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Heterosis and inbreeding depression in okra (*Abelmoschus esculentus* (L.) Moench)

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Abstract

Three generations i.e. Parents, F_1, and F_2, of twenty one crosses (Progeny) were used to estimate heterosis and inbreeding depression for growth, yield and yield contributing traits in okra. In general, twenty one crosses showed a wide range of heterotic effects for yield and yields related characters showing the importance of both additive and non-additive genes. VRO-6 × Pusa Sawni showed significant heterobeltiosis for almost all the no of fruit yield / Plant and its contributing traits particularly, VRO-3 x Arka Anamika for seed yield / plant (g) and no of seed / fruit. High heterotic cross combinations for different characters showed high inbreeding depression in the F_2 generation ranged from 50% flowering (- 9.72) to no of fruit / plant (-12.03) in cross VRO-3 x Arka Anamika, This may be due to most part of heterobeltiosis accounted for dominance and dominance × dominance type of epistatic interactions and less for additive × dominance type of gene effect. These findings useful for the improvement of no of fruit / plant and its seed yield / plant while handling the segregating generation for the development of improved varieties in okra.

Keywords: Three generations, heterosis, and inbreeding depression of okra

Introduction

Okra (*Abelmoschus esculentus* L. Moench), chromosomes 2x = 130 belongs to Malvaceae family assumed to be which originates in West Africa, possibly in Ethiopia, Okra is also known as 'Lady's Finger' in English, 'Gumbo' in French, 'Bamaiya' in Hindi and Arabic. Lady finger is a significant vegetable of tropical nations and is generally famous in India, Nigeria, Pakistan, Cameroon, Iraq and Ghana. Despite the fact that, it isn't generally filled in Europe and North America. Okra is a popular crop in India among Indian vegetables due to its easy cultivation, regular yield, wide adaptability and year round cultivation. The main states of India where the vegetables are grown commercially in Gujarat, Maharashtra, followed by Andhra Pradesh, Karnataka, Uttar Pradesh and Tamil Nadu etc. The total area in India is 10,436 mha with production of 1, 87,474 thousand metric tons and productivity is 17.96 tons per hectare (Anonymous 2019) [1]. Okra is one of the most nutritious vegetables, with an average of 1.9 grams of protein, 0.2 grams of fat, 6.4 grams of carbohydrates, 0.7 grams of minerals, 1.2 grams of fiber per 100 grams of edible portion (Apekey *et al.*, 2019) [2]. Exploitation of heterosis is considered one of the desirable and sustainable approaches. Heterosis has been exploited to increase yields in many crops. Heterosis helps to identify the best combiners, either to exploit hetrosis or to accumulate fixable genes through selection. Though, direct use of heterosis in okra is limited. Heterosis is more practical in generations ahead from an economic point of view, which implies that the degree of inbreeding depression should be lower. Inbreeding reduces the average phenotypic value of various fitness-related symptoms, and the phenomenon is known as inbreeding depression (Stebbins, 1958; Wright, 1977) [18, 19].

Materials and Methods

Field experiment and Plant material

The experimental material for the present investigation was generated by Parents (7) genotype-VRO-3, VRO4, VRO5, VRO6, PusaA4, Arka Anamika, Pusa Sawni, and crosses (21) Progeny VRO-3 X VRO-4, VRO-3 X VRO-5, VRO-3 X VRO-6, VRO-3 X Pusa A 4, VRO-3 X Pusa Sawni, VRO-3 X Arka Anamika, VRO-4 X VRO-5, VRO-3 X VRO-6, VRO-4 X Pusa A4, VRO-4 X Pusa Sawni, VRO-4 X Arka Anamika, VRO-5 X VRO-6, VRO-5 X Pusa A 4, VRO-5 X Pusa Sawni, VRO-5 X Arka Anamika, VRO-6 X Pusa A 4, VRO-6 X Pusa Sawni, VRO-6 X Arka Anamika, Pusa A 4 x Pusa Sawni, Pusa A 4 x Arka Anamika, Pusa Sawni x

Arka Anamika. (7) parents and their (21) $F_{1'S}$ were grown at carried out the research farm of the department of Genetics & Plant Breeding, Ch. Charan Singh University, Meerut (UP) India in Zaid seasons of 2017-18, 2018-19 & 2019-20. The experimental material consisting of 7 parents- VRO-3, VRO4, VRO5, VRO6, PusaA4, Arka Anamika, Pusa Sawni, using all cultural practices recommended for successful cultivation of okra crop were followed. Hybridization among parental lines was carried out by hand emasculation and pollination than produce F_1 hybrid seeds. All F_1's were allowed to self pollination to produce F_2 seeds. The experimental material was planted in half diallel mating design which allowed making 21 crosses. These experimental materials were performed in Randomized Complete Block Design (RBD) with three replications in the years 2017-18, 2018-19 & 2019-20.Each genotype was sown in three replications with three lines with four-meter distance. The experimental field maintains line to line 70 cm and plant to plant 30 cm distance.

Observations recorded

The data were recorded for 13 contributing characters *viz.* 50% days to flowering. First Flowering node, First fruiting node, Inter nodal length (cm), Fruit Length (cm), Fruit width (cm), Fruit Weight (g), no. of Fruit /Plant, no. of seed/fruit, no. of branches /plant, Seed Yield / plant(g), Plant height (cm), Harvest duration.

Statistical methods

In this investigation half diallel mating design was followed and the mean values of the treatments for all the characters were subjected to analysis of variance (ANOVA).General and specific combining variance and their effects will be calculated using Griffings (1956) [7] method second, model first, Components of variance analysis will be done by the procedure given by Hayman (1956) [8], Degree of heterosis in F_1cross will be estimated over the better parents and inbreeding depression in F_2 will be worked out over the F_1 hybrids, Heritability will be estimated according to the method enunciated Crumpacker and Allard (1962) [4] and genetic advance by the method of Robinson *et al* (1949) [15], Genotype and phenotype correlation coefficient will be worked out among all the characters to be studied according by Robinson (1951) [14].

Results and Discussion

Heterosis

The findings of the present investigation on heterosis and inbreeding depression are presented in Table-1.

First flowering node

The estimate of heterosis over better parent and mid parent in average negative direction is desirable attributes for many characters mainly those concerned with large fruiting like first flowering node in present study crosses, VRO-5 x VRO-6 (14.59%). Pusa sawni x Arka Anamika (11.68%), VRO-4 x Pusa sawni (10.40%) and VRO-4 x Arka Anamika (-8.23%) over better parent, whereas cross combinations VRO-4 x VRO-5 (-9.95%), VRO-4 x Arka Anamika (-9.40%), VRO-6 x Pusa A-4 (-8.77%) and VRO-5 x VRO-6 (7.87%) over mid parent. Negative heterosis for first flowering node has been observed by Neetu, *et al*. (2015) [11], has also revealed similar kind of studies in their was exploitation of heterosis for field and attributes in okra.

2. First fruiting node

First fruiting nodes are the indicators of earliness in okra. Early flowering not only gives early pickings and better returns but also widens fruiting period of the plant. Fruiting at lower nodes are helpful in increasing the number of fruits per plant as well as getting early yields.

Negative heterosis is highly desirable for first fruiting node attributes of earliness. The crosses VRO-5 x vro-6 (12.99), Pusa Sawni x Arka anamika (11.68), VRO-6 x Pusa sawni (9.83), VRO-4 x Pusa Sawni (7.46) over better parent, whereas cross combinations VRO-4 x VRO-5 (-10.17), VRO-4 x Arka Anamika (-10.10), Pusa sawni x Arka Anamika (9.41), VRO-6 x Pusa A4 (-8.32) over mid parent. Average negative heterosis for first fruiting node has been observed by Srikanth *et al*. (2019) [17], also has given similar interpretation.

3. 50% flowering

The estimates of heterosis over better parent and mid parent in negative direction is desirable attributes for many characters mainly those concerned with crop maturity like days to 50% flowering.

Crosses showing negative heterosis start early flowering, which provide early fruit, yield to the growers. In present study cross combination VRO-4 x VRO-5 (-11.95), VRO-6 x Pusa Sawni (11.38),VRO-5 x Pusa Sawni (-10.84),VRO-4 x Pusa Sawni (-10.84), over better parent whereas cross combination VRO-4 X VRO-5 (-14.29), VRO-5 X Pusa A4 (-11.30), VRO-6 x Pusa A4 (-8.39), VRO-4 X VRO-6 (-7.45), over mid parent. Srikanth *et al*. (2019) [17], also have given similar interpretation.

Table 1: Heterosis for hybrids

S. No.	Hybrids	First flowering node		First fruiting node		50% flowering		Harvest duration day		Plant height		No of branch/Plant	
		BP	MP	BP	MP	BP	MP	BP	MP	BP	MP	BP	MP
1	1 2	-0.94	-4.73 **	-2.88	-7.71 **	-1.46	-7.10 **	2.60	0.85	-0.28	4.25	13.70 **	22.06 **
2	1 3	-5.52**	-6.04 **	-6.04**	-7.66 **	-0.49	-3.53 *	2.60	1.07	7.99 **	12.99 **	-1.23	11.11 *
3	1 4	-0.39	-5.69 **	-1.80	-5.52 **	2.98	-0.7	5.19**	1.27	-3.55	-2.21	-1.08	17.95 **
4	1 5	3.28	0.38	2.09	0.78	1.60	-2.04	12.12**	7.25 **	15.85 **	19.88 **	0	9.35 *
5	1 6	5.60**	4.27 **	2.22	0.95	3.18	2.24	9.96**	2.42	16.90 **	23.44 **	39.68 **	47.90 **
6	1 7	8.11**	5.36 **	3.17*	2.36	4.79**	2.13	12.99**	11.54 **	23.42 **	30.03 **	6.49	17.14 **
7	2 3	-5.84**	-9.95 **	-3.73*	-10.17 **	-11.95**	-14.29 **	-2.94	-3.14 *	23.20 **	23.29 **	14.81 **	20.78 **
8	2 4	-5.78**	-7.19 **	-6.68**	-7.79 **	-5.41**	-7.45 **	-1.26	-3.26 *	-7.37 **	-1.88	-12.90 **	-2.41
9	2 5	4.28*	3.21 *	2.60	-1.18	0.19	-1.96	11.72**	8.76 **	29.47 **	30.85 **	5.26	7.38
10	2 6	10.40**	4.78 **	7.46**	0.8	10.25**	2.94 *	10.88**	5.16 **	13.21 **	14.40 **	24.66 **	41.09 **
11	2 7	-8.23**	-9.40 **	-6.17**	-10.10 **	-3.30	-6.39 **	5.06**	4.62 **	24.42 **	25.44 **	23.38 **	26.67 **
12	3 4	14.59**	7.87 **	12.99**	6.77 **	2.55	2.02	3.36*	1.05	3.62	9.83 **	-19.35 **	-13.79 **
13	3 5	-4.42*	-7.62 **	-3.88*	-6.77 **	-10.84**	-11.30 **	-0.42	-3.27 *	19.02 **	20.38 **	19.75 **	23.57 **
14	3 6	0.48	-0.24	-2.46	-2.93 *	2.19	-1.87	-0.84	-6.16 **	9.69 **	10.76 **	16.05 **	37.23 **

15	3 7	3.79*	0.57	2.39	-0.18	-1.98	-2.49	1.27	1.05	28.46 **	29.41 **	0	2.53
16	4 5	-6.42**	-8.77 **	-5.97**	-8.32 **	-8.39**	-8.39 **	-3.98*	-4.57 **	5.87 *	11.02 **	-26.88 **	-19.53 **
17	4 6	3.20	-3.59 **	9.83**	4.32 **	11.38**	6.39 **	1.65	-1.54	-4.23	2.44	-2.15	22.15 **
18	4 7	-4.67*	-7.32 **	-1.35	-4.30 **	-4.02*	-5.02 **	-4.64*	-6.98 **	17.05 **	24.94 **	-20.43 **	-12.94 **
19	5 6	0.80	-3.30 *	-0.96	-3.46 *	4.52*	-0.17	3.57*	0.97	7.22 **	9.48 **	18.42 **	36.36 **
20	5 7	-0.22	-0.48	0.28	-0.21	-1.32	-2.35	11.39**	7.98 **	7.97 **	10.00 **	-6.49	-5.88
21	6 7	11.68**	7.43 **	11.68**	9.41 **	10.25**	6.45 **	13.50**	7.17 **	33.41 **	33.72 **	3.9	20.30 **
	SE ±	0.645	0.559	0.719	0.623	0.828	0.717	1.262	1.093	1.211	1.049	0.118	0.102
	CD at 5%	1.293	1.120	1.442	1.249	1.659	1.437	2.530	2.191	2.428	2.103	0.236	0.205
	CD at 1%	1.470	1.273	1.638	1.419	1.885	1.633	2.875	2.490	2.758	2.389	0.269	0.233

Table 2: Heterosis for hybrids

	Hybrids	Inter nodal length		Fruit length		Fruit width		Fruit weight		No of fruit/plant	
		BP	MP	BP	MP	BP	MP	BP	MP	BP	MP
1	1 2	10.61 *	18.22 **	3.65	15.45 **	12.39	22.18 **	8.99 *	10.99 **	3.61	12.42 **
2	1 3	-7.43	4.18	11.28 **	22.31 **	-7.05	-0.34	11.39 **	17.39 **	30.46 **	44.59 **
3	1 4	15.38 **	22.45 **	32.50 **	38.86 **	52.78 **	59.24 **	35.47 **	36.41 **	62.50 **	73.33 **
4	1 5	-5	10.55 *	5.97 *	16.87 **	2.87	20.46 **	12.44 **	12.66 **	-2.3	18.77 **
5	1 6	-9.76 *	6.09	4.17	18.58 **	-5.77	-4.44	-8.12 *	-2.92	27.91 **	41.03 **
6	1 7	-8.22	2.68	0.71	13.77 **	0.43	4.68	15.62 **	20.80 **	5.61	23.21 **
7	2 3	0	5.71	6.57 *	8.15 **	-1.23	0.25	-3.59	3.37	32.76 **	35.88 **
8	2 4	10.61 *	11.45 *	13.87 **	21.40 **	40.70 **	47.02 **	7.88	10.61 **	48.80 **	51.53 **
9	2 5	-11.25 *	-2.74	-2.92	-1.85	-31.01 **	-13.47 *	10.65 *	12.89 **	-17.05 **	-6.01
10	2 6	-2.44	8.11 *	7.64 **	10.32 **	12.09	20.28 *	8.47 *	16.59 **	25.58 **	27.81 **
11	2 7	5.48	10.79 *	3.18	4.85 *	3.49	8.14	13.97 **	21.17 **	38.78 **	50.28 **
12	3 4	-6.08	0	15.79 **	21.74 **	6.05	9.22	-8.88 *	-4.6	-4.6	-0.6
13	3 5	-15.00 **	-11.69 **	2.24	2.62	-16.79 **	3.19	3.59	8.96 *	-26.27 **	-18.16 **
14	3 6	-7.32	-2.56	8.33 **	12.64 **	75.82 **	86.05 **	11.15 **	11.45 **	56.32 **	57.23 **
15	3 7	10.81 *	11.56 **	16.61 **	20.22 **	96.51 **	102.40 **	24.48 **	25.61 **	51.02 **	60.00 **
16	4 5	-13.75 **	-4.83	7.46 **	13.39 **	-24.36 **	-8.34	10.15 *	10.69 **	6.91	23.08 **
17	4 6	-10.98 *	-0.68	8.68 **	18.56 **	51.65 **	55.93 **	23.64 **	29.78 **	73.26 **	79.52 **
18	4 7	13.70 **	20.29 **	9.54 **	18.55 **	40.70 **	40.70 **	3.93	7.87 *	13.27 **	24.72 **
19	5 6	-4.88	-3.7	6.25 *	10.07 **	-12.25 *	3.94	7.05	12.89 **	-2.3	9.00 *
20	5 7	-15.00 **	-11.11 **	7.42 **	10.34 **	-22.09 **	-5.59	2.74	7.14 *	5.07	10.41 **
21	6 7	-3.66	1.94	6.94 **	7.88 **	7.69	10.73	7.4	8.66 *	28.57 **	36.96 **
	SE ±	0.230	0.199	0.239	0.207	0.254	0.220	0.288	0.249	0.270	0.234
	CD at 5%	0.462	0.400	0.479	0.415	0.509	0.441	0.576	0.499	0.541	0.469
	CD at 1%	0.524	0.454	0.544	0.471	0.579	0.501	0.655	0.567	0.615	0.533

Table 3: Heterosis for hybrids

	Hybrids	No of fruit/plant		No of seed / fruit		Seed yield/plant	
		BP	MP	BP	MP	BP	MP
1	1 2	3.61	12.42 **	-6.50 *	2.37	1.02	4.76
2	1 3	30.46 **	44.59 **	10.01 **	13.05 **	17.46 **	19.68 **
3	1 4	62.50 **	73.33 **	15.60 **	23.82 **	27.80 **	35.40 **
4	1 5	-2.3	18.77 **	5.35 *	12.40 **	11.21 **	22.47 **
5	1 6	27.91 **	41.03 **	6.39 *	13.75 **	5.43	6.01
6	1 7	5.61	23.21 **	17.27 **	17.64 **	34.62 **	34.62 **
7	2 3	32.76 **	35.88 **	-5.20 *	1.2	6.12	8.05 **
8	2 4	48.80 **	51.53 **	-4.91	-2.63	4.39	6.73 *
9	2 5	-17.05 **	-6.01	0.87	3.71	-15.70 **	-10.26 **
10	2 6	25.58 **	27.81 **	-0.87	1.7	-2.04	1.05
11	2 7	38.78 **	50.28 **	-2.75	6.18 *	9.69 **	13.76 **
12	3 4	-4.6	-0.6	5.82 *	10.43 **	5.37	9.64 **
13	3 5	-26.27 **	-18.16 **	4.66	8.78 **	-5.83	1.94
14	3 6	56.32 **	57.23 **	14.16 **	18.91 **	31.22 **	32.98 **
15	3 7	51.02 **	60.00 **	23.24 **	26.26 **	32.28 **	34.77 **
16	4 5	6.91	23.08 **	10.67 **	11.14 **	-9.42 **	-5.61 *
17	4 6	73.26 **	79.52 **	20.53 **	20.77 **	19.51 **	25.96 **
18	4 7	13.27 **	24.72 **	2.33	9.29 **	-3.41	2.33
19	5 6	-2.3	9.00 *	-0.76	-0.53	-4.48	4.67
20	5 7	5.07	10.41 **	5.81 *	12.56 **	-7.62 *	1.73
21	6 7	28.57 **	36.96 **	1.45	8.15 **	18.48 **	19.13 **
	SE ±	0.270	0.234	1.161	1.005	0.223	0.193
	CD at 5%	0.541	0.469	2.327	2.015	0.447	0.387
	CD at 1%	0.615	0.533	2.644	2.289	0.508	0.440

4. Harvest duration day

The estimate of heterosis over better parent and mid parent in positive direction is desirable attributes for many characters mainly those concerned with pod maturity like harvest duration day in present study crosses Pusa sawni x Arka Anamika (13.50), VRO-3 x Arka Anamika (12.99), VRO-3 x Pusa A4 (12.12), VRO-4 x Pusa A4 (11.72), over better parent wheeas cross combination VRO-3 X Arka Anamika (11.54), VRO-4 X Pusa A4 (8.76), Pusa A4 x Arka Anamika (7.98), VRO-3 X Pusa A4 (7.25), over mid parent. Similar results with respect to Fruit width were also reported by Mahajan *et al*. (2017) [10].

5. Plant height

Plant height is an indirect yield-contributing component in many crops like okra. In present investigation most of the crosses expressed significant and positive heterosis over better parent for plant height, which varied from Pusa Sawni x Arka Anamika (33.41) to VRO-4 X Pusa A4 (29.47) percent.Height plant height were recorded in cross combination VRO-5 x Arka Anamika (28.46) followed by VRO-4 X Arka Anamika (24.42), VRO-3 X Arka Anamika (23.42) over better parent wheeas cross combination Pusa Sawni x Arka Anamika (33.72), VRO-4 x Pusa A4 (30.85), VRO-3 x Arka Anamika (30.03), over mid Parent. Srikanth *et al*. (2019) [17] also have given similar interpretation.

6. No of branch /plant.

One of the important yield contributing components, *viz*. number of branches per plant exhibited positive better parent heterosis. Magnitude of positive heterosis varied from VRO-3 X Pusa Sawni (39.68), VRO-6 X PusaA 4 (-26.88), VRO-4 X Pusa Sawni (24.66), VRO-4 X Arka Anamika (23.38), was found best heterosis over better parent on the basis of mid parent crosses like VRO-3 x Pusa Sawni (39.68), VRO-4 X Pusa A4 (-26.88), VRO-4 X Pusa Sawni (24.66) good for heterosis over mid parent. Aware, *et al.* (2014) [3] a similar study has also shown that there was exploitation of heterosis in the area of Okra.

7. Inter nodal length.

The estimates of heterosis over better parent and mid parent in negative direction are desirable attributes for many characters mainly those concerned with crop maturity like internodal length. Crosses showing negative heterosis VRO-3 X VRO-6 (15.38), VRO-5 X PUSA A4 (-15.00), Pusa A4 x Arka Anamika (-15.00), VRO-6 X Pusa A4 (-13.75) was found best heterosis over better parent on the basis of mid parent crosses like VRO-3 X VRO-6 (22.45), VRO-6 X Arka Anamika (20.29), VRO-3 X VRO-4 (18.22), for heterosis over mid parent. Srikanth *et al*. (2019) [17], Sabesan, (2016) [16] also have given similar interpretation.

8. Fruit length

Length of fruit is also a major component of yield. Many crosses were observed positive and significant for this trait. Fruit length.

Crosses showing positive heterosis VRO-3 x VRO-6 (32.50), VRO-5 x Arka Anamika (16.61), VRO-5 x VRO-6 (15.79), was found best heterosis over better parent on the basis of mid parent crosses like VRO-3 X VRO-6 (38.86), VRO-3 x VRO-5 (22.31), VRO-5 x VRO-6 (15.79), good for heterosis over mid parent. Sabesan, *et al.* (2016) [16] a similar study has also shown that there was exploitation of heterosis in the area of Okra.

9. Fruit width

One of the important yield contributing components *viz*. Fruit width exhibited positive better parent heterosis. Magnitude of positive heterosis varied from VRO-5 X Arka Anamika (96.51), VRO-5 X Pusa sawni (75.82), VRO-3 X VRO-6 (52.78), was found best heterosis over better parent on the basis of mid parent crosses like VRO-5 x Arka Anamika (102.40), VRO-5 X Pusa sawni (86.05), VRO-3 X VRO-6 (59.24) for heterosis over mid parent. Similar results have been reported by Mahajan, *et al.* (2017) [10], Aware, *et al.* (2014) [3]. had also observed negative average heterosis for the fruit width conforming the finding of present investigation.

10. Fruit weight (g)

Yield is a complex trait and major component like fruit weight, length of fruits and fruit diameter. The estimates of heterosis over better parent and mid parent in positive direction for fruit weight in cross combinations VRO-3 X VRO-6 (35.47), VRO-5 X Arka Anamika (24.48), VRO-6 X Pusa Sawni (23.64), VRO-3 X Arka Anamika (15.62) was found best heterosis over better parent on the basis of mid parent crosses like VRO-3 X VRO-6 (36.41), VRO-6 X Pusa sawni (29.78), VRO-5 X Arka Anamika (25.61), Similar results with respect to Fruit weight were also reported by Mahajan, *et al*. (2017) [10].

11. No of fruit / plant

Yield is a complex trait and major component of yield are number of fruits/plant. weight of fruits, length and diameter of fruit. The per cent heterosis over mid parent and better parent was found to be significant for number of fruit/plant in a number of crosses. The range of positive better parent heterosis varied from VRO-6 X Pusa Sawni (73.26), VRO-3 X VRO-6 (62.50), VRO-5 X Pusa Sawni (56.32), was found best heterosis over better parent on the basis of mid parent crosses like VRO-6 X Pusa Sawni (79.52), VRO-3 X VRO-6 (73.33), VRO-5 X Arka Anamika (60.00) Similar results with respect to Fruit weight were also The results for mid parents and better parents as per cent of mean is in accordance with the findings of Mahajan, *et al*. (2017) [10]. Aware, *et al.* (2014) [3].

12. No of seed / fruit

The superiority of cross for number of seeds per fruit may be attributed to the high mean values of parent involved in this cross for number of seeds/ fruil cross combinations VRO-5 X Arka Anamika (23.24), VRO-6 X Pusa Sawni (20.53), VRO-3 X Arka Anamika (17.27), VRO-3X VRO-6 (15.60), was found best heterosis over better parent on the basis of mid parent crosses like VRO-5 X Arka Anamika (26.26), VRO-3 X VRO-6 (23.82), VRO-6 X Pusa Sawni (20.77), Gill (2000) [5] have been also reported positive heterosis over better parent.

13. Seed yield /Plant: Seed yield / Plant is also a major component of yield. Many crosses were observed positive and significant for this trait. Seed yield / plant. Crosses showing positive heterosis VRO-3 x Arka Anamika (34.62), VRO-5 x Pusa Sawni (31.22), VRO-5 x Arka Anamika (32.28), was found best heterosis over better parent on the basis of mid parent crosses like VRO-3 X VRO-6 (35.40), VRO-5 x Arka Anamika (34.77), VRO-3 x Arka Anamika (34.62), good for heterosis over mid parent.

Inbreeding Depression

In present experiment many crosses showed positive inbreeding depression. Crosses showing positive and significant inbreeding depression are undesirable. In the inbreeding depression crosses for various traits are presented in Table 2 it is observed from the results that the crosses which showed higher estimates of heterosis, in general, also exhibited higher degree of inbreeding depression. Maximum inbreeding depression was observed in cross VRO-4 x VRO-5 (-9.72%) First flowering node, for lst fruiting node VRO-3 x VRO-5 (-10.09%) and 50% flowering VRO-5 X Pusa A4 (-9.22) These crosses have exhibited negative inbreeding depression. Maximum inbreeding depression for harvest duration day was observed in crosses VRO-6 x Arka Anamika (-17.26%), for plant height in pusa A4 x Arka Anamika (-14.76%); for No of branch / plant in' pusa A4 x Arka Anamika (-8.33%); for Inter nodal length in VRO-4 x Pusa A4 (-9.87%); for Fruit length in VRO-3 x VRO-4 (-19.71%); for Fruit width in VRO-6 x PusaA4 (-20.01%); for fruit weight in VRO-5 x VRO-6 (-10.14%) for No of fruit / plant in VRO-3 X Arka Anamika (-12.03%); for No of seed / fruit in Pusa A4 x pusa sawni (-6.75%); Seeds yield / plant in VRO-4 x VRO-5 (-16.98%) maximum inbreeding depression. Some of the crosses even exhibited negative inbreeding depression for many characters, *viz*., First flowering node, first fruiting node, 50% flowering, Harvest duration days, Plant height, No of branch / plant, Inter nodal length, Fruit length, fruit width, fruit weight, No of fruit / plant, No of seed /fruit, Seed yield /plant, This could be due to the appearance of large number of transgressive segregants in the experimental population utilized for taking observations. The inbreeding depression results due to fixation of unfavourable recessive genes in F2 generations. In the present results high inbreeding depression indicates the presence of non-additive gene action for the characters under study. These findings are in close agreement with results observed by Sabesan *et al.* (2016) [16], Srikanth *et al.* (2019) [17], Mahajan, *et al.* (2017) [10], Tukaram *et al.* (2018), Pawar *et al.* (2016) [13]. Neha *et al.* (2016) [12], Neetu *et al.* (2015) [11], Aware *et al.* (2014) [3].

Table 4: Inbreeding depression for hybrids

S. No.		First flowering node	First Fruiting node	50% flowering	Harvest duration day	Plant height	No of branch / plant	Inter nodal length	Fruit length	Fruit width	Fruit weight	No of fruit / plant	No of seed / fruit	Seed yield / plant
1	1 2	-2.28**	-2.15**	-3.80**	-3.38**	-11.11**	-2.64**	-1.09**	-19.71**	-19.76**	-10.00**	-1.69**	-3.09**	-8.08**
2	1 3	-8.35**	-10.09**	1.40	-10.13**	-6.75**	-2.47**	-9.48**	-19.59**	-8.62**	-7.25**	-7.44**	-4.36**	-12.61**
3	1 4	-7.75**	-8.22**	-1.35	-9.47**	-14.29**	-1.40**	-4.60**	-9.43**	-1.32**	-4.18**	-5.11**	-0.98	-9.36**
4	1 5	-0.08	-3.67**	-3.28**	-3.09**	-7.38**	-2.65**	-5.25**	-11.97**	0.51	-4.74**	-8.53**	-1.02	-12.86**
5	1 6	0.15	-2.24**	-1.92*	-5.51**	-3.90**	-6.72**	-0.69*	-5.33**	-9.86**	-4.27**	-5.41**	-2.00	-5.66**
6	1 7	1.59**	-2.31**	0.66	-2.68	-3.69**	-2.82**	-1.48**	-3.16**	-19.60**	-1.07**	-12.03**	-3.41**	-9.38**
7	2 3	-9.72**	-8.06**	-7.49**	-14.29**	-4.30**	-1.61**	-3.59**	-4.11**	-9.49**	-3.11**	-7.40**	-2.14	-16.98**
8	2 4	-3.99**	-4.87**	-3.42**	-10.17**	-11.93**	-4.07**	-2.73**	-0.64**	-1.91**	-6.85**	-0.45	-0.61	-6.55**
9	2 5	-1.20	-1.23	0.06	3.00**	-2.67*	-2.74**	-9.87**	-19.54**	-6.25**	-2.12**	-5.50**	-0.86	-9.03**
10	2 6	-0.65	-0.14	2.82**	-0.76	-6.65**	-3.20**	-1.07**	-2.58**	-5.88**	-0.28	-10.14**	-1.02	-14.58**
11	2 7	-6.62**	-8.77**	-0.41	-5.62**	-3.09**	-3.25**	-5.98**	-17.82**	-5.49**	-6.37**	-6.65**	-0.89	-16.23**
12	3 4	-2.27**	-4.62**	-3.37**	-8.54**	-2.57*	-2.00**	-6.63**	-4.54**	-7.24**	-10.14**	-4.83**	-0.29	-8.33**
13	3 5	-9.24**	-9.78**	-9.22**	-12.24**	-1.45	-2.07**	-3.68**	-14.61**	-3.08**	-2.60**	-3.75**	-1.39	-11.71**
14	3 6	-8.28**	-8.03**	-2.07**	-15.68**	-13.46**	-0.54*	-2.03**	-6.41**	-3.69**	-0.52*	-3.67**	-3.33**	-4.03**
15	3 7	-5.93**	-7.73**	-3.37**	-8.33**	-3.47**	-0.74**	-2.43**	-1.27**	-2.61**	-1.91**	-2.46**	-1.61	-11.21**
16	4 5	-1.34*	-4.04**	-1.41	-10.04**	-6.06**	-1.90**	-2.89**	-7.64**	-20.01**	-4.92**	-1.77**	-2.88**	-2.97**
17	4 6	-3.64**	4.17**	6.98**	-6.72**	-5.13**	-3.53**	-5.40**	-11.83**	-3.26**	-3.35**	-6.61**	-5.03**	-11.55**
18	4 7	2.80**	1.44	2.41**	-17.26**	-6.06**	-3.36*	-1.75**	-18.72**	-2.41**	-9.83**	-6.35**	-6.37**	-7.12**
19	5 6	-1.11	-5.97**	3.04**	-1.53	-8.84**	-3.67**	-1.92**	-19.61**	-2.92**	-3.62**	-1.88**	-6.75**	-8.03**
20	5 7	0.45	1.77**	1.34	1.51	-14.76**	-8.33**	-5.89**	-9.87**	-7.78**	-4.80**	-1.75**	-1.01	-4.56**
21	6 7	-1.43*	1.79**	-0.64	-0.37	-0.06	-3.11**	-1.20**	-7.79**	-7.13**	-1.66**	-4.76**	-4.73**	-6.41**
	SE	0.65	0.72	0.83	1.26	1.21	0.12	0.23	0.24	0.25	0.29	0.27	1.16	0.22
	CD at 5%	1.29	1.44	1.66	2.53	2.43	0.24	0.46	0.48	0.51	0.58	0.54	2.33	0.45
	CD at 1%	1.47	1.64	1.89	2.87	2.76	0.27	0.52	0.54	0.58	0.65	0.62	2.64	0.51

Conclusion

Inbreeding depression was higher among well-performing hybrids. High-yielding F_1 hybrids produced less in the latter generation due to dominance and ingestion depression, while moderate F_1 hybrids of isolation were also found to be more stable undergoing a process of isolation due to combinatorial gene action. It also suggested that the combined performance of the F_1 and F_2 hybrids may be a good indicator for identifying the most promising populations for advanced selections or for use in advanced generations as resource populations. F2 hybrids with exceptional performance can also be used to improve yields.

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