International Journal of Chemical Studies

P-ISSN: 2349–8528
E-ISSN: 2321–4902
IJCS 2018; 6(5): 1919-1923

Received: 09-07-2018
Accepted: 13-08-2018

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Studies on assessment of heterosis for fruit yield and attributing characters in okra [*Abelmoschus esculentus* (L.) Moench]

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Abstract
Twenty one crosses from 7 × 7 diallel excluding reciprocals were studied to assess the magnitude of heterosis over standard check (SC) for fruit yield and its components in Okra [*Abelmoschus esculentus* (L) Moench]. Analysis of variance for genotypes manifested highly significant differences for different characters which indicating the considerable genetic diversity among the material studied. For total fruit yield per plant standard heterosis ranged from -31.36 to 35.01 per cent and total four hybrids showed positive direction heterosis over standard check. The cross AOL-10-22 x GAO-5 exhibited the highest magnitude of heterosis to the extent of 35.01 per cent over standard check for fruit yield per plant. Other best performing crosses on the basis of merit are AOL-10-22 x VRO-6 (34.15%), HRB-55 x AOL-12-59 (7.94%) and JDNOL-11-01 x Arka Anamika (2.78%) respectively and the crosses can be used for exploitation of hybrid vigor on commercial scale. For number of fruits per plant hybrids AOL-10-22 x GAO-5 (20.69%), AOL-10-22 x VRO-6 (19.83%) and HRB-55 x AOL-12-59 (5.17%) depicted higher heterosis over standard check (HOK-152). The values for standard heterosis for fruits per plant ranged from -27.16 to 20.69 per cent and three crosses exhibited positive standard heterosis. The study reveals good scope for exploitation of heterosis in okra for high yield.

Keywords: heterosis, fruit yield, attributing characters, okra, *Abelmoschus esculentus*

Introduction
Okra [*Abelmoschus esculentus* (L.) Moench] has a prominent position in vegetables due to its wide adaptability, wide popularity, year round export potential and high nutritive value. It is commonly known as Bhindi, lady’s finger or gumbo, being a native of tropical Africa and belongs to family Malvaceae. Okra is an amphidiploids having 2n=130 chromosomes. It is an often cross pollinated crop. Immature fresh and green seed pods are consumed as vegetable. It offers mucilaginous consistency after cooking. Often the extract obtained from the fruit is added to different recipes like soups, stews and sauces to increase the consistency. The immature pods are also used in making pickle. The entire plant is edible and is used to have several foods (Babu and Srinivasan, 1995; Madison, 2008; Lim, 2012; Jain *et al*., 2012; Maramag, 2013) [2, 18, 17, 10, 19]. Okra is widely used in ethno medicine in diverse cultures. In Ayurveda, okra is used as an edible infusion and in different preparation for diuretic effect (Maramag, 2013) [19]. An infusion of the fruit mucilage is also used to treat dysentery and diarrhea in acute inflammation and irritation of the stomach, bowels, and kidneys catarrhal infections ardour urinae, dysuria and gonorrhea. Seeds are used as antispasmodic, cordial and stimulant (Lim, 2012) [17]. Leaves and root extracts are served as demulcent and emollient poultice (Babu and Srinivasan, 1995) [2]. The magnitude of heterosis for yield and its components provides a basis for determining genetic diversity and also 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 placed greater emphasis for the improvement for 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 present study consists of 7 different okra genotypes viz., JDNOL-11-01, AOL-10-12, VRO-6, GAO-5, HRB-55, AOL-12-59 and Arka Anamika. The genotypes are crossed in

diallel fashion excluding reciprocals to produce 21 hybrids in late kharif 2016. These 21 F_1 hybrids evaluated along with their 7 parents and check HOK-152 in Randomized block design in three replications during summer 2017 at university farm, Department of Genetics and Plant Breeding, Navsari Agricultural University, Navsari.

Each plot consisted of a single row of 10 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 stand. The different 14 quantitative characters like Days to 50 per cent flowering, Plant height, Number of primary branches per plant, Number of fruits per plant, Fruit yield per Plant, Fruit weight, Fruit length, Fruit girth, Internodes per plant, Photosynthetic rate, Leaf area, Chlorophyll content, Stomatal conductance and Transpiration rate has been recorded. The various observations were recorded on five competitive plants in each plot leaving border ones.

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 can be further exploited. The hybrids are normally assessed in terms of per cent increase over standard check variety.

The range of heterosis over standard check found to be different for all the characters under study (Table 2). For days to flower, the parents which flowered earlier were considered as better so that negative heterosis were most promising. The quantum of standard heterosis ranged from -6.77 (VRO-6 × GAO-5) to 16.56 (HRB-55 × Arka Anamika) per cent over HOK-152. Out of twenty one hybrids, none of the hybrids depicted significant and negative heterosis over standard check. Among these, VRO-6 × GAO-5 (-6.77%), AOL-12-59 × Arka Anamika (-4.51%), JDNOL-11-01 × AOL-10-22, JDNOL-11-01 × Arka Anamika, VRO-6 × AOL-12-59 and GAO-5 × HRB-55 (-3.74%) were observed as the top ranking promising heterotic hybrids over the standard check for this trait. Similar result has been observed by Khanpara *et al.* (2009) [11], Kumar and sreeparvathy (2010) [16], Medagam *et al.* (2012) [20], Kishor *et al.* (2013) [13], Bhatt *et al.* (2015) [5], Patel (2015) [5], Tiwari *et al*. (2015) [27], Patel and Patel (2016) [21], Devi *et al.* (2017) [8] and Punia *et al.* (2017) [23] for days to 50 per cent flowering.

The extent of standard heterosis for plant height was ranged from -29.63 (JDNOL-11-01 × Arka Anamika) to 25.64 (AOL-10-22 × GAO-5) per cent. Only two hybrids, AOL-10-22 × GAO-5 (25.64%) and AOL-10-22 × VRO-6 (22.15%) exhibited significant and positive heterosis over standard check. The present findings are in close association with results reported by Khanpara *et al*. (2009) [11], Khatik *et al.* (2012) [12], Bhatt *et al.* (2015) [5], Patel (2015) [5], Patel and Patel (2016) [21], Tonde *et al.* (2016) [28], Devi *et al.* (2017) [8], Paul *et al*. (2017) [22] and Punia *et al.* (2017) [23].

For primary branches per plant, positive heterosis is desirable. The range of standard heterosis was varied from -62.50 (GAO-5 × AOL-12-59) to 54.38 (AOL-10-22 × GAO-5) per cent. Among twenty one hybrids, only AOL-10-22 × GAO-5 (54.38%) and AOL-10-22 × VRO-6 (50.00%) show significantly positive heterosis over standard check for this trait. Dhaduk *et al*. (2003) [9], Kumar (2011) [15], Medagam *et al.* (2012) [20], Kishor *et al.* (2013) [13], Bhatt *et al.* (2015) [5] and Tiwari *et al*. (2015) [27] and also reported similar result in okra.

The estimates of standard heterosis for fruits per plant were varied between –27.15 (GAO-5 × HRB-55) to 20.69 (AOL-10-22 × GAO-5) per cent. Among twenty one hybrids, two hybrids AOL-10-22 × GAO-5 (20.69%), AOL-10-22 × VRO-6 (19.78%) found significant and positive standard heterosis. These results are in harmony with the earlier findings of Dhaduk *et al.* (2003) [9], Dahake *et al.* (2007) [7], Khanpara *et al*. (2009) [11], Kumar and Sreeparvathy (2010) [16], Kumar (2011) [15], Kishor *et al.* (2013) [13], Bhatt *et al.* (2015) [5], Patel and Patel (2016) [21], Tonde *et al.* (2016) [28], Devi *et al.* (2017) [8], Paul *et al*. (2017) [22] and Punia *et al.* (2017) [23] for numbers of fruits per plant.

The spectrum of variation for standard heterosis for fruit yield per plant was ranged from -31.36 (AOL-10-22 × HRB-55) to 35.01 (AOL-10-22 × GAO-5) per cent over standard check. AOL-10-22 × GAO-5 (35.01%), AOL-10-22 × VRO-6 (34.15%) and HRB-55 × AOL-12-59 (7.94%) were showed positive and standard heterosis for this trait. Similar observations were reported by Dhaduk *et al.* (2003) [9], Dahake *et al.* (2007) [7], Khanpara *et al*. (2009) [11], Kumar and Sreeparvathy (2010) [16], Ramya and Senthil (2010) [25], Kumar (2011) [15], Kishor *et al.* (2013) [13], Singh *et al*. (2013) [26], Bhatt *et al.* (2015) [5], Patel and Patel (2016) [21], Tonde *et al.* (2017), Devi *et al.* (2017) [8], Paul *et al*. (2017) [22] and Punia *et al.* (2017) [23] for fruit yield per plant.

The quantum of standard heterosis for fruit weight recorded from -18.34 (AOL-10-22 × HRB-55, GAO-5 × Arka Anamika) to 14.22 (AOL-10-22 × GAO-5) per cent over standard check. Among twenty one hybrids, only two hybrids AOL-10-22 × GAO-5 (14.22%), AOL-10-22 × VRO-6 (13.71%) positive standard heterosis for this trait. The present findings are in close association with the results reported by Dhaduk *et al.* (2003) [9], Khanpara *et al*. (2009) [11], Medagam *et al.* (2012) [20], Kishor *et al.* (2013) [13], Bhatt *et al.* (2015) [5], Tiwari *et al*. (2015) [27], Patel and Patel (2016) [21], Tonde *et al.* (2017), Devi *et al.* (2017) [8], Paul *et al*. (2017) [22] and Punia *et al.* (2017) [23].

For fruit length, the minimum and maximum value of heterosis over standard check was -19.77(GAO-5 × Arka Anamika, AOL-12-59 × Arka Anamika) and 12.04 (JDNOL-11-01 × Arka Anamika) per cent respectively. JDNOL-11-01 × Arka Anamika (12.04%), GAO-5 × HRB-55 (8.45%) and JDNOL-11-01 × VRO-6 (4.85%) were exhibited higher heterosis for this trait. The present findings are in close association with the results reported by Khanpara *et al*. (2009) [11], Kumar and Sreeparvathy (2010) [16], Khatik *et al.* (2012) [12], Medagam *et al.* (2012) [20], Kishor *et al.* (2013) [13], Bhatt *et al.* (2015) [5], Patel and Patel (2016) [21], Tonde *et al*. (2017), Devi *et al.* (2017) [8], Paul *et al.* (2017) [22] and Punia *et al.* (2017) [23].

The standard heterosis for fruit girth was varied from -29.17 (GAO-5 × Arka Anamika) to 16.67 (AOL-12-59 × Arka Anamika) per cent. Among twenty one hybrids, only one hybrids AOL-12-59 × Arka Anamika (16.67%) manifested significantly positive standard heterosis. Present findings are in close association with the results of Khanpara *et al.* (2009) [11], Kumar and Sreeparvathy (2010) [16], Kishor *et al.* (2013) [13], Devi *et al.* (2017) [8] and Paul *et al*. (2017) [22].

The range of standard heterosis was fluctuated between -32.48 (GAO-5 × HRB-55) to 11.70 (AOL-10-22 × VRO-6) per cent for fruit yield per plant. Among twenty one hybrids, AOL-10-22 × VRO-6 (11.70%) and AOL-10-22 × GAO-5 (10.24%) exhibited higher and positive standard heterosis.

Similar observations were reported by Dahake *et al.* (2007) [7], Khanpara *et al*. (2009) [11], Khatik *et al.* (2012) [12] and Bhatt *et al.* (2015) [5] for fruit yield per plant.

The spectrum of standard heterosis for photosynthetic rate ranged between -40.39 (AOL-10-22 × HRB-55) to 8.81 (AOL-10-22 × GAO-5) per cent. Only two hybrids, AOL-10-22 × GAO-5 (8.81%) and HRB-55 × AOL-12-59 (2.52%) exhibited positive and higher standard heterosis. The present findings are in close association with the results reported by Bhatt and Rao (1980) [4], and Alkuddsi *et al*. (2013) [1].

For leaf area, the range of standard heterosis was between -25.66 (AOL-10-22 × HRB-55) to 3.44 (AOL-10-22 × GAO-5). None of the hybrids were found to be significant for standard heterosis for this trait. Among hybrids, AOL-10-22 × GAO-5 (3.44%), HRB-55 × AOL-12-59 (2.58%) and AOL-10-22 × VRO-6 (1.70%) were showed higher standard heterosis for this trait. Present findings are in close association with the results of Borgaonkar *et al.* (2013).

For chlorophyll the quantum of standard heterosis for chlorophyll content was from -46.76 (AOL-10-22 × HRB-55) to 18.95 (AOL-10-22 × GAO-5) per cent over. Only two hybrids, AOL-10-22 × GAO-5 (18.94%) and HRB-55 × AOL-12-59 (8.06%) showed significantly positive standard heterosis. Present findings are in close association with the result of Bhati *et al.* (2015) [3].

For stomatal conductance, the range of standard heterosis observed from -26.28 (JDNOL-11-01 × GAO-5) to 4.08 (AOL-10-22 × GAO-5) per cent. Out of twenty one hybrids, total three hybrids exhibited positive direction standard heterosis. AOL-10-22 × GAO-5 (4.08%) was found to be best heterotic cross combination for stomatal conductance followed by HRB-55 × AOL-12-59 (3.28%) and AOL-10-22 × VRO-6 (2.06%). Present findings are in close association with the results of Konda *et al.* (1998) [14], Rajagopal *et al*. (1998) [24] and Alkuddsi *et al*. (2013) [1].

The heterosis for transpiration rate was fluctuated between -48.20 (AOL-10-22 × HRB-55) to 20.11 (AOL-10-22 × VRO-6) per cent over HOK-152. Crosses AOL-10-22 × VRO-6 (20.11%), AOL-10-22 × GAO-5 (11.39%) and HRB-55 × AOL-12-59 (10.06%) exhibited desired directional standard heterosis for this trait. Present findings are in close association with the results of Konda *et al.* (1998) [14], Rajagopal *et al*. (1998) [24] and Alkuddsi *et al*. (2013) [1].

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

Sources of variation	d.f.	Days to 50% flowering	Plant height (cm)	Primary branches per plant	Fruits per plant	Fruit yield per plant (g)	Fruit weight (g)	Fruit length (cm)
Replications	2	14.62	81.71	0.043	1.59	1.87	0.59	0.84
Genotypes	27	25.39**	389.95**	0.45**	9.82**	3591.48**	3.99**	2.84**
Parents	6	24.27*	137.49*	0.22**	7.01*	2590.67**	3.84*	1.77
Hybrids	20	22.48**	461.53**	0.52**	11.15**	3724.65**	3.69**	3.08**
Parents *Vs*. Hybrids	1	90.48**	473.09**	0.22*	0.036	6933.37**	10.94**	4.27*
Error	54	7.74	58.96	0.04	2.91	326.82	1.30	1.04

Sources of variation	d.f	Fruit girth (cm)	Internodes per plant	Photosynthetic rate (μ mole/m²)	Leaf area (cm²)	Chlorophyll content (SPAD reading)	Stomatal conductance (μmole/m²/sec)	Transpiration rate
Replications	2	0.17	0.78	3.72	3.40	5.34	73.15	0.01
Genotypes	27	1.20**	6.93**	53.60**	148.31**	121.19**	468.48**	2.79**
Parents	6	1.61**	4.93	52.95**	65.40	100.72**	542.17**	2.95**
Hybrids	20	1.08**	7.86**	56.20**	179.22**	119.96**	464.98**	2.79**
Parents *Vs*. Hybrids	1	1.12*	0.39	5.55	27.69	268.54**	96.47	2.14*
Error	54	0.16	2.99	9.05	29.33	3.51	62.40	0.034

Table 2: Estimation of per cent heterosis over standard check (SC) for various characters of okra

Crosses	Days to 50% flowering	Plant height (cm)	Primary branches per plant	Fruits per plant	Fruit yield per plant (g)	Fruit weight (g)	Fruit length (cm)
	Heterosis over standard check (SC)						
JDNOL-11-01 × AOL-10-22	-3.74	-12.83	0.00	-6.08	-1.17	3.43	3.05
JDNOL-11-01 × VRO-6	-3.00	-15.11*	-12.50	-12.54	-5.56	-9.17	4.85
JDNOL-11-01 × GAO-5	-2.26	-24.69**	-12.50	-18.10*	-23.36**	-8.57	-4.76
JDNOL-11-01 × HRB-55	3.02	-13.16	0.00	-17.71	-16.62*	0.00	-8.36
JDNOL-11-01 × AOL-12-59	0.00	-7.17	-25.00*	-9.95	-15.79	-1.20	-0.54
JDNOL-11-01 × Arka Anamika	-3.74	-29.63**	-12.50	-6.46	2.78	3.43	12.04
AOL-10-22 × VRO-6	-3.00	22.15**	50.00**	19.78*	34.15**	13.71	-2.96
AOL-10-22 × GAO-5	-2.26	25.64**	54.38**	20.69*	35.01**	14.22	1.80
AOL-10-22 × HRB-55	0.00	-19.59**	-12.50	-17.71	-31.36**	-18.34*	-16.71*
AOL-10-22 × AOL-12-59	2.26	-16.53*	-12.50	-11.64	-9.62	2.83	-3.59
AOL-10-22 × Arka Anamika	9.79	-19.43**	-25.00*	-16.42	-28.36**	-11.48	-5.39
VRO-6 × GAO-5	-6.77	-16.08*	4.37	0.00	-0.70	-1.20	2.43
VRO-6 × HRB-55	14.30**	-23.29**	-4.38	-9.95	-24.91**	-13.71	-3.59
VRO-6 × AOL-12-59	-3.74	-14.60*	4.37	-19.00*	-1.46	-4.63	-9.52
VRO-6 × Arka Anamika	3.77	-23.78**	12.50	-20.30*	-26.65**	-15.42	-7.19
GAO-5 × HRB-55	-3.74	-20.46**	-50.00**	-27.15*	-9.02	-10.28	8.45
GAO-5 × AOL-12-59	-2.26	-14.49*	-62.50**	-16.81	-15.42	-0.60	4.22
GAO-5 × Arka Anamika	2.26	-16.49*	-16.88	-17.71	-30.89**	-18.34*	-19.77*
HRB-55 × AOL-12-59	-2.26	-27.62**	-12.50	5.17	7.94	3.94	-12.58
HRB-55 × Arka Anamika	16.56**	-8.29	0.00	-8.21	-13.78	-6.86	-17.34*
AOL-12-59 × Arka Anamika	-4.51	-16.18*	-12.50	-19.84*	-29.38**	-14.91	-19.77*

Table 2: contd….

Crosses	Fruit girth (cm)	Internodes per plant	Photosynthetic rate (μ mole/m²)	Leaf area (cm²)	Chlorophyll content (SPAD reading)	Stomatal conductance (μmole/m²/sec)	Transpiration rate
	Heterosis over standard check (SC)						
JDNOL-11-01 × AOL-10-22	-25.00**	-6.88	-6.22	-1.74	-6.91	-12.97**	-6.45
JDNOL-11-01 × VRO-6	-4.17	-12.73	-29.79**	-15.83**	-31.66**	-13.94**	-21.63*
JDNOL-11-01 × GAO-5	-20.83**	-17.56	-36.53**	-24.22**	-39.82**	-26.28**	-39.28**
JDNOL-11-01 × HRB-55	-8.33	-14.19	-29.13**	-14.75**	-26.63**	-13.39**	-14.04
JDNOL-11-01 × AOL-12-59	4.17	-5.85	-12.14	-7.92	-20.05**	-7.63	-1.33
JDNOL-11-01 × Arka Anamika	-12.50	-7.32	-4.32	-5.10	-9.57*	-5.81	-6.45
AOL-10-22 × VRO-6	-25.00**	11.70	-0.46	1.70	-2.32	2.06	20.11*
AOL-10-22 × GAO-5	-8.33	10.24	8.81	3.44	18.95**	4.08	11.39
AOL-10-22 × HRB-55	-20.83**	-22.97*	-40.39**	-25.66**	-46.76**	-24.73**	-48.20**
AOL-10-22 × AOL-12-59	0.00	-14.63	-20.59*	-9.06	-18.44**	-9.59*	-15.18
AOL-10-22 × Arka Anamika	-16.67*	-23.92*	-30.93**	-18.94**	-34.95**	-19.72**	-33.02**
VRO-6 × GAO-5	-25.00**	-9.80	-4.55	-2.12	-12.27**	-3.03	7.59
VRO-6 × HRB-55	-20.83**	-12.73	-27.23**	-17.03**	-25.03**	-14.38**	-21.63*
VRO-6 × AOL-12-59	12.50	-14.19	-23.63**	-12.07*	-19.67**	-7.73	-18.98*
VRO-6 × Arka Anamika	8.33	-20.04	-33.06**	-24.64**	-35.23**	-20.88**	-33.02**
GAO-5 × HRB-55	-12.50	-32.48**	-26.32**	-22.17**	-29.62**	-20.61**	-31.69**
GAO-5 × AOL-12-59	4.17	-12.73	-27.43**	-11.27*	-21.40**	-8.92	-17.84
GAO-5 × Arka Anamika	0.00	-16.61	-33.81**	-23.46**	-36.58**	-23.74**	-37.95**
HRB-55 × AOL-12-59	-20.83**	3.88	2.52	2.58	8.06*	3.28	10.06
HRB-55 × Arka Anamika	-8.33	-9.80	-23.21**	-9.78	-21.40**	-11.71*	-18.98*
AOL-12-59 × Arka Anamika	16.67*	-20.48	-26.28**	-14.47**	-31.40**	-16.86**	-21.63*

* Significant at 5% level, ** Significant at 1% level

Conclusion
The present study concludes that that these crosses AOL-10-22 × GAO-5 and AOL-10-22 × VRO-6 were found to be most promising for fruit yield and other desirable traits, hence could be further evaluated in heterosis breeding programme and simultaneously could be advanced in segregating generations to obtain desirable segregants for the development of superior genotypes in okra genetic improvement.

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