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Heterosis studies in okra [*Abelmoschus esculentus* (L) Moench]

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Abstract
Seven parental lines of okra and their 21 F_1 hybrids obtained from half diallel were studied to investigate the extent of heterosis for yield. The experiment laid out in randomized block design, two replications with spacing 45 x 20 cm during *summer* season 2021 at experimental Research Farm Department of Horticulture, College of Agriculture Latur. The significant heterosis for F_1's over better parents and over standard heterosis for the various characters *viz*., Phule Vimukta x Arka Abhay (Number of nodes per plant, node at which first flower appeared, days required for first fruit of harvest, length of fruit, weight of fruit, fruit yield per plant, fruit yield per plot) Arka Anamika x Arka Abhay (internodal length, days required to 50% flowering) Arka Anamika x Kashi Pragati (plant height, Diameter of fruit) Arka Anamika x Varsha Uphar (number of fruits per plant). Using parents in these crosses can be used in the future breeding programme for hybrid development.

Keywords: Half diallel, heterosis, better parent, yield, okra

Introduction
Okra (*Abelmoschus esculentus* [L.] Moench) is an economically valuable crop known in the tropical or subtropical areas of the world. It it also known as *Bhendi* or lady's finger. Okra is a valued vegetable in India, despite its origins in Tropical Africa. Cultivated okra and closely related wild species have identical distributions in Southeast Asia. In the regions of Indian and West Africa the variety of Okra is also recognised. It is a common fruit vegetable in India for its tender pods, and it can be grown as a garden crop or in commercial farms. India is the world's second-largest producer of vegetables. Okra belongs to family malvaceae and genus *Abelmoschus*.

Okra is a major plant to expand to its high nutritional content, good market demand and therapeutic value for the export of high potential. The crop is extensively cultivated throughout India for its tender fruits, which are in various ways used as a vegetable. The ripe and tender green fruit are highly valued. Okra cortex is shown to be useful as one of the potential sources of mucilages, (Giras *et al.*, 2003) [2].

West Africa, India, Southeast Asia, the southern United States, Brazil, and Turkey are the countries that grow okra commercially. The states that produce the okra in India are Uttar Pradesh, Assam, Bihar, Orissa, Maharashtra, West Bengal, and Karnataka. Okra is one of the most widely cultivated vegetable in India, with a total area of 509 million hectares and an annual production of 6095 million metric tonnes (Anon, 2017) [1]. Okra is grown on 13.98 million hectares in Maharashtra, with a yield of 139.40 million tonnes (Anon, 2017) [1]. It's a potential export earner, accounting for 13% of fresh vegetable exports.

As demand for plants grows, new hybrids for different agro-climatic zones in India need to be developed with better fruit yield. In okra development programmes, however, hybrid vigour must be exploited, the biology of different characters will be understood, and production aspects must be improved with an eye on the export market. It has been recognised as a useful method for breeders looking to increase okra yields. Because of the broad range of out crossing nature of okra, crop improvement is difficult. In many pollinated varieties the heterogeneous and variable nature produced by the application of population breeding methods causes a lack of uniformity in growth and agricultural character, especially in vegetation and development. Whereas hybrid production is of benefit for growers, owing to the higher levels of yield hybrid development, dwarf ness is unusual in resistant to diseases and environmental tolerance.

Materials and Methods

The experiment was conducted at Instructional Cum-Research Farm, Department of Horticulture, College of Agriculture, Latur during summer season 2021. The study was undertaken by using diallel analysis (without reciprocal) involving 21 F_1 hybrids and seven parental lines namely Phule Utkarsha (P_1), Phule Vimukta (P_2), Arka Anamika (P_3), Kashi Pragati (P_4), Arka Abhay (P_5), Konkan Bhendi (P_6) and Varsha Uphar (P_7). Seven parental lines were sown in randomized block design with two replications. All treatments were grown at 45 x 20 cm spacing and recommended practices was applied. Five plants were selected and tagged for recording the observations on different characters *viz.*, Plant height (cm), Internodal length (cm), Number of nodes per plant, Node at which first flower appeared, Days required to 50% flowering, Days required for first fruit of harvest, Length of fruit (cm), Weight of fruit (g), Diameter of fruit (mm), Number of fruits per plant, Fruit yield per plant (kg), Fruit yield per plot (kg).

Heterosis was calculated by using formulae.

$$\overline{BP} = \frac{\overline{F1} - \overline{BP}}{\overline{BP}} \times 100 \quad \text{(Over better parent)}$$

Result and Discussion

The analysis of variance (Table 1) indicated that the mean square due to genotypes were highly significant for all characters under study.

In the analysis of mean squares, the differences due to the treatments were significant for all the characters studied. The treatment means were further subdivided into parents, crosses and parent versus crosses. The parents showed significant differences for all the characters except intermodal length, days required for first fruit of harvest, length of fruit, diameter of fruit. The crosses were found significantly for all the characters except diameter of fruit. The parent versus crosses showed significant differences for most of the characters except days required to 50% flowering.

The analysis of variance showed highly significant difference among the genotypes studied. The mean value of seven parents and 21 F_1 hybrids and their heterosis percentage over better parent and over standard check are presented in Table 1.

The range of F_1 hybrid was wider than that of parents for all the characters under study, where lower value shows early maturity which is a desirable trait. Similarly, the average heterosis was negative in internodal length, node at which first flower appeared, days required for 50% female flowering and days required to first harvest of fruit which is also a desirable economic trait. The range of heterotic crosses in all the characters over their respective better parents varied from -22.51 to 84.37 plant height (cm), -30.04 to 15.42 internodal length (cm), -27.08 to 15.98 number of nodes per plant, -51.61 to 10.71 in node at which first flower appeared, -7.89 to 4.18 in days required to 50% flowering, -9.05 to 3.15 in days required for first fruit of harvest, -8.08 to 16.94 in length of fruit (cm), -29.01 to 13.61 in weight of fruit (g), -1.67 to 13.19 in diameter of fruit (mm), -42.28 to 28.51 in number of fruits per plant, -58.82 to 42.31 in fruit yield per plant (kg), -40.83 to 41.13 in fruit yield per plot (kg).

Out of 21 cross combinations studied, 7 and 4 crosses displayed significant positive heterosis over better parent and standard check respectively for plant height. The cross combinations Phule Vimukta x Arka Anamika (84.37%) and Phule Vimukta x Kashi Pragati (27.97%) exhibit significant positive heterosis over better parent and standard check respectively. Similar results were obtained by Harne *et al*. (2014), Singh *et al*. (2015) [11].

A cultivar having less internodal length is of extremely valuable in breeding programme. Among hybrids 8 and 4 crosses displayed significant negative heterosis over better parent and standard check respectively. Out of 21 cross combinations Phule Utkarsha x Varsha Uphar (-30.04%) recorded highest significant negative heterosis over better parent and the cross combination Arka Anamika x Arka Abhay (-19.50%) over standard check. Similarly results were reported by Reddy *et al*. (2012) [9], Harne *et al*. (2014)

Among 21 crosses 8 hybrids each recorded the highest significantly positive heterosis over better parent and standard check respectively. The cross combinations Phule Utkarsha x Arka Abhay (15.98%) exhibited highest positive significant heterosis over better parent and the cross Kashi Pragati x Varsha Uphar (24.42%) showed significantly the highest per cent of positive heterosis over standard check. Similar result obtained by Harne *et al*. (2014).

Among the 21 crosses 9 and 7 crosses were showed negative significant heterosis over better parent and standard check respectively for node at which first flower appeared. The cross combinations Arka Abhay x Varsha Uphar (-51.61%) and Phule Utkarsha x Arka Abhay (-43.48%) showed significantly highest per cent of negative heterosis over better parent and over standard check respectively. Similar findings reported by Reddy *et al*. (2012) [9], Patel *et al*. (2015) [8] and Kumar *et al*. (2017) [6].

Among the 21 crosses 4 crosses were recorded negative significant heterosis over parent and standard check for days required to 50% flowering. The cross combinations Arka Anamika x Arka Abhay (-7.89%) and Phule Utkarsha x Arka Abhay (-10.00%) found significantly the highest per cent of negative heterosis over better parent and standard check respectively. Similar observations were reported by Reddy *et al*. (2012) [9], Kumar *et al*. (2017) [6].

Out of 21 crosses 7 crosses each were found negative significant heterosis over parent and standard check for days required for first fruit of harvest. The cross combinations Arka Abhay x Varsha Uphar (-9.05%) exhibited highest negative significant heterosis over better parent. Whereas, the cross combinations Phule Utkarsha x Arka Abhay (-8.68%) recorded significantly highest per cent of negative heterosis over standard check. Similar findings in agreement with those of Kerure *et al*. (2019) and Sapavadiya *et al*. (2019) [10].

From 21 crosses, 6 cross combinations each recorded the highest significantly positive heterosis over better parent and standard check respectively for the length of fruit. The cross Kashi Pragati x Arka Abhay (16.94%) exhibited highest positive significant heterosis over better parent. While, the cross combinations Kashi Pragati x Arka Abhay (18.70%) reported significantly highest *per cent* of positive heterosis over standard check. The results are in agreement with the previous findings of Jindal *et al*. (2010) [4], Harne *et al*. (2014).

Out of 21 crosses 5 and 10 cross combinations recorded highest significantly positive heterosis over better parent and standard check respectively for the weight of fruit. The crosses Phule Vimukta x Konkan Bhendi (13.61%) and cross Phule Utkarsha x Konkan Bhendi (23.19%) showed significantly highest *per cent* of positive heterosis over better parent and over standard check respectively. Similar results

were reported by Jindal *et al*. (2010) [4], Harne *et al*.(2014), Patel *et al*. (2015) [8].

Among 21 crosses 7 and 2 cross combinations reported highest significantly positive heterosis over better parent and standard check respectively for the diameter of fruit. The cross combinations Arka Anamika x Arka Abhay (13.19%) exhibited maximum positive significant heterosis over better parent. Whereas, the cross combinations Arka Anamika x Arka Abhay (6.60%) showed significantly the highest *per cent* of positive heterosis over standard check. Similar findings are in agreement with those of Harne *et al*. (2014a), Kerure *et al*. (2019)

Out of 21 crosses 7 and 11 crosses reported maximum significantly positive heterosis over better parent and standard check respectively for the number of fruits per plant. The hybrid Arka Anamika x Konkan Bhendi (28.51%) and the cross Kashi Pragati x Varsha Uphar (23.66%) reported significantly maximum *per cent* of positive heterosis over better parent and over standard check. Similar results are in confirmation with the earlier findings of Reddy *et al*. (2012) [9], Harne *et al*. (2014) and Nagesh *et al*. (2014) [7].

Out of 21 crosses 7 and 8 cross combinations reported significantly maximum positive heterosis over better parent and standard check respectively for fruit yield per plant. The cross combinations Phule Vimukta x Arka Abhay (42.31%) exhibited maximum positive significant heterosis followed by Phule Utkarsha x Arka Abhay (38.46%), Phule Vimukta x Arka Anamika (29.69%) over better parent. Whereas, the cross combinations Kashi Pragati x Varsha Uphar (56.08%) showed significantly highest *per cent* of positive heterosis Similar results were obtained by Harne *et al*. (2014a), Singh *et al*. (2015) [11], Kerure *et al*. (2019).

As regard the character of fruit yield per plot, 7 and 8 crosses reported significant maximum positive heterosis over better parent and standard check respectively. The crosses Phule Vimukta x Arka Abhay (41.13%) showed Kashi Pragati x Varsha Uphar (45.72%) showed significantly highest *per cent* of positive heterosis over better parent and over standard check respectively.

Table 1: Analysis of variance for different characters in 7 x 7 half diallel of bottle gourd

Source	d.f	Plant height (cm)	Internodal length (cm)	Number of nodes per plant	Node at which 1st flower appeared	Days required for 50% flowering	Days required for 1st fruit of harvest
		1	2	4	5	6	7
Treatment	27	204.03**	0.87**	5.89**	0.77**	5.83*	7.25**
Parent	6	282.72**	0.49	2.02*	0.46*	1.97*	2.87
Crosses	20	114.07**	0.92**	6.60**	0.79**	6.99**	8.44**
P x C	1	1531.01**	2.17**	14.88**	2.43**	5.79	9.76*
Error	27	34.82	0.26	1.19	0.20	2.34	1.38

Table 1: Continued…...

Source	d.f	Length of fruit (cm)	Weight of fruit (g)	Diameter of fruit (mm)	Number of fruits per plant	Days required for 1st fruit of harvest	Fruit yield per plot (kg)
		8	9	10	11	7	13
Treatment	27	1.27**	6.54**	1.35*	9.57**	7.25**	1.04**
Parent	6	0.34	6.02**	0.72	4.78**	2.87	0.65**
Crosses	20	1.49**	6.70**	1.12	10.68**	8.44**	1.10**
P x C	1	2.29*	6.56*	9.77**	15.97**	9.76*	2.06**
Error	27	0.33	0.87	0.58	0.81	1.38	0.10

Table 2: High *per se* performance of parents

Sr. no.	Characters	Best performing parents	High *per se* performance
1	Plant height (cm)	Arka Aabhay	54.84
2	Internodal length (cm)	Arka Anamika	5.45
3	Number of nodes per plant	Kashi Pragati	13.85
4	Node at which first flower appeared	Arka Aabhay	1.90
5	Days required to 50% flowering	Phule Utkarsha	44.10
6	Days required for first fruit of harvest	Arka Aabhay	49.00
7	Length of fruit (cm)	Kashi Pragati	11.13
8	Weight of fruit (g)	Kashi Pragati	12.43
9	Diameter of fruit (mm)	Arka Aabhay	15.04
10	Number of fruits per plant	Kashi Pragati	13.60
11	Fruit yield per plant (kg)	Kashi Pragati	0.16
12	Fruit yield per plot (kg)	Kashi Pragati	3.38

Table 3: *Percent* heterosis over better parent and standard heterosis

Parent/ Crosses	Plant height (cm)		Internodal length (cm)		Number of nodes per plant		Node at which 1st flower appeared		Days required for 50% flowering		Days required for 1st fruit of harvest	
	1		2		4		5		6		7	
	BP	SH	BP	SH	BP	BP	SH	SH	BP	SH	BP	SH
Phule Utkarsha x Phule Vimukta	-0.23	-1.06	-16.22*	-2.37	-5.23	-5.80*	-7.10**	-5.54	-14.72	-12.40	-43.33**	-26.09
Phule Utkarsha x Arka Anamika	18.58**	17.58**	-22.18**	-9.32	-5.37	-2.90	-4.24	-6.20*	14.89**	16.67*	-44.44*	-34.78**
Phule Utkarsha x Kashi Pragati	19.41*	18.41**	-0.51	15.93	0.75	1.54	3.75	1.85	9.75	17.83*	-42.86*	-30.43*
Phule Utkarsha x Arka Abhay	3.00	11.40	-8.80	6.27	-6.55	-5.70*	-8.68**	10.00**	15.98**	9.69	-35.00	-43.48*
Phule Utkarsha x Konkan Bhendi	-12.95	-13.68	-19.13*	-5.76	3.57	3.15	3.25	1.43	3.33	-3.88	-10.34	13.04
Phule Utkarsha x Varsha Uphar	9.77	11.70	-30.04**	-18.47*	-7.19*	-9.04**	-6.71**	-5.98	-10.00	-16.28	-45.16**	-26.09
Phule Vimukta x Arka Anamika	84.37**	9.08	11.10	6.86	-1.53	0.60	-0.79	-1.85	13.96*	17.05*	-3.33	26.09
Phule Vimukta x Kashi Pragati	18.47	27.97**	15.42	11.02	-1.51	-3.38	-1.28	-0.43	-27.08**	-21.71*	-6.67	21.74
Phule Vimukta x Arka Abhay	4.03	12.51	-20.00*	-15.25	-6.54	-5.90*	-7.20**	-6.85*	15.09**	18.22*	-46.67**	-30.43*
Phule Vimukta x Konkan Bhendi	61.07**	-2.86	-12.29	-12.29	1.64	-2.17	-2.07	1.30	7.17	10.08	-13.33	13.04
Phule Vimukta x Varsha Uphar	12.93	14.91	-22.80**	-17.37*	-0.11	-4.23	-1.78	1.20	13.21*	16.28*	-22.58	4.35
Arka Anamika x Kashi Pragati	57.82**	-4.04	-9.17	-13.56	-3.98	-2.03	0.10	-2.93	3.97	11.63	10.71	34.78*
Arka Anamika x Arka Abhay	-15.86	-9.00	-24.00**	-19.50*	-7.89*	-6.70**	-7.99**	-8.70*	6.49	8.14	-48.15**	-39.13*
Arka Anamika x Konkan Bhendi	46.24*	-11.80	-17.71	-17.71	-0.55	-0.59	-0.49	-1.41	12.98*	14.73	-31.03	-13.04
Arka Anamika x Varsha Uphar	-22.51	-21.15	-15.28	-9.32	4.18	0.19	2.76	5.54	11.83*	13.57*	-12.90	17.39
Kashi Pragati x Arka Abhay	11.66	-20.77**	-15.20	-10.17	-7.74*	-8.98**	-7.00**	-6.74	9.75	17.89*	-46.43**	-34.75*
Kashi Pragati x Konkan Bhendi	66.66**	1.33	3.39	3.39	-1.29	-1.74	0.39	-0.22	1.44	8.91	-3.45	21.74
Kashi Pragati x Varsha Uphar	-11.71	-10.16	-24.78**	-19.49*	-3.76	-1.83	0.69	-2.50	15.88**	24.42**	-6.45	26.09
Arka Abhay x Konkan Bhendi	-19.54	-12.98	-7.84	-2.37	-4.11	-4.33	-4.24	-6.09	-3.28	-8.53	-41.38 *	-26.09
Arka Abhay x Varsha Uphar	14.61	23.95*	7.68	15.25	-6.87*	-9.05**	-6.71**	-5.65	-6.56	-11.63	-51.61**	-34.72**
Konkan Bhendi x Varsha Uphar	12.19	14.16	-14.33	-8.31	-1.50	-0.48	2.07	-0.22	-3.08	-14.73	-9.68	21.74
S.E.D ±	**5.90**	**0.44**	**0.51**	**0.51**	**1.52**	**1.17**	**1.17**	**1.52**	**1.09**	**1.09**	**0.44**	**0.44**
C.D. At 5 %	**12.10**	**0.91**	**1.05**	**1.05**	**3.13**	**2.40**	**2.40**	**3.13**	**2.23**	**2.23**	**0.91**	**0.91**
C.D. At 1%	**16.34**	**1.23**	**1.42**	**1.42**	**4.23**	**3.25**	**3.25**	**4.23**	**3.02**	**3.02**	**1.23**	**1.23**

Table 3: Continue….

Crosses	Days required for 1st fruit of harvest		Length of fruit (cm)		Weight of fruit (g)		Diameter of fruit (mm)		Number of fruits per plant		Fruit yield per plant (kg)	
	7		8		9		10		11		12	
	BP	SH	BP	SH	BP	BP	SH	SH	BP	SH	BP	SH
Phule Utkarsha x Phule Vimukta	-5.80*	-7.10**	-0.98	-7.39	-31.75**	-36.36*	-44.02**	-27.43**	11.45*	-13.81	0.39	-10.39*
Phule Utkarsha x Arka Anamika	-2.90	-4.24	-8.08	-9.12	25.00**	-11.11	-4.00	20.25*	-13.72	-6.01	1.05	-6.42
Phule Utkarsha x Kashi Pragati	1.54	3.75	2.16	3.70	2.21	5.88	44.00**	17.30*	7.76	17.45*	-0.80	-7.10
Phule Utkarsha x Arka Abhay	-5.70*	-8.68**	5.38*	5.43	22.22**	38.46**	44.00**	16.03*	9.63	14.82*	1.50	-4.41
Phule Utkarsha x Konkan Bhendi	3.15	3.25	-3.84	-8.58	0.89	5.56	-24.00	-4.22	-9.32	23.19**	4.89*	-8.61*
Phule Utkarsha x Varsha Uphar	-9.04**	-6.71**	-0.78	-6.66	-11.56	-21.74	-28.00*	-16.03*	-13.53	-16.53	8.22*	-6.48
Phule Vimukta x Arka Anamika	0.60	-0.79	-6.51	-7.57	7.94	29.69*	40.00**	14.77	7.77	17.40*	9.16*	1.10
Phule Vimukta x Kashi Pragati	-3.38	-1.28	4.27	5.84*	-42.28**	-58.82**	-44.00**	-33.76**	-25.99**	-19.33*	1.74	-4.73
Phule Vimukta x Arka Abhay	-5.90*	-7.20**	7.62*	7.66*	12.70	42.31**	48.00**	19.83*	11.80*	17.10*	-0.96	-6.73
Phule Vimukta x Konkan Bhendi	-2.17	-2.07	6.91	1.64	10.32	22.73*	8.00	17.30*	13.61*	-3.77	4.35	-6.85
Phule Vimukta x Varsha Uphar	-4.23	-1.78	1.12	-4.88	15.87*	17.39*	8.00	23.21**	-15.71	-18.63	2.45	-8.54*
Arka Anamika x Kashi Pragati	-2.03	0.10	8.40*	10.04*	2.94	5.88	45.00**	18.14*	5.71	15.21*	7.75	0.91
Arka Anamika x Arka Abhay	-6.70**	-7.99**	4.38	4.43	17.98*	29.63*	40.00**	13.50	5.84	15.30*	13.19*	6.60**
Arka Anamika x Konkan Bhendi	-0.59	-0.49	-5.17	-6.25	28.51**	3.70	12.00	23.63**	-20.32*	-13.20	1.05	-6.42
Arka Anamika x Varsha Uphar	0.19	2.76	-3.46	-4.56	25.44**	-3.70	4.00	20.68*	-29.01**	-22.67*	3.99	-3.69
Kashi Pragati x Arka Abhay	-8.98**	-7.00**	16.94**	18.70**	4.41	14.71*	56.00**	19.83*	11.14*	21.13*	7.28*	1.03
Kashi Pragati x Konkan Bhendi	-1.74	0.39	-5.21	-3.79	0.00	-11.76	20.00	14.77	-10.18	-2.10	-1.67	-7.92*
Kashi Pragati x Varsha Uphar	-1.83	0.69	9.66*	11.31*	7.72*	14.71*	56.08**	23.66**	6.72	16.31**	-0.87	-7.17
Arka Abhay x Konkan Bhendi	-4.33	-4.24	-4.70	-4.65	-10.76	-34.62**	-32.00*	-16.03*	-14.99*	-10.96	7.11*	0.88
Arka Abhay x Varsha Uphar	-9.05**	-6.71**	8.98*	9.03*	-18.83*	-11.54	-8.00	-23.63**	9.04	14.20*	10.34**	3.91*
Konkan Bhendi x Varsha Uphar	-0.48	2.07	4.27	-0.87	-6.64	4.35	-4.00	-16.88 *	12.17*	8.29	6.07	-7.57*
S.E.D ±	**1.17**	**1.17**	**0.57**	**0.57**	**0.89**	**0.01**	**0.01**	**0.89**	**0.93**	**0.93**	**0.76**	**0.76**
C.D. At 5 %	**2.40**	**2.40**	**1.18**	**1.18**	**1.84**	**0.03**	**0.03**	**1.84**	**1.91**	**1.91**	**1.56**	**1.56**
C.D. At 1%	**3.25**	**3.25**	**1.60**	**1.60**	**2.48**	**0.04**	**0.04**	**2.48**	**2.58**	**2.58**	**2.11**	**2.11**

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