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HETEROSIS AND POTENCE RATIO OF MALE STERILITY AND FERTILITY LINE BASED HYBRIDS OF OKRA [*ABELMOSCHUS ESCULENTUS* (L.) MOENCH] FOR YIELD AND ITS COMPONENTS

[*1]Mahesh Badiger, [2]Parvati Pujer, [1]Gangadhar Rao, P., [1]Pradeep Kumar Jatav and [c] Pitchaimuthu, M.
[1]Division of Vegetable Science, ICAR-Indian Agricultural Research Institute, New Delhi, India- 110012
[2] Department of biotechnology and crop improvement, University of Horticultural Sciences, Bagalkot, India- 587104
[3] Division of Vegetable Crops, ICAR-Indian Institute of Horticultural Research, Bangalore, India- 560089
*Corresponding author email: maheshhort536@gmail.com

ABSTRACT
Present investigation was undertaken to estimate the potential of heterosis and potence ratio in total 35 okra hybrids consisting of 10 Genic Male Sterility (GMS) based hybrids. ANOVA for Line x Tester analysis revealed the presence sufficient genetic diversity for different traits in the experimental material used which eventually reflected via broader range of mid parent heterosis obtained in both positive and negative direction. Degree of dominance based on potence ratio manifested over dominance for Total yield per plant. None of the hybrid showed heterotic effects for all the traits consistently. However, based on total yield per plant (TY/P) five crosses naming IIHR-294 x JNDO-5 (107.74 %), GMS-1 X Varsha Uphar (94.16 %), IIHR-294 x Varsha Uphar (88.19 %), IIHR -294 X Parbhani Kranti (60.07 %) and GMS-1 x Parbhani Kranti (55.89 %) in their order of merit found to be most promising along with high magnitude of heterosis for other desirable traits in desired direction. Out of these top five hybrids (GMS -1 X Varsha Uphar) and (GMS-1 x Parbhani Kranti) are being GMS based hybrids, offering greater advantage of easy and economic hybrid seed production on commercial scale. Present study explicitly revealed the scope for improving okra productivity trough heterosis breeding and prospective role of GMS system in it.

KEYWORDS: *Abelmoschus esculentus*, Genic male sterility, Heterosis, Okra and Potence Ratio.

INTRODUCTION

Okra [*Abelmoschus esculentus* (L.) Moench] is an annual herbaceous plant, native of tropical Africa grown extensively in tropics, sub-tropics and warmer seasons of the temperate areas in the world. Okra immature fruits can be used in various culinary preparations, curing goitre, leaves as remedy for dysentery and stems in clearing cane juice. The mucilage of okra binds cholesterol and bile acid carrying toxins dumped into it by the liver (Maramag *et al.,* 2013). Apart from nutritional and health importance, okra has great potential as foreign exchange earner and accounts for about 60% of the export of fresh vegetables from India to the Middle East and European countries (Singh *et al*., 2014). India is the largest producer of okra with 6.35 million tonnes production (72.9% of total world production) from 0.53 million hectare area (Anon, 2015).

Although India is leading producer of okra in the world, its productivity potential is low. To break productivity plateau development of F_1 hybrids through heterosis breeding is the better option. Vijayraghvan and Warier (1946) are first to report its occurrence of heterosis in okra and suggested that heterosis breeding is the quickest possible way of improving productivity of okra. Okra is being an often cross-pollinated crop, responds well to heterosis breeding. Relative heterosis (mid parent heterosis, average heterosis) is the superiority of a hybrid over its mid parent value will help in understanding the genetic status of the yield and its component characters (Moll and Stuber, 1974). Hence, knowledge of heterosis along with estimates of potence ratio which shed light about degree of dominance will yield more meaningful results to breeders for practical utility and exploitation of heterosis. In spite of presence of heterosis, its exploitation will take practical shape only when their F_1 hybrid seeds are produced at an affordable cost. In India, traditionally okra F_1 hybrid seeds are produced by hand emasculation and hand pollination which is apart from being very laborious and tedious process, inflates hybrid seed cost and reduces its commercial acceptance. But now there is availability of Genic Male Sterile (GMS) okra lines at Indian Institute of Horticultural Research (IIHR) is the first report in the world which makes the okra hybrid seed production more easy, economic and commercially feasible (Pitchaimuthu *et al.,* 2012). Male sterility in okra has been induced by gamma radiation and is conditioned by single recessive gene (ms_1) (Dutta, 1976). The gene is stable and not influenced by environmental factors. Therefore, the present investigation was undertaken to estimate the potential of heterosis and potence ratio in okra hybrids including novel GMS based hybrids.

MATERIALS & METHODS

Experimental material

Experimental material comprised of seven elite lines (IIHR-285, IIHR-291, IIHR-294, IIHR-296, IIHR-299, GMS-1 and GMS-4) developed at IIHR-Bangalore and five broad based testers (VRO-6, Parbhani Kranti, Arka

Anamika, JNDO-5 and Varsha Uphar). Thirty five hybrids were developed by crossing 7 lines and 5 testers in line x testers fashion during first season. Hybrid seeds of male fertility based lines were produced by conventional hand emasculation and hand pollination. While in case of GMS lines (GMS-1 and GMS-4), male fertile segregants were rouged out at the onset of flowering and hybrid seeds were produced by hand pollination without hand emasculation (Fig. 1). Total 35 hybrids along with parents (12) were evaluated in randomized block design with three replications during second season. Recommended agronomic practices and need based plant protection measures were taken.

Experimental data

Five plants of each entry in each replication were randomly selected for recording the observations on 13 yield and its component characters. Data were recorded on days to first flowering (DFF), days to first harvest (DFH), node at first flower appeared (NFF), plant height (PH) (cm), internodal length (INL) (cm), number of branches per plant (NB/P), final stem girth (FSG) (cm), average fruit weight (AFW) (g), number of fruits per plant (NF/P), fruit length (FL) (cm), fruit girth (FG) (cm), marketable yield per plant (MY/P) (g) and total yield per plant (TY/P) (g). The data recorded were used to analyze genetic parameters like Line x Tester ANOVA, mid parent heterosis and potence ratio.

Statistical analysis and estimation of genetic parameters

Estimation of Line x Tester ANOVA

Data of all the previously mentioned characters were arranged and statistically analyzed to get ANOVA for line x tester analysis as per the model suggested by Kempthorne (1957) using statistical software package SPAR 2.0.

Estimation of heterosis percentages

Heterosis percentages, relative to the mid-parents, for the different studied characters were calculated using the procedure illustrated by Mather and Jinks (1971) as follows:

$$\text{Mid parent heterosis (\%)} = \frac{F_1 - M.P.}{M.P.} \times 100$$

Where F_1 = mean value of the particular hybrid population. M.P. = mean value of the two parents for that hybrid (P1 + P2)/2.

Estimation of potence ratio

Potence ratio was calculated according to Smith (1952) to determine the degree of dominance as follows:

$$P = \frac{F_1 - M.P.}{0.5\,(P_2 - P_1)}$$

Where P: relative potence of gene set, F1: first generation mean, P1: the mean of lower parent, P2: the mean of higher parent, M.P.: mid-parents value = (P1 + P2)/2.

Complete dominance was indicated when P = +1; while partial dominance is indicated when "P" is between (−1 and +1), except the value zero, which indicates absence of dominance. Overdominance was considered when potence ratio exceeds ±1. The positive and negative signs indicate the direction of dominance of either parent.

RESULTS & DISCUSSION

ANOVA for Line x Tester analysis

Mean squares (Table 1) due to genotypic differences found significant for all the traits studied except for FG. This indicated that the experimental material under study had sufficient genetic diversity for different traits. Further, partitioning of sum of squares due to genotypes indicated that the differences among parents and among hybrids were significant for most of the characters under study. While, mean squares due to parents vs. hybrids were significant for TY/P, MY/P, FL, NF/P, AFW, PH, DFF and DFH is the indication of prevalence heterosis for yield, earliness and its components.

Heterosis percentages (relative to the mid parent)

Estimates of mid parent heterosis for 13 characters studied is presented in the table 2. In case of okra, for earliness traits like DFF, DFH and NFF heterosis in negative direction is desirable to catch early market. Range of the mid parent heterosis was -5.39 to 16.02 for DFF, -10.64 to 21.74 for DFH and -20.69 to 80.06 for NFF. The cross IIHR-291 x JNDO-5 showed significantly highest negative heterosis for DFF, IIHR-296 x Varsha Uphar for DFH and IIHR-299 x Arka Anamika for NFF. The negative heterosis for these traits also revealed that that the hybrids are early matured types than their parents. For growth parameters like PH, INL, NB/P and FSG range of mid parent heterosis was -29.351 to 26.67, -33.19 to 58.4, -31.37 to 31.08 and -20.84 to 24.70 respectively. Out of thirty five hybrids, significantly higher positive (desirable) heterosis was observed in 18 hybrids for PH, 10 for NB/P and 25 hybrids for FSG. While significantly higher negative (desirable) heterosis was observed in 19 hybrids for INL with highest being recorded in IIHR-299 x Arka Anamika. Highest significant and positive mid parent heterosis was recorded by cross IIHR-294 x JNDO-5 for PH and NB/P and GMS-4 x JNDO-5 for FSG. The magnitude of heterosis over mid parent was highly significant in both the directions for above traits is the indication of varied degree of dominance involved in the inheritance of above traits. These results corroborated with findings of Jindal *et al.* (2009) and Singh *et al.* (2012), Hazem *et al.* (2013), Hosamani *et al.* (2008) and Krushna *et al.* (2007).

The cross IIHR-294 x JNDO-5 showed significant highest positive (desirable) heterosis over mid parent for NF/P and FG with range from -30.71 to 61.19 and -24.02 to 18.36 respectively. Cross GMS-1 x Arka Anamika and IIHR-291 x JNDO-5 gave highest positive heterosis for AFW and FL with the range -25.27 to 42.44 and -24.02 to 18.36 respectively.

TABLE 1: ANOVA for Line x Tester analysis in okra

Source	df	DFF	DFH	NFF	PH	INL	NB/P	FSG	AFW	NF/P	FL	FG	MY/P	TY/P
Replications	2	1.79	25.73**	0.68	57.03**	0.99	0.37	2.75	4.14 *	0.81	2.53	0.02	2623.02 **	2935.00 **
Genotypes	46	15.19**	34.15**	1.50 *	552.63**	2.01**	2.25 **	0.11	24.92**	31.26**	9.51**	0.29	3956.67**	4236.57**
Parents	11	17.23**	45.00**	3.10**	478.13**	1.05	0.10	0.12	34.13**	14.51**	10.89**	0.51	2809.61**	2729.53**
Lines	6	70.55**	237.59**	9.75**	1247.04**	1.75	0.01	0.57	11.19**	1.98	11.97**	0.38	10728.11**	19008.01**
Testers	4	12.90**	24.65**	0.74	556.31**	2.53**	2.01	0.10	22.35**	37.54**	8.99**	0.22	4128.61**	4289.69**
Line Vs. Tester	24	21.16**	43.04**	1.09	685.81**	1.86 *	0.26	0.10	10.65**	38.12**	4.04**	0.42	13566.74**	14719.17**
Hybrids	34	11.66**	32.16**	0.86	594.90**	2.48*	2.8*	0.23	58.93**	31.74**	21.94**	0.18**	1848.65**	2442.67**
Parents Vs Hybrids	1	11.04**	18.81**	0.64	517.49**	2.42	2.03	0.08	19.18**	38.36**	8.08**	0.17	2149.07**	1990.15**
Error	92	10.20	7.89	0.22	34.38	0.24	0.11	0.07	3.23	1.90	2.38	0.06	700.60	675.17

*and** indicate significance of values at p=0.05 and p=0.01, respectively.

DFF	Days to first flowering	INL	Internodal length (cm)	NF/P	No. of fruits per plant
DFH	Days to first harvest	NBP	Number of branches/plant	FL	Fruit length (cm)
NFF	Node at first flower appear	FSG	Final stem girth (cm)	FG	Fruit girth (cm)
PH	Plant height (cm)	AFW	Average fruit weight (g)	MY/P	Marketable yield/plant (g)
				TY/P	Total yield/plant (g)

TABLE 2: Heterosis percentages (relative to the mid parent) for 13 quantitative traits in okra

Crosses	DFF	DFH	NFF	PH	INL	NB/P	FSG	AFW	NF/P	FL (cm)	FG (cm)	MY/P (g)	TY/P (g)
IIHR -285 X VRO 6	13.30**	5.19*	-1.80**	-7.94	25.71**	-15.15**	-4.98**	-17.9**	-2.86*	-2.50*	-3.39**	7.84	3.99
IIHR -285 X Parbhani Kranti	7.21**	7.69**	-9.31**	-8.09	6.42**	-4.17**	-4.25**	-21.4**	-3.02**	-19.6**	9.92**	-2.95	-5.81
IIHR -285 X Arka Anamika	9.73**	1.81	-1.05**	-6.09	-22.61**	-27.55**	-10.0**	-12.1**	-3.41**	-8.64**	14.75**	57.71**	49.52*
IIHR -285 X JNDO 5	8.30**	11.03**	-2.20**	6.90	11.96**	-7.53**	2.38**	-16.9**	25.66**	-10.2**	31.58**	28.62	29.30
IIHR -285 X Varsha Uphar	1.74	-1.81	-6.59**	-3.95	58.40**	-7.07**	10.91**	-3.24*	-13.0**	-24.0**	-16.8**	71.30**	55.87**
IIHR -291 X VRO 6	2.04	2.41	3.31**	-13.0**	-23.20**	-15.38**	-20.2**	-4.55**	2.00	6.31**	3.28**	29.22	31.86
IIHR -291 X Parbhani Kranti	13.68**	6.91**	-11.2**	-15.9**	-32.10**	2.97**	-20.8**	-24.4**	-8.50**	10.08**	-12.5**	40.83	31.70
IIHR -291 X Arka Anamika	-5.24*	-3.94	-5.01**	-14.8**	-21.00**	-12.62**	15.15**	41.94**	-30.3**	1.13	1.59**	36.51	41.67
IIHR -291 X JNDO 5	-5.39*	0.73	-4.08**	-8.46	20.08**	-6.12**	-5.78**	19.79**	-15.5**	18.36**	18.64**	18.91	24.48
IIHR -291 X Varsha Uphar	2.48	3.94	22.77**	-9.00	-3.33**	5.77**	7.87**	3.24*	-2.41*	-10.6**	-3.88**	43.73*	45.76**
IIHR -294 X VRO 6	4.31	6.76**	-8.36**	-12.0*	-19.38**	-23.23**	6.52**	11.83**	0.48	-1.61	7.69**	62.88**	53.86**
IIHR -294 X Parbhani Kranti	10.41**	-1.13	-8.72**	9.6*	-10.41**	24.48**	-1.00**	-16.7**	38.65**	-5.88**	1.54**	75.14**	60.07**
IIHR -294 X Arka Anamika	8.44**	11.52**	-15.5**	-6.89	-15.21**	4.08**	1.25**	10.54**	-26.0**	1.08	9.09**	44.47*	43.35*
IIHR -294 X JNDO 5	7.02**	14.39**	-16.3**	26.7**	27.73**	31.08**	20.45**	-1.78**	61.19**	-22.7**	18.58**	118.12**	107.74**
IIHR -294 X Varsha Uphar	-0.44	2.60	-13.1**	-27.1**	-6.46**	-5.05**	-1.90**	-11.9**	28.25**	-19.6**	-1.61**	101.06**	88.19**
IIHR -296 X VRO 6	2.93	2.72	-5.69**	1.40	46.73**	-5.05**	-3.29**	29.95**	-27.9**	2.42	-11.0**	43.68*	26.10
IIHR -296 X Parbhani Kranti	13.16**	8.63**	-6.64**	-17.0**	57.33**	2.08**	-0.19	-13.7**	7.68**	4.02*	-18.5**	12.02	0.69
IIHR -296 X Arka Anamika	7.76**	5.67*	6.24**	-11.9*	19.01**	-6.12**	11.19**	10.22**	-30.7**	2.94*	-12.3**	48.79*	37.24
IIHR -296 X JNDO 5	1.28	3.25	-3.97**	-2.55	8.40**	1.08**	16.56**	28.19**	-22.3**	-21.2**	-2.44**	25.01	15.98
IIHR -296 X Varsha Uphar	-1.69	-10.64**	-0.44	-20.1**	8.23**	-1.01**	24.43**	13.66**	16.15**	-6.07**	-22.7**	41.50	31.54
IIHR -299 X VRO 6	-2.40	-8.31**	38.53**	-18.4**	4.35**	-31.37**	-0.72**	-17.7**	11.35**	-4.17**	13.84**	-0.54	0.28
IIHR -299 X Parbhani Kranti	2.09	3.16	-9.13**	-29.5**	-20.87**	7.07**	-7.71**	-25.2**	14.86**	0.26	-44.9**	18.59	17.88
IIHR -299 X Arka Anamika	6.17*	7.27**	-20.6**	-15.2**	-33.19**	-2.97**	13.53**	-10.6**	-12.4**	2.39	3.21**	34.46	27.21
IIHR -299 X JNDO 5	1.63	-4.23	-20.1**	-9.7*	-18.92**	2.08**	6.30**	-1.34**	6.89**	-10.7**	-23.7**	70.23**	59.50**
IIHR -299 X Varsha Uphar	5.26*	1.04	-17.0**	-22.3**	5.16**	-7.84**	18.76**	-13.2**	7.57**	-18.5**	-15.8**	49.82*	44.02*
GMS -1 X VRO 6	4.96	2.30	80.80**	-8.59	1.89**	-13.88**	-1.98**	-20.3**	8.91**	-8.95**	-34.4**	36.90	23.76
GMS -1 X Parbhani Kranti	16.02**	12.11**	-5.04**	-12.2*	2.06**	4.43**	-2.17**	-22.6**	1.39**	1.42	5.43**	78.15**	55.89**
GMS -1 X Arka Anamika	-2.98	-9.90**	33.67**	-1.32	-3.16**	-9.18**	-3.48**	42.44**	-25.8**	0.22	-3.33**	28.77	29.12
GMS -1 X JNDO 5	-2.52	4.17	-7.61**	-10.7*	19.58**	-8.73**	9.23**	-10.8**	24.64**	-15.3**	-25.0**	59.70**	52.88*
GMS -1 X Varsha Uphar	11.30**	9.22**	6.79**	7.40	-8.25**	-4.31**	21.80**	4.06**	26.38**	-7.54**	-12.2**	107.68**	94.16**
GMS -4 X VRO 6	10.55**	13.19**	56.90**	-18.8**	-23.33**	-6.22**	1.49**	-8.29**	19.32**	-6.50**	5.26**	20.13	25.95
GMS -4 X Parbhani Kranti	2.65	5.15*	43.90**	-26.1**	-26.25**	-7.39**	5.79**	-23.9**	11.73**	6.33**	5.51**	11.03	18.07
GMS -4 X Arka Anamika	12.17**	18.84**	22.83**	-22.4**	-14.45**	-5.31**	16.18**	34.98**	0.00	-2.58*	-5.08**	11.93	20.75
GMS -4 X JNDO 5	3.86	9.96**	1.47**	-14.4**	-4.02**	-4.57**	27.40**	-19.8**	27.91**	-19.8**	45.45**	15.90	15.09
GMS -4 X Varsha Uphar	12.82**	21.74**	7.05**	-17.0**	-21.77**	2.68**	2.53**	1.19	40.69**	8.21**	9.09**	67.39**	55.44*
SEm±	**1.84**	**1.62**	**0.27**	**3.39**	**0.28**	**0.19**	**0.15**	**1.04**	**0.80**	**0.89**	**0.14**	**15.28**	**15.00**
CD at 5%	**5.19**	**4.56**	**0.76**	**9.53**	**0.79**	**0.53**	**0.43**	**2.92**	**2.24**	**2.51**	**0.38**	**43.00**	**42.21**
CD at 1%	**6.86**	**6.03**	**1.00**	**12.59**	**1.05**	**0.70**	**0.57**	**3.86**	**2.96**	**3.31**	**0.51**	**56.83**	**55.79**

*and** indicate significance of values at p=0.05 and p=0.01, respectively.

TABLE 3: ***Potence ratio***

Crosses	DFF	DFH	NFF	PH	INL	NB/P	FSG	AFW	NF/P	FL	FG	MY/P	TY/P
IIHR -285 X VRO 6	10.3	15	-0.37	-1.71	3.33	-2.97	-0.7	-12.68	-0.14	-1.46	-0.33	7.62	3.25
IIHR -285 X Parbhani Kranti	2	1.4	-2.54	-0.56	0.47	-1.95	-2.94	-59.77	-0.26	-5.95	14.44	-0.63	-0.83
IIHR -285 X Arka Anamika	5.51	0.45	-0.23	-0.36	-0.97	-6.67	-37.33	-0.92	-4.16	-4.44	2.22	13.11	15.57
IIHR -285 X JNDO 5	19.19	1.88	-0.3	0.62	5.87	-7.37	0.79	-5.53	1.1	-1.12	2.24	13.05	24.17
IIHR -285 X Varsha Uphar	-400	-0.45	-0.58	-1.03	6.11	-1.39	8.64	-13.94	-1.02	-8.5	-4.12	22.13	27.27
IIHR -291 X VRO 6	0.56	6.93	1.83	-7.33	-1.35	-32.0	-5.04	-0.56	0.08	1.14	0.25	8.09	81.59
IIHR -291 X Parbhani Kranti	1.6	1.12	-20	-1.36	-2.83	0.98	-4.58	-2.67	-0.48	2.59	-5.67	19.49	5.87
IIHR -291 X Arka Anamika	-0.75	-0.85	-3.23	-1.04	-14.6	-12.38	4.49	11.41	-5.47	-0.21	0.17	20.05	26.63
IIHR -291 X JNDO 5	-1	0.11	-0.99	-1.03	0.89	3.95	-69	1.58	-0.53	-9.63	1.1	48.4	60.52
IIHR -291 X Varsha Uphar	0.5	0.85	2.78	-9.39	-0.22	12.0	1.8	0.33	-0.13	-2.43	-0.56	7.54	12.49
IIHR -294 X VRO 6	2.5	2.11	-0.6	-4.74	-8.33	-4.55	0.88	2.21	0.02	-1.17	0.83	4.32	2.74
IIHR -294 X Parbhani Kranti	3.29	-0.43	-0.69	1.3	-1.25	11.46	-0.85	-2.6	2.93	-1.52	0.95	3.74	2.39
IIHR -294 X Arka Anamika	6.33	10.37	-1.14	-0.69	-0.84	0.99	0.89	1.64	-32.6	-12.34	1.59	2.24	2.01
IIHR -294 X JNDO-5	0.6	4.76	-1.01	6.8	8.24	30.53	6.21	-0.18	2.47	-2.1	1.41	6.68	5.48
IIHR -294 X Varsha Uphar	-1	2.34	-0.65	-8.09	-1.55	-0.99	-1.91	-1.71	1.96	-3.86	-0.51	8.16	5.35
IIHR -296 X VRO 6	2.34	2	-3.14	0.65	2.77	-0.99	-0.28	2.25	-1.2	-0.85	-1.44	3.74	3.88
IIHR -296 X Parbhani Kranti	2.14	1.2	-11.82	-2.18	2.54	0.98	-0.06	-0.95	0.52	-0.4	-5.64	0.7	0.06
IIHR -296 X Arka Anamika	1.8	1	4.03	-1.15	0.6	-1.48	2.49	6.45	-12.96	-22.97	-3.06	2.87	4.3
IIHR -296 X JNDO 5	0.43	0.43	-0.96	-0.59	0.74	1.05	2.13	1.59	-0.85	-2.17	-0.21	1.68	2.38
IIHR -296 X Varsha Uphar	-0.67	-1.87	-0.05	-6.77	0.44	-0.2	6.97	0.91	1.01	-2.08	-15.39	4.36	9.13
IIHR -299 X VRO 6	-0.43	-2.27	2.12	-4.96	0.53	-15.61	-0.24	-3.51	0.91	-4.95	1.93	-0.02	0.01
IIHR -299 X Parbhani Kranti	0.2	0.33	-0.54	-4.69	-9.62	7.37	-1.39	-4.13	4.04	0.1	-11.92	0.65	0.72
IIHR -299 X Arka Anamika	0.71	0.91	-1.15	-1.72	-4.27	-2.86	3.1	-1.59	-1.42	-0.18	0.9	1.21	1.28
IIHR -299 X JNDO 5	0.22	-0.43	-0.99	3.54	-1.38	0.51	5.85	-0.14	0.44	-1.26	-2.15	2.65	3.07
IIHR -299 X Varsha Uphar	0.76	0.13	-0.7	-4.93	0.82	-3.9	3.5	1.97	1.53	-9.33	-16	2.33	2.71
GMS -1 X VRO 6	2	0.47	16	-2.04	0.85	-29	-0.29	-9.09	0.47	-6.64	-4	4.75	3.64
GMS -1 X Parbhani Kranti	2.18	1.13	-1.32	-2.11	0.55	1.29	-1.26	-19.15	0.14	0.48	2.33	5.83	4.57
GMS -1 X Arka Anamika	-0.54	-1.07	7.03	-0.16	-0.23	-6.33	-6.5	3.04	-12.08	-0.91	-0.67	2.19	3.44
GMS -1 X JNDO 5	-0.6	0.38	-1.03	-4.73	2.48	-1.32	3.34	-4.83	1.12	-1.7	-2	5.44	8.12
GMS -1 X Varsha Uphar	3	1	0.6	1.47	-22.7	-9	14.24	6.87	2.28	-3.03	-5	19.28	28.7
GMS -4 X VRO 6	24.75	19.1	9.88	-6.9	-2.8	-13	0.21	-28.13	2.28	-1.97	0.76	9.57	7.94
GMS -4 X Parbhani Kranti	0.5	1	9.72	-2.06	-11.11	-2.14	4	-17.68	37.67	3.78	1.37	1.41	2
GMS -4 X Arka Anamika	3.5	5.19	4.15	-1.47	-1.91	-3.67	60.33	3.05	0	-0.7	-1.54	1.59	3.98
GMS -4 X JNDO 5	1.8	1.8	0.18	-1.57	-0.29	-0.69	9.06	-4.16	2.4	-4.5	4.2	2.99	4.64
GMS -4 X Varsha Uphar	7.48	5.99	0.58	-8.87	-3.36	5.6	2	0.61	43	3.81	12.22	74.56	77.69

FIGURE 1: Difference observed between male fertile (left- anthers with pollen) and male sterile (right- empty anthers) flower in okra

Out of 35 hybrids heterosis in desired direction was observed in 12 crosses for AFW, 18 crosses for NF/P, 7 crosses for FL and 16 crosses for FG. Significant magnitude of mid parent heterosis in both direction for above traits were also reported by Ram *et al.* (2015) and Rani (2015).Mid parent heterosis for MY/P and TY/P varied between -2.95 to 118.12 and -5.81 to 107.74 respectively with highest significant positive heterosis expressed by IIHR-294 X JNDO-5 followed by GMS-1 X Varsha Uphar. Out of 35 crosses 16 crosses for MY/P and 13 crosses for TY/P showed significant positive mid parent heterosis. Significant positive average heterosis for yield per plant were also reported by Lyngdo *et al.* (2013), Tonde *et al.* (2016) and Sabesan *et al.* (2016).

Based on mid parent heterosis estimates of the study it was palpable that the expression of heterosis for TY/P in various hybrids associated with heterotic manifestation in some other yield contributing traits. Although, none of the hybrid showed heterotic effects for all the traits studied, five crosses naming IIHR-294 x JNDO-5 (107.74 %), GMS -1 X Varsha Uphar (94.16 %), IIHR-294 x Varsha Uphar (88.19 %), IIHR -294 X Parbhani Kranti (60.07 %) and GMS-1 x Parbhani Kranti (55.89 %) in their order of merit found to be most promising for TY/P along with high magnitude of heterosis for other desirable traits in desired direction. Out of these top five hybrids (GMS -1 X Varsha Uphar) and (GMS-1 x Parbhani Kranti) hybrids are being GMS based hybrids, expressing comparable magnitude of heterosis as that of fertile line based hybrids and offering greater advantage of easy and economic hybrid seed production on commercial scale. Badiger *et al.* (2014) also in their study on GMS based hybrids it was found that performance of GMS based hybrids were comparatively better with that of male fertility line based hybrids. Hence, GMS lines in okra could be further evaluated in heterosis breeding programme and okra hybrid seeds can be produced to farmers at more affordable price.

Potence ratio

The estimated values of potence ratio (Tables 3) illustrated that in most F_1 crosses the estimated potence ratios had a positive nature for the characters DFF, DFH, FSG, NF/P, FG, MY/P and TY/P. These results reflected, generally, various degrees of dominance; *i.e.*, partial- to over-dominance which involved in the inheritance of these characters. On the contrary, negative values of potence ratio in most of the F_1 hybrids for NFF, INL, NB/P, PH, AFW and FL indicated the presence of various degrees of recessiveness, *i.e.,* partial- to under-recessiveness in their inheritance. This was because asymmetrical distribution of positive and negative alleles and unequal distribution of dominant and recessive genes found in parents for these traits. In the present investigation for TY/P only one cross IIHR -285 X Parbhani Kranti showed negative estimate of potence ratio (-0.83) and three crosses showed potence ratio value <1. While remaining all the hybrids including all the 10 GMS based hybrids estimated positive potence ratio with >1 value is the indication of prevalence of over-dominance for TY/P and scope for its exploitation via heterosis breeding. Over dominance for fruit yield and its components was also reported by Ram *et al.* (2016), Kumar *et al*. (2006) and Reddy *et al*. (2012). However, estimate of heterosis and potence ratio are population dependent.

CONCLUSION

In the present investigation broader range of mid parent heterosis and potence ratio in both positive and negative direction Degree of dominance based on potence ratio manifested over dominance for TY/P. Out of top five hybrids based on TY/P, crosses GMS-1 x Varsha Uphar and GMS-1 x Parbhani Kranti are being GMS based hybrids, offering greater advantage of easy and economic hybrid seed production on commercial scale. Therefore, GMS based hybrids should be given due attention to improve and exploit their full potential further.

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