x GAO-5	-28.97**	-17.13**	-1.58	-4.08	-9.13	-9.55	12.63**	-10.92**	9.08*	-11.98**	-6.24	7.31
EC-305623 x Pusa Sawani	-3.21	25.46**	2.99	6.00	6.42	3.03	-45.61**	-56.98**	-48.93**	-58.82**	-30.4**	-20.35**
IC-052273 x GO-2	-4.64	4.63	4.64	9.31	-2.03	-12.42*	-5.94	-32.01**	-6.60	-29.91**	-10.59*	10.59
IC-052273 x GJO-3	16.74**	25.93**	7.04	2.92	3.48	-0.76	-42.84**	-58.68**	-43.44**	-57.55**	-34.06**	-18.44**
IC-052273 x GAO-5	-10.73	-3.70	10.10	7.31	-1.37	-1.82	1.47	-21.15**	1.03	-18.48**	-21.72**	-3.18
IC-052273 x Pusa Sawani	-3.57	25**	-4.04	-1.23	1.25	-1.97	-13.62**	-37.56**	-14.63**	-35.94**	-16.91**	2.78
IC-090107 x GO-2	1.69	11.57	-5.67	-1.46	9.56	-6.21	-22.20**	-44.84**	-24.46**	-44.84**	-22.08**	-6.33
IC-090107 x GJO-3	3.02	10.65	2.32	-1.62	-3.48	-7.42	-28.05**	-48.99**	-28.96**	-48.13**	-27.26**	-12.55
IC-090107 x GAO-5	32.76**	42.59**	5.37	2.69	-4.57	-5.00	-28.91**	-44.76**	-28.3**	-42.14**	-6.68	12.19
IC-090107 x Pusa Sawani	8.93	41.2**	-11.81*	-9.23	-4.23	-7.27	-29.04**	-49.69**	-31.18**	-49.74**	-9.29	9.04
IC-111493 x GO-2	-18.99**	-11.11	-17.16**	-13.46*	4.42	-10.61	3.20	-34.16**	-4.41	-38.95**	-18.58**	-16.86*
IC-111493 x GJO-3	-20.35**	-16.67**	-4.32	-8.00	-11.06	-14.70*	-18.22**	-47.82**	-23.72**	-51.29**	-39.08**	-37.8**
IC-111493 x GAO-5	6.19	11.11	-1.42	-3.92	-9.13	-9.55	-38.7**	-52.37**	-44.05**	-54.86**	-25.38**	-23.81**
IC-111493 x Pusa Sawani	-13.93**	11.57	-18.54**	-16.15**	-6.26	-9.24	-32.03**	-56.64**	-32.63**	-56.98**	-25.03**	-23.45**
Range	-31.35	-19.91	-31.65	-28.46	-15.53	-17.88	-55.14	-63.55	-55.82	-64.10	-39.08	-37.80
	to	to	to	to	to	to	to	to	to	to	to	to
	47.09	53.24	10.10	9.31	19.29	3.03	31.70	-8.16	33.81	-7.94	33.77	24.67
Mean heterosis	-1.95	13.93	-5.66	-3.67	-3.02	-7.73	-11.33	-41.62	-11.93	-41.39	-11.63	-6.59
S. Ed. ±	0.44	0.44	0.53	0.53	0.27	0.27	0.88	0.88	0.83	0.83	7.19	7.19
Total no. of +	19	31	13	14	16	02	16	00	15	00	12	15
hybrids -	29	17	35	34	32	46	32	48	33	48	36	33

*,** Significant at P=0.05 and P=0.01, respectively.

Conclusion

From the results, it can be concluded that the crosses, IC-282248 x GAO-5 (33.77%) followed by IC-282248 x Pusa Sawani (22.84%) and IC-89819 x GAO-5 (19.65%) recorded the most promising heterobeltiosis combinations for fruit yield per plant and the top ranking desirable heterotic crosses for fruit yield per plant over standard check were IC-282248 x GAO-5 (24.67%) followed by IC-282248 x Pusa Sawani (14.30%) and IC-31398 x GO-2 (13.14%). These short-listed hybrids may be further tested for fruit yield and other quality traits under different agro-climatic conditions before commercial exploitation of hybrid vigour in okra.

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