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Heterosis studies for yield and yield components in okra [*Abelmoschus esculentus* (L.) Moench]

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Abstract
The study of heterosis would help in selection of heterotic crosses for commercial exploitation of F_1 hybrids in okra [*Abelmoschus esculentus* (L.) Moench] to achieve improvement in production and productivity. Forty-five F_1s were developed by crossing 10 elite lines of okra in half diallel fashion during *kharif*-2017. All 45 F_1s along with their 10 parents and one standard check (GJOH 4) were evaluated in a randomized complete block design with three replicates during *kharif* (July to October) 2018. The significance of mean squares due to genotypes revealed the presence of considerable genetic variability among the material studied for almost yield and all yield attributes. The heterosis for fruit yield per plant was ranged from -21.85 (AOL 13-144 × Phule Prajatika) to 37.09 per cent (GAO 5 × Kashi Kranti) over batter parent and -9.45 (AOL 13-144 × JF 108-02) to 75.51 (GAO 5 × Kashi Kranti) per cent for standard check. For number of fruits per plant hybrids GAO 5 × Kashi Kranti (28.26%) followed by AOL 12-59 × JF 5 (25.88%) and Phule Prajatika × JF 5 (19.32%) depicted higer heterobeltiosis, while the hybrids AOL 13-144 × VRO 6 (34.20%), JF 5 × JF 108-02 (31.97%), GAO 5 × Kashi Kranti and Phule prajatika × JF 108-02 (31.60%) exhibited higher heterosis over standard check. The superior crosses identified through heterosis analysis were GAO 5 × Kashi Kranti, Phule Prajatika × Red One Long and Phule Prajatika × JF 5 as these crosses had high *per se* performance as well significant and higher estimates of standard heterosis for fruit yield per plant and yield attributing other characters.

Keywords: heterosis studies for yield, *Abelmoschus esculentus* (L.) Moench

Introduction
Okra [*Abelmoschus esculentus* (L.) Moench] also known as Lady's finger is an annual vegetable crop belong to *Malvaceae* family and it is propagated by seeds in subtropical and tropical region of the world. Its immature fruits are used as vegetable, stem and roots for clarification of sugar cane juice to make jaggery, crude fibre of mature fruits and stems are used in the paper industry. Okra seeds is an alternative source for edible oils with high unsaturated fats like oleic acid and linolic acid. It is a potential source of numerous minerals like potassium, phosphorus, sulphur, iron, sodium, calcium, manganese, etc. and vitamins A, B, C and K, as well as folates. The amount of ascorbic acid content varies from 13-18 mg/100 g of fresh fruit weight; while as green tender fruits and immature seeds have a little protein content 2.08 and 2.09 per cent respectively (Singh *et al.*, 2001) [17-19]. According to research, fresh okra fruits contain the soluble fibre is in the form of gums and pectin which allows to lower serum cholesterol and reducing the risk of heart diseases. It has been found to possess various ethno-pharmacological and medicinal properties against cancer, high-cholesterol, and diabetes mellitus and also reported to be useful for persons suffering from genitor-urinary disorders.
In India, among fresh vegetables, around 60 per cent share of export goes to okra which is grown in 511-thousand-hectare area with average 12.17 tonnes productivity (Anonymous, 2018) [1]. Considering the potentiality of this crop there is a prime need for its improvement and to develop high yielding hybrid varieties with superior marketable fruit quality and resistance/tolerance to biotic and abiotic stresses that are suitable for specific agro-climatic zones. Moreover, widespread adoption of hybrids by farmers also necessitates the development of new higher yielding hybrids, which are able to express the high degree of economic heterosis. The magnitude of heterosis for yield and its component traits serves as a guide for the choice of desirable parents for developing superior F_1 hybrids to exploit hybrid vigour. Knowledge of heterosis of yield and its component characters should be helpful for the improvement of this crop. Keeping this in view the objective of the present investigation was to assess the magnitude of heterosis for fruit yield and its components in okra.

Materials and Methods

The experimental material was tested during *Kharif*-2018 at the Main Vegetable Research Station, Anand Agricultural University, Anand, Gujarat, India. The basic materials consisted of ten diverse genotypes of okra *viz*. P_1 (GAO 5), P_2 (AOL 12-59), P_3 (AOL 13-144), P_4 (Phule Prajatika), P_5 (Kashi Kranti), P_6 (Arka Abhay), P_7 (VRO 6), P_8 (Red One Long), P_9 (JF 5) and P_{10} (JF 108-02). These lines/varieties have been maintained by Main Vegetable Research Station, Anand Agricultural University, Anand and have been selected for the present study on the basis of genetic variability for various agronomic traits and maturity parameters. The genotypes are crossed in diallel fashion excluding reciprocals to produce 45 hybrids in *kharif* 2017. These 45 F_1s along with their 10 parents and one standard check (GJOH 4) were evaluated in a randomized complete block design with three replicates during *kharif* (July to October) 2018 at the Main Vegetable Research Station, Anand Agricultural University, Anand, Gujarat, India. Each plot consisted of a single row of 15 plants. Inter and intra row spacing was kept 60 and 30 cm, respectively. Agronomic practices followed as per the standard recommendation and sufficient protection measures were taken to raise a healthy crop. Observations were recorded on days to 50 per cent flowering, days to first picking, number of fruits per plant, fruit length (cm), fruit girth (cm), fruit weight (g), fruit yield per plant (g), plant height (cm), number of internodes on main stem, length of internodes (cm), number of primary branches per plant and crude fiber content (%). The various observations were recorded on five competitive plants in each plot leaving border ones. Heterosis percentage was worked out as per formula suggested by Fonseca and Patterson (1968) and Meredith and Bridge (1972) [9] for calculation of heterobeltiosis and standard heterosis, respectively.

Results and Discussion

Analysis of variance [Table 1] showed significant differences for all the characters which indicated the presence of appreciable genetic diversity for the traits under study and the hybrid with high value of heterosis in desired direction can be further exploited. The hybrids are normally assessed in terms of per cent increase better parent and over standard check hybrid.

The range of heterosis over better parent and standard check found to be different for all the characters under study [Table 2].

With respect to days to fifty per cent flowering, the quantum of heterobeltiosis (HB) and standard heterosis (SH) varied from -4.58 (GAO 5 × JF 5) to 27.59 per cent (Phule Prajatika × Kashi Kranti) and -10.71 (GAO 5 × JF 5) to 6.43 per cent (AOL 12-59 × Arka Abhay), respectively. Perusal of [Table-3] showed that the first three top ranking heterotic hybrids possessed at least one good *per se* performing parent for days to first flowering. Similar result has been observed by Gajera (2013) [5] and Singh *et al*. (2013) [17-19] for heterobeltiosis, results of standard heterosis were in conformity with Satish *et al*. (2017) [16] and Sujit *et al*. (2017) [19].

With regards to days first picking, the extent of heterobeltiosis and standard heterosis ranged from -4.20 (GAO 5 × JF 5) to 24.81 per cent (Phule Prajatika × Kashi Kranti) and -9.87 (GAO 5 × JF 5) to 5.92 per cent (AOL 12-59 × Arka Abhay and Phule Prajatika × Kashi Kranti), respectively. Out of 45 crosses studied, only 2 and 21 crosses displayed significant negative heterobeltiosis and standard heterosis for this trait, respectively. The results are in agreement with Gajera (2013) [5] (HB) and Bhatt (2015) [16] (HB and SH).

Number of fruits per plant is an important yield contributing trait. Total eleven cross combinations revealed positive significant heterobeltiosis of which top ranking were GAO 5 × Kashi Kranti (28.26%) followed by AOL 12-59 × JF 5 (25.88%) and Phule Prajatika × JF 5 (19.32%). Total 21 crosses had significant positive estimates. Three top ranking standard heterosis combination were AOL 13-144 × VRO 6 (34.20%), JF 5 × JF 108-02 (31.97%) and GAO 5 × Kashi Kranti and Phule prajatika × JF 108-02 (31.60%). The results are in concordant to the findings of Gajera (2013) [5] (HB and SH), Reddy *et al.* (2013) [14, 15] (HB) and Singh *et al.* (2013) [17-19] (HB and SH).

In respect to fruit length, the estimates of heterobeltiosis ranged from -12.97 (AOL 13-144 × Phule Prajatika) to 16.68 per cent (AOL 12-59 × JF 108-02) among which, two crosses AOL 12-59 × JF 108-02 (16.68%) and VRO 6 × JF 108-02 (10.29%) had significantly positive effects. Total 21 crosses had significant positive estimates of standard heterosis. Among which, three top ranking hybrids were Kashi Kranti × Arka Abhay (24.20%), Kashi Kranti × VRO 6 (22.99%) and Kashi Kranti × Red One Long (22.27%). Bhatt *et al*. (2015) [16] (HB and SH), and Valluru (2015) [20] (HB and SH).

In the present investigation, the range of better parent heterosis and standard heterosis for fruit girth varied from -8.09 (GAO 5 × AOL 12-59) to 8.23 per cent (Kashi Kranti × VRO 6) -0.64 (GAO 5 × AOL 12-59) and 10.89 per cent (AOL 12-59 × AOL 13-144), respectively. Only two crosses Kashi Kranti × VRO 6 (8.23%) and JF 5 × JF 108-02 (5.22%) depicted significant positive heterobeltiosis. Three top ranking standard heterosis combination were listed in table 3. The results corroborate with findings of Indurani *et al*. (2003) [7] (HB and SH) and Bhatt (2015) [16] (HB and SH).

Fruit weight is an important yield contributing trait. The range of better parent heterosis and standard heterosis varied from -15.14 (GAO 5 × AOL 13-144) to 13.32 per cent (Kashi Kranti × VRO 6) and -9.11 (AOL 13-144 × VRO 6) to 34.16 per cent (Phule Prajatika × Red One Long), respectively. The crosses Phule Prajatika × Red One Long (34.16%) and GAO 5 × Kashi Kranti (33.39%) also showed higher fruit yield per plant which indicated the association of fruit weight and fruit yield per plant. Heterosis for fruit weight was also reported by Ahlawat *et al*. (2004) [2] (HB and SH), Weerasekar (2006) [22] (HB and SH), Reddy (2012) [14, 15] (HB and SH).

Considerable degree of heterosis was registered in a number of crosses for fruit yield per plant. In all, 9 and 27 hybrids manifested significant positive heterobeltiosis and standard heterosis, respectively. The estimates of heterobeltiosis for fruit yield varied from -21.85 (AOL 13-144 × Phule Prajatika) to 37.09 per cent (GAO 5 × Kashi Kranti). The estimates of standard heterosis ranged from -9.45 (AOL 13-144 × JF 108-02) to 75.51 per cent (GAO 5 × Kashi Kranti). Perusal of [Table-3] showed that the first three top ranking heterotic hybrids possessed at least one good *per se* performing parent for fruit yield per plant. The results are in congruent with the findings of Reddy *et al*. (2013) [14, 15] (HB), and Patel and Patel (2016) (SH) [3, 12].

The extent of heterosis over better parent was -18.42 (GAO 5 × JF 108-02) to 13.32 per cent (Arka Abhay × VRO 6) and over standard check was -4.38 (AOL 12-59 × AOL 13-144) to 45.51 per cent (Arka Abhay × VRO 6) for plant height. The results are in agreement with Reddy *et al*. (2012) [14, 15] (HB), Hosamani *et al*. (2008) [6] (SH) and Verma and Sood (2015) [19, 21] (SH).

With regards to number of internodes on main stem, the estimates of heterobeltiosis varied from -7.88 (Red One Long × JF 108-02) to 16.89 per cent (Arka Abhay × VRO 6). While, estimates of standard heterosis ranged from -4.25 (GAO 5 × Phule Prajatika) to 26.64 per cent (Kashi Kranti × Arka Abhay), respectively. Among all, total 5 and 24 hybrids manifested significant positive heterobeltiosis and standard heterosis, respectively. The results are in agreement with Ahlawat *et al*. (2004) [2] (HB and SH).

The estimates of heterobeltiosis varied from -22.38 (AOL 13-144 × VRO 6) to 7.10 per cent (AOL 12-59 × Red One Long) and over standard check was -11.82 (AOL 12-59 × AOL 13-144) to 28.75 per cent (GAO 5 × Red One Long) for length of internode. Total six hybrids depicted significant positive standard hetrotic effects. The results are in agreement with Patel and Patel (2016) [3, 12] (SH) and Paul *et al*. (2017) (SH) [13].

For number of primary branches, the estimates of heterobeltiosis varied from -48.21 (Arka Abhay × JF 108-02) to 73.03 per cent (AOL 12-59 × VRO 6). Six crosses have heterobeltiosis in positive direction. The values of standard heterosis ranged from -29.73 (AOL 13-144 × Red One Long) to 78.38 per cent (VRO 6 × JF 5). Total 17 crosses were depicted significant heterotic effects in positive direction. The results corroborate with findings of Reddy (2012) [14, 15] (HB and SH), Neetu (2014) (HB and SH) and Bhatt *et al*. (2015) [16] (HB and SH).

The estimates of heterobeltiosis for crude fiber content varied from -31.04 (AOL 12-59 × Phule Prajatika) to 9.19 (AOL 12-59 × VRO 6) per cent. Total 6 hybrids had significant positive estimates. The hybrid AOL 12-59 × VRO 6 (9.19%) depicted the highest significant heterobeltiosis followed by GAO 5 × VRO 6 (6.01%) and Phule Prajatika × JF 108-02 (4.76%). The quantum of standard heterosis for crude fiber content ranged from -29.08 (AOL 12-59 × Phule Prajatika) to 10.52 (AOL 12-59 × VRO 6) per cent. Total 4 F_1 had significant positive estimates. The findings were in conformity with reports of More *et al*. (2015) [10], Bhatt (2015) [16] and Jethva (2014) [8] for standard heterosis.

Table 1: Analysis of variance (Mean squares) for various characters in okra

Source of variations / Characters	df	Days to 50 percent flowering	Days to first picking	Number of fruits per plant	Fruit length (cm)	Fruit girth (cm)	Fruit weight (g)
Replications	2	0.34	0.19	2.21	1.19	0.07	0.56
Genotypes	55	17.71**	17.30**	13.04**	2.75**	0.10**	6.37**
Parents	9	37.13**	35.71**	6.51*	5.27**	0.26**	11.03**
Hybrids	44	14.38**	14.17**	12.79**	2.14**	0.06**	5.58**
Parents *Vs.* Hybrids	1	2.85*	3.17*	82.90**	4.69*	0.43**	1.38
Check *Vs.* Hybrids	1	4.16*	3.83*	13.46*	4.83*	0.12*	4.29*
Error	110	0.72	0.76	3.18	0.80	0.03	0.64

Source of variations / Characters	df	Fruit yield per plant (g)	Plant height (cm)	Number of internodes on main stem	Length of internode (cm)	Number of primary branches per plant	Crude fiber content (%)
Replications	2	793.77	5682.75	1.70	8.77	0.79	0.003
Genotypes	55	5369.99**	606.72**	4.25**	1.49**	1.16**	1.47**
Parents	9	4030.95**	883.43**	2.90	3.18**	1.03**	0.33**
Hybrids	44	5179.96**	510.24**	3.65*	1.16**	1.19**	1.62**
Parents *Vs.* Hybrids	1	23420.52**	967.08*	34.30**	0.84	1.07*	5.78**
Check *Vs.* Hybrids	1	7731.93**	2001.35**	12.73*	1.45	0.91*	0.83**
Error	110	859.83**	227.09	2.44	0.59	0.19	0.03

*, ** significant at 5% and 1% levels of probability, respectively.

Table 2: Estimation of heterobeltiosis (HB) and standard heterosis (SH) in percentage for various characters in okra

Hybrids / Characters	Days to 50 percent flowering		Days to first picking		Number of fruits per plant	
	HB	SH	HB	SH	HB	SH
(1)	(2)	(3)	(4)	(5)	(6)	(7)
GAO 5 × AOL 12-59	4.58**	-2.14	4.20**	-1.97	19.05**	20.82**
GAO 5 × AOL 13-144	-0.76	-7.14**	-0.70	-6.58**	6.87	15.61*
GAO 5 × Phule Prajatika	10.34**	-8.57**	8.53**	-7.89**	-9.49	-0.74
GAO 5 × Kashi Kranti	3.05*	-3.57**	2.80*	-3.29*	28.26**	31.60**
GAO 5 × Arka Abhay	6.87**	0.00	4.90**	-1.32	-2.93	-1.49
GAO 5 × VRO 6	1.53	-5.00**	1.40	-4.61**	-4.85	9.29
GAO 5 × Red One Long	-1.53	-7.86**	-1.40	-7.24**	5.42	8.55
GAO 5 × JF 5	-4.58**	-10.71**	-4.20**	-9.87**	3.66	5.20
GAO 5 × JF 108-02	1.59	-8.57**	2.17	-7.24**	-11.04	1.86
AOL 12-59 × AOL 13-144	2.13	2.86*	1.96	2.63*	-9.62	-2.23
AOL 12-59 × Phule Prajatika	15.52**	-4.29**	13.18**	-3.95**	17.63**	29.00**
AOL 12-59 × Kashi Kranti	0.00	4.29**	0.00	3.95**	17.75*	20.82**
AOL 12-59 × Arka Abhay	6.43**	6.43**	5.92**	5.92**	6.67	1.12
AOL 12-59 × VRO 6	8.21**	3.57**	7.53**	3.29*	1.94	17.10*
AOL 12-59 × Red One Long	4.44**	0.71	4.08**	0.66	8.66	11.90
AOL 12-59 × JF 5	7.52**	2.14	6.90**	1.97	25.88**	19.33**
AOL 12-59 × JF 108-02	11.11**	0.00	10.87**	0.66	2.60	17.47*
AOL 13-144 × Phule Prajatika	8.62**	-10.00**	6.98**	-9.21**	-11.53	-2.97
AOL 13-144 × Kashi Kranti	-1.42	-0.71	-1.31	-0.66	2.06	10.41
AOL 13-144 × Arka Abhay	4.29**	4.29**	3.95**	3.95**	-0.34	7.81

AOL 13-144 × VRO 6		1.49	-2.86*	3.42*	-0.66	16.83**	34.20**
AOL 13-144 × Red One Long		2.96*	-0.71	2.72*	-0.66	5.15	13.75
AOL 13-144 × JF 5		6.77**	1.43	6.21**	1.32	6.87	15.61*
AOL 13-144 × JF 108-02		11.90**	0.71	10.87**	0.66	-17.53**	-5.58
Phule Prajatika × Kashi Kranti		27.59**	5.71**	24.81**	5.92**	3.39	13.38
Phule Prajatika × Arka Abhay		18.97**	-1.43	16.28**	-1.32	10.17	20.82**
Phule Prajatika × VRO 6		13.79**	-5.71**	12.40**	-4.61**	10.68	27.14**
Phule Prajatika × Red One Long		17.24**	-2.86*	14.73**	-2.63*	10.51	21.19**
Phule Prajatika × JF 5		10.34**	-8.57**	8.53**	-7.89**	19.32**	30.86**
Phule Prajatika × JF 108-02		10.34**	-8.57**	9.30**	-7.24**	14.94*	31.60**
Kashi Kranti × Arka Abhay		-2.14	-2.14	-1.97	-1.97	0.36	2.97
Kashi Kranti × VRO 6		-3.73**	-7.86**	-2.74*	-6.58**	7.12	23.05**
Kashi Kranti × Red One Long		9.63**	5.71**	8.84**	5.26**	2.17	5.20
Kashi Kranti × JF 5		7.52**	2.14	6.90**	1.97	0.00	2.60
Kashi Kranti × JF 108-02		9.52**	-1.43	8.70**	-1.32	1.95	16.73*
Arka Abhay × VRO 6		0.75	-3.57**	0.68	-3.29*	-2.59	11.90
Arka Abhay × Red One Long		7.41**	3.57**	6.80**	3.29*	-6.50	-3.72
Arka Abhay × JF 5		3.76**	-1.43	3.45*	-1.32	3.97	-2.60
Arka Abhay × JF 108-02		4.76**	-5.71**	4.35**	-5.26**	-9.42	3.72
VRO 6 × Red One Long		-2.24	-6.43**	-2.05	-5.92**	6.80	22.68**
VRO 6 × JF 5		0.75	-4.29**	0.69	-3.95**	12.94*	29.74**
VRO 6 × JF 108-02		3.17*	-7.14**	2.90*	-6.58**	11.97*	28.62**
Red One Long × JF 5		0.75	-4.29**	0.69	-3.95**	8.66	11.90
Red One Long × JF 108-02		10.32**	-0.71	9.42**	-0.66	-2.27	11.90
JF 5 × JF 108-02		2.38	-7.86**	2.17	-7.24**	15.26*	31.97**
Range	Maximum value	27.59	6.43	24.81	5.92	28.26	34.20
	Minimum value	-4.58	-10.71	-4.20	-9.87	-17.53	-5.58
Significant crosses	Positive crosses	29	8	30	8	11	21
	Negative crosses	2	22	2	21	1	0
	Total crosses	31	30	32	29	12	21
S.E. ±		0.65	0.65	0.67	0.67	1.32	1.32

*, ** significant at 5% and 1% levels of probability, respectively.

Characters hybrids	**Fruit length**		**Fruit girth**		**Fruit weight**	
	HB	**SH**	**HB**	**SH**	**HB**	**SH**
(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**
GAO 5 × AOL 12-59	-7.42	7.16	-8.09**	-0.64	-11.08**	12.55*
GAO 5 × AOL 13-144	-7.02	7.63	-1.37	4.40	-15.14**	7.40
GAO 5 × Phule Prajatika	-8.62*	5.77	-4.82*	0.75	-2.26	23.71**
GAO 5 × Kashi Kranti	3.53	19.83**	-2.35	3.36	5.39	33.39**
GAO 5 × Arka Abhay	-2.52	12.83*	0.88	6.78**	-2.66	23.21**
GAO 5 × VRO 6	-3.90	11.24*	0.38	6.26*	-14.62**	8.06
GAO 5 × Red One Long	-2.73	12.59*	-2.63	3.07	-2.85	28.88**
GAO 5 × JF 5	-7.28	10.65*	1.31	7.24**	-4.25	21.19**
GAO 5 × JF 108-02	-7.37	7.21	-1.59	4.17	-13.94**	8.93
AOL 12-59 × AOL 13-144	3.51	-2.38	2.57	10.89**	-5.38	-6.20
AOL 12-59 × Phule Prajatika	-6.80	3.88	-7.82**	-0.35	-2.83	20.74**
AOL 12-59 × Kashi Kranti	-1.90	12.31*	-7.98**	-0.52	1.22	0.34
AOL 12-59 × Arka Abhay	-12.35**	-0.67	-2.63	5.27*	-4.24	1.29
AOL 12-59 × VRO 6	5.37	4.60	-1.50	6.49*	-5.27	-6.09
AOL 12-59 × Red One Long	-3.85	9.93*	-0.96	7.07**	-10.47*	18.77**
AOL 12-59 × JF 5	-8.26**	9.49	-2.52	5.39*	-9.13	1.94
AOL 12-59 × JF 108-02	16.68**	14.90**	-1.07	6.95**	-0.45	-1.31
AOL 13-144 × Phule Prajatika	-12.97**	-3.00	2.69	8.34**	-11.98**	9.37
AOL 13-144 × Kashi Kranti	0.99	15.62**	-3.08	2.26	-3.03	-5.04
AOL 13-144 × Arka Abhay	-3.78	9.04	-1.04	4.40	-6.55	-1.16
AOL 13-144 × VRO 6	7.35	6.57	1.92	7.53**	-1.93	-9.11
AOL 13-144 × Red One Long	-7.80	5.40	-1.26	4.17	-14.13**	13.91*
AOL 13-144 × JF 5	-11.33**	5.82	1.92	7.53**	-8.78	2.34
AOL 13-144 × JF 108-02	3.91	2.33	-0.88	4.58	-1.94	-4.36
Phule Prajatika × Kashi Kranti	4.18	19.27**	-0.40	1.62	-9.36*	12.63*
Phule Prajatika × Arka Abhay	2.33	15.96**	0.68	2.72	-4.54	18.61**
Phule Prajatika × VRO 6	-1.30	10.01*	1.02	3.07	-12.00**	9.35
Phule Prajatika × Red One Long	-0.72	13.50**	-2.43	2.38	1.13*	34.16**
Phule Prajatika × JF 5	-8.60*	9.08	2.08	5.10	-3.47	19.95**
Phule Prajatika × JF 108-02	-1.93	9.31	0.06	2.09	-7.82	14.54**
Kashi Kranti × Arka Abhay	8.49	24.20**	1.71	3.36	0.62	6.43
Kashi Kranti × VRO 6	7.43	22.99**	8.23**	2.90	13.32**	10.97*
Kashi Kranti × Red One Long	6.80	22.27**	-2.10	2.72	-14.23**	13.78*

Kashi Kranti × JF 5		2.34	22.14**	2.19	5.21*	-6.11	5.33
Kashi Kranti × JF 108-02		3.14	18.08**	3.81	2.49	2.09	-0.03
Arka Abhay × VRO 6		-3.51	9.34	1.82	3.48	-6.73	-1.34
Arka Abhay × Red One Long		-0.93	13.27**	-2.04	2.78	-8.71*	21.11**
Arka Abhay × JF 5		1.95	21.67**	1.46	4.46	-5.15	6.41
Arka Abhay × JF 108-02		-5.09	7.55	0.17	1.80	-2.33	3.31
VRO 6 × Red One Long		-6.45	6.96	-3.09	1.68	-14.55**	13.36*
VRO 6 × JF 5		-9.64*	7.84	1.41	4.40	-9.43	1.60
VRO 6 × JF 108-02		10.29*	9.49	3.87	2.55	7.40	4.75
Red One Long × JF 5		-6.67	11.38*	-2.48	2.32	-6.23	24.39**
Red One Long × JF 108-02		-7.80	5.40	-2.76	2.03	-13.64**	14.57**
JF 5 × JF 108-02		-10.96*	6.26	5.22*	3.88	-5.36	6.17
Range	Maximum value	16.68	24.20	8.23	10.89	13.32	34.16
	Minimum value	-12.97	-3.00	-8.09	-0.64	-15.14	-9.11
Significant crosses	Positive crosses	2	21	2	13	1	20
	Negative crosses	8	0	4	0	13	0
	Total crosses	10	21	6	13	14	20
S.E. ±		0.65	0.65	0.15	0.15	0.69	0.69

*, ** significant at 5% and 1% levels of probability, respectively

Characters / Hybrids		Fruit yield per plant		Plant height		Number of internodes on main stem	
		HB	**SH**	**HB**	**SH**	**HB**	**SH**
(1)		**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**
GAO 5 × AOL 12-59		6.03	35.75**	2.18	29.44**	-3.39	10.04
GAO 5 × AOL 13-144		-3.02	24.17*	-3.72	21.96*	0.80	13.13*
GAO 5 × Phule Prajatika		-9.80	22.82*	-15.73*	6.74	-2.20	-4.25
GAO 5 × Kashi Kranti		37.09**	75.51**	-8.10	26.15**	11.81*	24.32**
GAO 5 × Arka Abhay		-5.85	20.54*	1.05	28.00**	3.20	11.97
GAO 5 × VRO 6		-7.75	18.11	-9.65	16.01	-1.42	6.95
GAO 5 × Red One Long		2.32	39.58**	2.83	34.10**	-4.45	7.72
GAO 5 × JF 5		-0.64	27.21**	-3.96	21.66*	4.27	13.13*
GAO 5 × JF 108-02		-13.78	10.39	-18.42*	3.34	-7.47	0.39
AOL 12-59 × AOL 13-144		-8.71	-8.34	-9.19	-4.38	-5.08	8.11
AOL 12-59 × Phule Prajatika		14.22*	55.53**	-5.46	11.75	-0.34	13.51*
AOL 12-59 × Kashi Kranti		21.48*	21.62*	-15.19*	16.42	-2.97	10.52
AOL 12-59 × Arka Abhay		3.15	2.43	1.39	21.66*	-4.41	8.88
AOL 12-59 × VRO 6		5.61	10.06	-0.22	28.11**	10.17	25.48**
AOL 12-59 × Red One Long		-2.59	32.88**	3.05	34.39**	-4.75	8.49
AOL 12-59 × JF 5		17.15	21.50*	-3.00	13.71	3.05	17.37**
AOL 12-59 × JF 108-02		4.22	16.38	10.03	23.27*	2.99	17.31**
AOL 13-144 × Phule Prajatika		-21.85**	6.41	-14.42	1.15	5.43	12.36
AOL 13-144 × Kashi Kranti		4.22	4.65	-15.86*	15.50	5.21	16.99**
AOL 13-144 × Arka Abhay		6.26	6.70	-2.58	16.89	6.88	13.90*
AOL 13-144 × VRO 6		16.90	21.83*	-16.91*	6.68	1.52	9.65
AOL 13-144 × Red One Long		-5.02	29.58**	-1.24	28.80**	-3.08	9.27
AOL 13-144 × JF 5		13.68	17.91	0.84	18.20	5.80	12.74
AOL 13-144 × JF 108-02		-18.92*	-9.45	-3.91	7.66	-0.72	5.79
Phule Prajatika × Kashi Kranti		-6.34	27.53**	-9.19	24.65*	4.86	16.60*
Phule Prajatika × Arka Abhay		5.63	43.83**	9.70	31.62**	10.95	17.37**
Phule Prajatika × VRO 6		2.00	38.88**	-2.96	24.60*	4.02	12.36
Phule Prajatika × Red One Long		18.59*	61.79**	2.78	34.04**	1.71	14.67*
Phule Prajatika × JF 5		14.89*	56.44**	-1.32	16.65	4.38	10.42
Phule Prajatika × JF 108-02		10.81	50.88**	2.14	20.74*	9.12	15.44*
Kashi Kranti × Arka Abhay		9.41	9.54	2.01	40.03**	13.89*	26.64**
Kashi Kranti × VRO 6		30.91**	36.42**	-2.64	33.64**	3.82	15.44*
Kashi Kranti × Red One Long		-12.10	19.92*	-2.81	33.41**	-4.79	7.34
Kashi Kranti × JF 5		4.12	7.99	-0.17	37.04**	4.86	16.60*
Kashi Kranti × JF 108-02		4.35	16.53	5.67	45.05**	10.76	23.17**
Arka Abhay × VRO 6		5.64	10.09	13.32	45.51**	16.89**	26.25**
Arka Abhay × Red One Long		-14.48*	16.68	3.71	35.25**	2.05	15.06*
Arka Abhay × JF 5		-0.42	3.28	4.51	25.40*	8.46	8.88
Arka Abhay × JF 108-02		-4.11	7.08	10.61	32.72**	9.58	10.42
VRO 6 × Red One Long		1.87	38.97**	1.10	31.85**	1.03	13.90*
VRO 6 × JF 5		25.86**	31.16**	-0.63	27.59**	12.24*	21.24**
VRO 6 × JF 108-02		20.12*	34.14**	-6.73	19.76*	5.09	13.51*
Red One Long × JF 5		1.99	39.15**	0.84	31.51**	4.11	17.37**
Red One Long × JF 108-02		-5.88	28.41**	-8.75	19.01	-7.88	3.86
JF 5 × JF 108-02		25.44**	40.08**	7.51	20.45*	16.57*	17.47**
Range	Maximum value	37.09	75.51	13.32	45.51	16.89	26.64
	Minimum value	-21.85	-9.45	-18.42	-4.38	-7.88	-4.25

Significant crosses	Positive crosses	9	27	0	30	5	24
	Negative crosses	3	0	5	0	0	0
	Total crosses	12	27	5	30	5	24
S.E. ±		22.41	22.41	11.53	11.53	1.13	1.13

*, ** significant at 5% and 1% levels of probability, respectively

Characters / Hybrids		Length of internode		Number of primary branches per plant		Crude fiber content	
		HB	**SH**	**HB**	**SH**	**HB**	**SH**
(1)		**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**
GAO 5 × AOL 12-59		-7.05	18.25	60.00**	72.97**	-5.82**	-4.67**
GAO 5 × AOL 13-144		-15.55	7.44	28.57*	45.95**	1.59	0.70
GAO 5 × Phule Prajatika		-11.31	12.83	-8.21	10.81	-7.26**	-4.63**
GAO 5 × Kashi Kranti		-21.26**	0.17	-13.79	35.14*	-24.21**	-22.88**
GAO 5 × Arka Abhay		-10.36	14.05	-14.29	29.73*	-19.12**	-15.41**
GAO 5 × VRO 6		-14.70	8.52	2.50	10.81	6.01**	0.09
GAO 5 × Red One Long		1.20	28.75**	-20.00	-13.51	-0.42	-6.51**
GAO 5 × JF 5		-15.78	7.15	22.50	32.43*	-23.89**	-25.02**
GAO 5 × JF 108-02		-19.16*	2.85	-8.70	13.51	-3.63	-9.52**
AOL 12-59 × AOL 13-144		-4.55	-11.82	-11.90	0.00	-15.14**	-14.10**
AOL 12-59 × Phule Prajatika		-11.52	-1.36	11.94	35.14*	-31.04**	-29.08**
AOL 12-59 × Kashi Kranti		-10.35	10.55	-29.31**	10.81	-27.04**	-25.76**
AOL 12-59 × Arka Abhay		-9.31	12.65	-25.00**	13.51	-4.22**	0.17
AOL 12-59 × VRO 6		-18.52*	1.47	73.03**	77.70**	9.19**	10.52**
AOL 12-59 × Red One Long		7.10	23.55*	-2.63	0.00	0.56	1.79
AOL 12-59 × JF 5		-16.83	-2.98	30.77*	37.84**	-8.50**	-7.38**
AOL 12-59 × JF 108-02		-1.95	9.49	15.22	43.24**	-6.17**	-5.02**
AOL 13-144 × Phule Prajatika		-19.13*	-9.84	20.90	45.95**	-2.59	0.17
AOL 13-144 × Kashi Kranti		-20.02*	-1.38	-32.76**	5.41	-5.58**	-3.93*
AOL 13-144 × Arka Abhay		-18.02*	1.84	-3.57	45.95**	-14.49**	-10.57**
AOL 13-144 × VRO 6		-22.38**	-3.33	-11.90	0.00	2.29	1.40
AOL 13-144 × Red One Long		2.40	18.12	-38.10**	-29.73	-9.69**	-10.48**
AOL 13-144 × JF 5		-9.96	5.03	-19.64	-8.78	3.79*	2.88
AOL 13-144 × JF 108-02		-8.63	2.04	-28.26*	-10.81	-0.79	-1.66
Phule Prajatika × Kashi Kranti		-13.90	6.17	-34.48**	2.70	-9.30**	-6.72**
Phule Prajatika × Arka Abhay		-10.19	11.56	-21.43*	18.92	-1.21	3.32*
Phule Prajatika × VRO 6		-11.27	10.50	5.22	27.03	-1.95	0.83
Phule Prajatika × Red One Long		1.06	16.58	0.75	21.62	4.25**	7.21**
Phule Prajatika × JF 5		-5.47	10.27	14.18	37.84**	-0.21	2.62
Phule Prajatika × JF 108-02		-2.26	9.15	28.26**	59.46**	4.76**	7.73**
Kashi Kranti × Arka Abhay		-11.42	10.04	-3.45	51.35**	-16.87**	-13.06**
Kashi Kranti × VRO 6		-6.71	16.19	8.62	70.27**	-17.77**	-16.33**
Kashi Kranti × Red One Long		0.91	24.43*	-24.14**	18.92	-11.97**	-10.44**
Kashi Kranti × JF 5		3.64	27.80**	-6.90	45.95**	-17.73**	-16.29**
Kashi Kranti × JF 108-02		-4.49	17.76	-22.41*	21.62	-14.68**	-13.19**
Arka Abhay × VRO 6		-7.53	15.17	-3.57	45.95	-25.30**	-21.88**
Arka Abhay × Red One Long		-2.05	21.67*	-25.00**	13.51	-16.28**	-12.45**
Arka Abhay × JF 5		-7.54	14.86	-23.21*	16.22	-17.12**	-13.32**
Arka Abhay × JF 108-02		-0.76	23.28*	-48.21**	-21.62	-23.09**	-19.56**
VRO 6 × Red One Long		-7.19	15.58	25.00	8.11	-1.43	-6.94**
VRO 6 × JF 5		-15.26	5.54	69.23**	78.38**	-21.76**	-22.93**
VRO 6 × JF 108-02		-15.41	5.35	-2.17	21.62	3.61*	-2.18
Red One Long × JF 5		-3.96	12.03	10.26	16.22	-9.35**	-10.70**
Red One Long × JF 108-02		0.13	15.50	-10.87	10.81	0.93	-5.24**
JF 5 × JF 108-02		-11.82	2.86	-8.70	13.51	-14.32**	-15.59**
Range	Maximum value	7.10	28.75	73.03	78.38	9.19	10.52
	Minimum value	-22.38	-11.82	-48.21	-29.73	-31.04	-29.08
Significant crosses	Positive crosses	0	6	6	17	6	4
	Negative crosses	7	0	12	0	27	30
	Total crosses	7	6	18	17	33	34
S.E. ±		0.70	0.70	0.35	0.35	0.12	0.12

*, ** significant at 5% and 1% levels of probability, respectively

Table 3: Better performing parents (*per se*) and hybrids (*per se*, HB, SH) for different characters

Characters	Parental performance	Top ranking hybrids		
	Per se	***Per se***	**HB**	**SH**
Days to 50 per cent flowering	Phule Prajatika (38.67)	GAO 5 × JF 5 (41.67)	GAO 5 × JF 5 (-4.58)	GAO 5 × JF 5 (-10.71)
	JF 108-02 (42.00)	AOL 13-144 × Phule Prajatika (42.00)	Kashi Kranti × VRO 6 (-3.73)	AOL 13-144 × Phule Prajatika (-10.00)
	GAO 5 (43.67)	GAO 5 × Phule Prajatika (42.67) GAO 5 × JF 108-02 (42.67) Phule Prajatika × JF 5 (42.67)	VRO 6 × Red One Long (-2.24)	GAO 5 × Phule Prajatika (-8.57) Phule Prajatika × JF 5 (-8.57) Phule Prajatika × JF 108-02 (-8.57)
Days to first picking	Phule Prajatika (43.00)	GAO 5 × JF 5 (45.67)	GAO 5 × JF 5 (-4.20)	GAO 5 × JF 5 (-9.87)
	JF 108-02 (46.00)	AOL 13-144 × Phule Prajatika (46.00)	Kashi Kranti × VRO 6 (-2.74)	AOL 13-144 × Phule Prajatika (-9.21)
	GAO 5 (47.67)	GAO 5 × Phule Prajatika (46.67) Phule Prajatika × JF 5 (46.67)	VRO 6 × Red One Long (-2.05)	GAO 5 × Phule Prajatika (-7.89) Phule Prajatika × JF 5 (-7.89)
Number of fruits per plant	VRO 6 (20.60)	AOL 13-144 × VRO 6 (24.07)	GAO 5 × Kashi Kranti (28.26)	AOL 13-144 × VRO 6 (34.20)
	JF 108-02 (20.53)	JF 5 × JF 108-02 (23.67)	AOL 12-59 × JF 5 (25.88)	JF 5 × JF 108-02 (31.97)
	Phule Prajatika (19.67)	Phule Prajatika × JF 108-02 (23.60) GAO 5 × Kashi Kranti (23.60)	Phule Prajatika × JF 5 (19.32)	GAO 5 × Kashi Kranti (31.60)
Fruit length (cm)	JF 5 (15.38)	Kashi Kranti × Arka Abhay (16.01)	AOL 12-59 × JF 108-02 (16.68)	Kashi Kranti × Arka Abhay (24.20)
	GAO 5 (14.92)	Kashi Kranti × VRO 6 (15.85)	VRO 6 × JF 108-02 (10.29)	Kashi Kranti × VRO 6 (22.99)
	Kashi Kranti (14.76)	GAO 5 × Kashi Kranti (15.45)	Kashi Kranti × Arka Abhay (8.49)	Kashi Kranti × Red One Long (22.27)
Fruit girth (cm)	AOL 12-59 (6.22)	AOL 12-59 × AOL 13-144 (6.38)	Kashi Kranti × VRO 6 (8.23)	AOL 12-59 × AOL 13-144 (10.89)
	GAO 5 (6.09)	AOL 13-144 × Phule Prajatika (6.23)	JF 5 × JF 108-02 (5.22)	AOL 13-144 × Phule Prajatika (8.34)
	AOL 13-144 (6.07)	AOL 13-144 × VRO 6 (6.19) AOL 13-144 × JF 5 (6.19)	VRO 6 × JF 108-02 (3.87)	AOL 13-144 × VRO 6 (7.53) AOL 13-144 × JF 5 (7.53)
Fruit weight (g)	Red One Long (16.84)	Phule Prajatika × Red One Long (17.03)	Kashi Kranti × VRO 6 (13.32)	Phule Prajatika × Red One Long (34.16)
	GAO 5 (16.07)	Red One Long × JF 5 (15.79)	VRO 6 × JF 108-02 (7.40)	GAO 5 × Kashi Kranti (33.39)
	Phule Prajatika (15.78)	Arka Abhay × Red One Long (15.38)	GAO 5 × Kashi Kranti (5.39)	GAO 5 × Red One Long (28.88)
Fruit yield per plant (g)	Red One Long (310.87)	GAO 5 × Kashi Kranti (399.93)	GAO 5 × Kashi Kranti (37.09)	GAO 5 × Kashi Kranti (75.51)
	Phule Prajatika (310.27)	Phule Prajatika × Red One Long (368.67)	Kashi Kranti × VRO 6 (30.91)	Phule Prajatika × Red One Long (61.79)
	GAO 5 (291.73)	Phule Prajatika × JF 5 (356.47)	VRO 6 × JF 5 (25.86)	Phule Prajatika × JF 5 (56.44)
Plant height (cm)	Kashi Kranti (158.87)	Arka Abhay × VRO 6 (168.40)	Arka Abhay × VRO 6 (13.32)	Arka Abhay × VRO 6 (45.51)
	Red One Long (150.93)	Kashi Kranti × JF 108-02 (167.87)	Arka Abhay × JF 108-02 (10.61)	Kashi Kranti × JF 108-02 (45.05)
	VRO 6 (148.60)	Kashi Kranti × Arka Abhay (162.07)	AOL 12-59 × JF 108-02 (10.03)	Kashi Kranti × Arka Abhay (40.03)
Number of internodes on main stem	AOL 12-59 (19.67)	Kashi Kranti × Arka Abhay (21.87)	Arka Abhay × VRO 6 (16.89)	Kashi Kranti × Arka Abhay (26.64)
	Red One Long (19.47)	Arka Abhay × VRO 6 (21.80)	Kashi Kranti × Arka Abhay (13.89)	Arka Abhay × VRO 6 (26.25)
	Kashi Kranti (19.20)	AOL 12-59 × VRO 6 (21.67)	VRO 6 × JF 5 (12.24)	AOL 12-59 × VRO 6 (25.48)
Length of internode (cm)	GAO 5 (8.55)	GAO 5 × Red One Long (8.66)	AOL 12-59 × Red One Long (7.10)	GAO 5 × Red One Long (28.75)
	VRO 6 (8.37)	Kashi Kranti × JF 5 (8.59)	Kashi Kranti × JF 5 (3.64)	Kashi Kranti × JF 5 (27.80)
	Arka Abhay (8.35)	AOL 12-59 × Red One Long (8.31)	AOL 13-144 × Red One Long (2.40)	Kashi Kranti × Red One Long (24.43)
Number of primary branches per plant	Kashi Kranti (3.87)	VRO 6 × JF 5 (4.40)	AOL 12-59 × VRO 6 (73.03)	VRO 6 × JF 5 (78.38)
	Arka Abhay (3.73)	AOL 12-59 × VRO 6 (4.38)	VRO 6 × JF 5 (69.23)	AOL 12-59 × VRO 6 (77.70)
	JF 108-02 (3.07)	GAO 5 × AOL 12-59 (4.27)	GAO 5 × AOL 12-59 (60.00)	GAO 5 × AOL 12-59 (72.97)
Crude fiber content (%)	Arka Abhay (7.98)	AOL 12-59 × VRO 6 (8.44)	AOL 12-59 × VRO 6 (9.19)	AOL 12-59 × VRO 6 (10.52)
	Phule Prajatika (7.85)	Phule Prajatika × JF 108-02 (8.22)	GAO 5 × VRO 6 (6.01)	Phule Prajatika × JF 108-02 (7.73)
	Kashi Kranti (7.77)	Phule Prajatika × Red One Long (8.18)	Phule Prajatika × JF 108-02 (4.76)	Phule Prajatika × Red One Long (7.21)

Conclusion

The results of heterosis calculated over better parent and standard check GJOH 4 revealed that superiority of some outstanding cross combinations. A perusal of *per se* performance and heterosis indicated that crosses GAO 5 × Kashi Kranti, Kashi Kranti × VRO 6, Phule Prajatika × Red One Long, VRO 6 × JF 5 and Phule Prajatika × JF 5 found to be most promising for fruit yield and other desirable traits, hence they could be further evaluated to exploit the heterosis or utilized in future breeding programme to obtain desirable segregants for the development of superior genotypes/variety.

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