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

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Abstract

Heterosis studies were carried out involving 10 lines and 3 testers in line x tester model. The study revealed EC-169476 x Arka Abhay and LB Local x P-8 as promising cross-combinations over better parent for fruit yield per plant along with node at which first flowers appears, inter-nodal length, fruits per plant and inter-nodal length, respectively. Whereas EC-7194 x P-8, EC-329424 x Arka Abhay, EC-329424 x Varsha Uphar were the top ranking combinations exhibiting significant standard heterosis for fruit yield per plant along with its components.

Key words: Okra, *Abelmoschus esculentus* and heterosis.

Introduction

Okra [*Abelmoschus esculentus* (L.) Moench] is an important vegetable crop of India. Heterosis has been as one of the important techniques to increase crop productivity. Several workers have demonstrated hybrid vigour for fruit yield and its components in okra (Mandal and Das, 1991, Dhankhar and Dhankhar, 2001 Sood and Sharma, 2001 Yadav *et al.*, 2002). The ease in emasculation and very high percentage of fruit setting indicate the possibilities of exploitation of hybrid vigour in okra. For breeders, agro-ecological diversity of environments represents a double edged sword. This diversity complicates breeding and testing of improved genotypes with adequate adaptation but it also permits the identification of extreme environmental conditions that guarantee selection pressure from important stresses. The present investigation was, therefore, undertaken to study the extent of heterosis for fruit yield and its components by growing okra material under different sets of environment.

Material and Methods

The experimental material comprised 30 F_1s developed by crossing ten diverse genotypes of okra *viz.*, IC-117236, IC-128061, IC-128099, EC-169476, EC-169513, EC-305644, EC-329356, EC-329424, EC-7194 and LB local as female parents and horticulturally superior and genetically diverse three testers namely Varsha Uphar, Arka Abhay and P-8. Thirty F_1 hybrids along with 13 parents were grown in randomized block design with three replications at two environments. Each F_1/ parent was raised in a single row of 3m long with inter- and intra-row spacing of 45cm and 30cm, respectively. The observations were recorded on 10 randomly selected plants in each replication. The characters studied were node at which first flower bud appears, days to first picking, inter-nodal length (cm), fruit length (cm), fruit diameter (cm), number of fruits per plant , average fruit weight (g), fruit yield/plant (g), nodes per plant and plant height (cm). Data were analysed according to the model suggested by Kempthorne (1957). Heterobeltiosis and standard heterosis were calculated as per cent increase or decrease in F_1 hybrids over better parent and standard parent as per the formulae suggested by Singh and Chaudhary (1977).

Results and Discussion

The analysis of variance for the experimental design exhibited significant differences for most of the traits studied over the environments indicating the presence of substantial variability in the experimental material under study. The variances due to environment and genotype x environment were also significant for almost all the traits displaying the key role of environment in variable performance of genotypes (Table 1 & 2). The results are in consonance with the findings of earlier researchers viz., Chaudhary *et al.* (1991) and Chauhan and Singh (2002), who have reported significant differences among the genotypes for yield and related traits.

A perusal of data presented in Table 3-7 revealed that five crosses *viz.*, EC-169476 x Arka Abhay, EC-169476 x Varsha Uphar, EC-329356

x Varsha Uphar, LB Local x Varsha Uphar and LB Local x P-8 exhibited significant heterosis over better parent at two environments for fruit yield per plant. The cross, EC-169476 x Arka Abhay, which exhibited heterosis over better parent for fruit yield per plant also showed desirable heterobeltiosis for node at which first flower appears, inter-nodal length and number of fruits per plant.

Table 1. Analysis of variance (mean squares) for different traits at Akrot (E_1) and Palampur (E_2)

Source of variation		Genotypes		Error	
		E_1	E_2	E_1	E_2
Traits	df	42	42	84	84
Days to 50% emergence		1.80	0.09	1.87	012
Node at which first flower appears		0.45*	0.24	0.23	0.17
Days to 50% flowering		8.34	2.85	7.87	2.40
Inter-nodal length		0.32*	5.71*	0.18	0.68
Stem diameter		0.02*	0.03*	0.01	0.005
Days to first-picking		3.20*	19.36*	1.87	11.80
Fruit length		12.09	4.87	12.95	3.60
Fruit diameter		0.02*	0.04*	0.01	0.02
Fruits per plant		10.93*	10.40*	1.93	2.19
Ridges per fruit		6.87*	5.53*	0.17	0.27
Fruit yield per plant		1444.33*	1824.47*	141.27	429.57
Average fruit weight		2.48*	9937.57	0.45	9958.7
Nodes per plant		9.58*	11.69*	2.13	2.75
Plant height		486.63*	667.80*	68.71	197.07
Days to last-picking		3.76*	3.65	1.82	2.98
Duration of availabilit y of fruits		5.50	29.76*	3.95	17.52

*Significant at P = 0.05

The cross, LB Local x P-8 exhibited maximum desirable heterobeltiosis for fruit yield and inter-nodal length. Therefore, in these combinations, the higher fruit yield may be attributed to lesser inter-nodal length and number of fruits per plant. The cross EC-169476 x P-8 expressed desirable heterosis over better parent for five traits *viz.*, node at which first flower appears, inter-nodal length, days to first picking, fruit length and average fruit weight. The results are in agreement with by Thaker *et al.* (1982), Vijay and Manohar (1986), Mandal and Das (1991) and Yadav *et al.* (2002). Breeder's interest always lies in hybrids only if they are superior to standard check. Generally, cross combinations exhibiting standard heterosis for fruit yield per plant also exhibited standard heterosis for some of the yield components. Only 12. crosses exhibited significant standard heterosis over two or more environments for fruit yield per plant. The cross, EC-7194 x Arka Abhay also expressed desirable standard heterosis at Akrot and pooled over environments for number of fruits per plant, average fruit weight, nodes per plant and plant height. EC-329424 x Arka Abhay also revealed significant standard heterosis along with seven of the component traits *viz.*, fruits per plant, average fruit weight, nodes per plant, duration of availability of fruits, days to first picking, inter-nodal length and stem diameter. The cross, EC-329424 x Varsha Uphar showed significant standard heterosis for fruit yield per plant, number of fruits per plant, nodes per plant, plant height and inter-nodal length. The crosses, EC-329424 x P-8, EC-7194 x Varsha Uphar, EC-7194 x P-8, LB Local x Arka Abhay, LB Local x Varsha Uphar, LB Local x P-8, EC-169476 x Arka Abhay, IC-128099 x Varsha Uphar and EC-329356 x Varsha Uphar also expressed significant desirable standard heterosis for fruit yield along with component traits (Table 3-7). Pratap and Dhankhar (1980), Agarrado and Rasco (1986), Sood (1999), Dhankhar and Dhankhar (2001) and Sood and Sharma (2001) also reported standard heterosis for fruit yield per plant and some of the component traits in okra.

Table 2. Analysis of variance (mean squares) for different traits in pooled over environment (E_3)

Source of variation		Environment	Genotype	Interaction (genotype x environment)	Error
Traits	df	1	42	42	168
Days to 50% emergence		3146.52*	0.98	0.91*	1.00
Node at which first flower appears		108.20*	0.42*	0.28*	0.20
Days to 50% flowering		314.81*	5.92	5.28*	5.13
Inter-nodal length		1394.47*	2.90*	3.12*	0.43
Stem diameter		6.38*	0.02*	0.03*	0.008
Days to first-picking		33.50*	13.81*	8.75*	6.83
Fruit length		41.40*	11.39	5.56	8.27
Fruit diameter		1.86*	0.04*	0.02*	0.01
Ridges per fruit		0.94*	12.28*	0.12	0.22
Fruits per plant		431.66*	14.22*	7.11*	2.06
Fruit yield per plant		140786.00*	1966.06*	1301.73*	285.42
Average fruit weight		6567.53	4929.86	5010.19*	4979.58
Nodes per plant		197.59*	14.16*	7.11*	2.44
Plant height		488283.50*	718.45*	435.98*	132.89
Days to last picking		664.50*	3.67*	3.73*	2.40
Duration of availability of fruits		396.94*	19.31*	15.95*	10.73

*Significant at P = 0.05

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Table 3. Heterosis for node at which first flower appears and days to first picking at Akrot (E_1), Palampur (E_2) and pooled over environment (E_3)

Crosses	Node at which first flower appears						Days to first picking					
	Better Parent			Standard Check			Better Parent			Standard Check		
	E_1	E_2	E_3	E_1	E_2	E_3	E_1	E_2	E_3	E_1	E_2	E_3
IC-117236 x Arka Abhay	-7.50	-0.41	-2.63	-2.40	-2.41	-2.29	-0.55	0.00	1.39	2.25	-5.67	-1.88
IC-117236 x Varsha Uphar	-16.80	-14.87*	-13.71*	-12.00	-14.69*	-13.53*	1.10	-3.14	0.00	3.95*	-4.64	-0.53
IC-117236 x P-8	-6.74	1.48	0.04	-1.60	1.41	0.23	0.00	-3.16	-0.54	2.83	-3.62	-0.53
IC-128061 x Arka Abhay	-31.57*	8.28	-18.53*	-25.33*	-4.23	-13.30*	-3.98*	-9.27*	-3.15	3.39	-4.13	-0.53
IC-128061 x Varsha Uphar	-16.31	-5.33	-10.17	-8.80	-1.01	-4.13	1.12	-5.37	-1.84	1.69	0.00	0.81
IC-128061 x P-8	-30.51*	-13.80*	-21.16*	-24.27*	-9.86	-16.06*	1.69	-7.80	-3.15	1.69	-2.58	-0.53
IC-128099 x Arka Abhay	-10.03	0.96	-3.25	-3.47	-1.01	-2.06	1.69	4.92	4.20	1.69	-1.04	0.27
IC-128099 x Varsha Uphar	-12.69	2.88	-2.15	-6.40	3.02	-0.92	0.56	-3.66	-1.63	1.14	-5.16	-2.15
IC-128099 x P-8	-9.54	0.54	-2.12	-2.93	0.60	-0.92	0.56	-5.67	-2.70	0.56	-5.67	-2.68
EC-169476 x Arka Abhay	-24.72*	-7.19	-15.16*	-16.80	-7.24	-11.47*	0.56	-6.56	-2.24	0.56	-11.86*	-5.92*
EC-169476 x Varsha Uphar	-23.67*	3.62	-8.64	-15.73	3.82	-4.59	-1.69	-7.33	-4.61	-1.14	-8.77*	-5.11*
EC-169476 x P-8	-29.15*	-5.10	-15.96*	-21.87*	-5.03	-12.39*	-0.56	-10.82*	-5.93*	-0.56	-10.82*	-5.92*
EC-169513 x Arka Abhay	-14.73	-8.73	-10.91	-12.00	-9.66	-10.78	2.86	-1.09	1.12	1.69	-6.71	-2.68
EC-169513 x Varsha Uphar	-1.38	-2.88	-1.57	-11.20	-2.82	-6.42	-0.56	-4.19	-2.44	0.00	-5.67	-2.96
EC-169513 x P-8	-6.93	-5.37	-6.04	-6.93	-5.43	-5.96	-3.95*	-8.25	-2.43	3.95*	-8.26	-2.43
EC-305644 x Arka Abhay	-6.55	4.65	-0.31	-3.47	2.62	0.00	-1.12	-4.37	-1.68	-0.56	-9.80*	-5.39*
EC-305644 x Varsha Uphar	24.72*	-1.21	9.16	10.40	-1.01	3.90	0.56	-6.81	-3.25	1.14	-8.26	-3.77
EC-305644 x P-8	-23.09*	-4.49	-12.50*	-22.93*	-4.43	-12.39*	-0.56	-7.22	-3.77	0.00	-7.22	-3.77
EC-329356 x Arka Abhay	-30.43*	-2.46	-11.17	-17.60	-4.43	-10.09	4.00*	-2.73	0.84	2.83	-8.26	-2.96
EC-329356 x Varsha Uphar	-34.63*	-8.84	-15.70*	-22.40*	-8.65	-14.68*	0.00	-7.85	-4.07	0.56	-9.28*	-4.58
EC-329356 x P-8	-21.06*	-15.43*	-12.65*	-6.40	-15.49*	-11.47*	0.56	-8.25	-4.04	0.56	-8.26	-4.04
EC-329424 x Arka Abhay	-16.37	0.62	-6.90	-13.60	-1.41	-6.65	0.57	-4.92	-2.24	-1.14	-10.31*	-5.92*
EC-329424 x Varsha Uphar	0.46	2.55	5.15	-1.87	2.62	0.69	-1.12	-5.76	-3.52	-0.56	-7.22	-4.04
EC-329424 x P-8	-19.80*	-13.48*	-16.20*	-19.73*	-13.48*	-16.28*	-1.69	-12.89*	-7.55*	-1.69	-12.90*	-7.54*
EC-7194 x Arka Abhay	-9.30	6.50	-0.50	-6.40	4.43	-0.23	0.00	-1.64	-0.56	-1.14	-7.22	-4.30
EC-7194 x Varsha Uphar	8.64	-7.97	-1.33	-4.00	-7.85	-6.19	-0.56	-2.62	-1.63	0.00	-4.13	-2.15
EC-7194 x P-8	-21.40*	-4.16	-11.58	-21.33*	-4.23	-11.47*	-1.13	-9.28*	-5.39*	-1.14	-9.28*	-5.39*
LB Local x Arka Abhay	-17.57	-1.57	-8.66	-14.93	-3.62	-8.49	5.75*	-1.64	1.96	3.95*	-7.22	-1.88
LB Local x Varsha Uphar	-17.23	-4.76	-6.15	-18.93	-4.63	-10.78	1.12	-9.42*	-4.34	1.69	-10.82*	-4.85*
LB Local x P-8	-3.73	-17.04*	-11.31	-3.73	-17.10*	-11.24*	1.13	-9.79*	-4.58	1.14	-9.80*	-4.58
SE (d) ±	0.37	0.33	0.25	0.37	0.33	0.25	1.12	2.80	1.51	1.12	2.80	1.51

*Significant at P = 0.05

Table 4. Heterosis for inter-nodal length and fruit length at Akrot (E_1), Palampur (E_2) and pooled over environment (E_3)

Crosses	Inter-nodal length						Fruit length					
	Better Parent			Standard Check			Better Parent			Standard Check		
	E_1	E_2	E_3	E_1	E_2	E_3	E_1	E_2	E_3	E_1	E_2	E_3
IC-117236 x Arka Abhay	-4.35	21.53*	13.66*	-1.78	2.68	1.19	-11.07	-2.49	6.96	12.20	-12.27	-1.63
IC-117236 x Varsha Uphar	-3.91	19.55*	10.65*	0.20	2.68	1.85	-6.00	3.84	0.20	-1.77	-10.32	-6.59
IC-117236 x P-8	-2.94	-15.37*	-10.38*	-0.20	-15.31*	-10.30*	-1.31	-15.25	-7.20	3.17	-15.22	-7.24
IC-128061 x Arka Abhay	-14.28*	19.28*	8.87	-15.98*	20.78*	8.45	-0.74	8.18	3.54	25.23	-2.67	9.51
IC-128061 x Varsha Uphar	-8.07	4.65	2.99	-4.14	5.96	2.51	-4.12	-2.56	-1.01	15.46	-15.87	-2.20
IC-128061 x P-8	-4.53	14.20*	8.85	-4.54	15.61*	8.85	-1.34	-17.99	-1.91	18.81	-17.97	-1.95
IC-128099 x Arka Abhay	-4.71	2.59	0.22	-5.72	-13.32*	-10.83*	-8.42	-6.96	-2.92	15.55	-4.11	4.47
IC-128099 x Varsha Uphar	-11.53	-6.44	-8.37	-4.69	-19.58*	-15.72*	1.04	-4.10	-3.35	14.62	-4.26	3.98
IC-128099 x P-8	-9.46	12.22	4.95	-9.47	12.23	4.99	-4.49	-5.79	-5.19	8.38	-2.96	2.03
EC-169476 x Arka Abhay	-3.75	-20.71*	-15.56*	-5.52	-8.55	-7.66	-22.07	-2.78	-12.36	8.10	5.92	6.83
EC-169476 x Varsha Uphar	-8.19	-11.23	-8.49	-4.14	2.39	0.13	-2.86	-0.22	1.53	34.73	8.73	20.08
EC-169476 x P-8	-5.26	-28.15*	-20.65*	-5.13	-17.10*	-13.21*	54.16	7.46	30.65*	113.78*	17.10	59.27*
EC-169513 x Arka Abhay	-10.37	12.01	4.16	-11.83	15.21*	9.64	-12.94	18.10	3.64	18.16	6.20	11.46
EC-169513 x Varsha Uphar	-17.58*	27.34*	11.58*	-9.07	31.01*	17.57*	-21.65	7.41	-8.23	6.33	-7.29	-1.29
EC-169513 x P-8	-11.62	-12.01	-11.88*	-5.56	-9.44	-7.13	-29.86	11.21	-3.07	-4.75	11.18	4.23
EC-305644 x Arka Abhay	-1.47	24.55*	14.94*	-3.35	5.27	2.25	-7.87	4.34	0.38	16.20	-1.66	6.18
EC-305644 x Varsha Uphar	-10.27	32.74*	16.41*	-6.31	14.02*	7.13	-18.70	-6.58	-12.53	-4.75	-11.90	-8.78
EC-305644 x P-8	-1.71	-9.87	-7.13	-1.58	-9.84	-7.13	-5.19	-7.74	-3.64	10.08	-7.72	0.49
EC-329356 x Arka Abhay	-1.95	-12.46	-9.06	-0.79	-6.66	-4.76	-18.04	-9.81	-10.36	3.35	-7.58	-2.76
EC-329356 x Varsha Uphar	-1.07	-18.92*	-12.15*	3.16	-13.52*	-7.93	-9.41	8.57	0.16	5.21	11.26	8.62
EC-329356 x P-8	8.17	-0.28	2.63	10.06	6.36	7.53	-4.28	-19.58	-12.42	11.17	-17.60	-5.04
EC-329424 x Arka Abhay	-3.04	-8.02	-6.27	-1.58	-13.82*	-9.78*	-13.81	-15.78	-14.84	9.96	-8.30	-0.33
EC-329424 x Varsha Uphar	-3.65	-14.53*	-9.24	0.59	-19.88*	-13.08*	-9.82	-5.88	-7.76	15.08	2.45	7.97
EC-329424 x P-8	0.45	-3.71	-1.83	1.97	-3.68	-1.85	-10.12	-6.19	-8.06	14.71	2.09	7.64
EC-7194 x Arka Abhay	3.22	1.92	2.40	1.18	-13.92*	-8.85	-7.53	-1.81	-3.20	16.67	-8.73	2.36
EC-7194 x Varsha Uphar	-2.65	10.72	5.65	1.58	-4.87	-2.77	29.11	0.52	16.02	25.23	-6.57	7.32
EC-7194 x P-8	-3.02	-4.97	-4.32	-2.96	-4.97	-4.36	17.11	-2.02	6.33	17.04	-2.02	6.34
LB Local x Arka Abhay	-10.66*	-0.67	-4.35	-12.43	-16.10*	-14.93*	-15.35	-3.58	-9.71	6.80	-13.28	-4.55
LB Local x Varsha Uphar	-25.58*	1.70	-8.66	-22.29*	-12.62	-15.98*	-9.34	17.38	3.49	9.59	1.66	5.12
LB Local x P-8	-16.75*	15.07*	-15.64*	-16.77*	-15.01	-15.72*	-3.26	-12.36	-1.13	16.95	-12.34	0.41
SE (d) ±	0.34	0.67	0.38	0.34	0.67	0.38	2.94	1.55	1.66	2.94	1.55	1.66

*Significant at P = 0.05

Table 5. Heterosis for fruit diameter and fruits per plant at Akrot (E_1), Palampur (E_2) and pooled over environment (E_3)

Crosses	Fruit diameter						Fruits per plant					
	Better Parent			Standard Check			Better Parent			Standard Check		
	E_1	E_2	E_3	E_1	E_2	E_3	E_1	E_2	E_3	E_1	E_2	E_3
IC-117236 x Arka Abhay	3.47	-1.79	-4.05	23.14*	-2.72	8.96	-16.54	-19.69*	-13.69	-11.43	-10.02	-10.72
IC-117236 x Varsha Uphar	-8.10	-6.22	-7.11	9.09	2.72	5.22	7.22	-11.24	-3.50	0.51	-0.56	-0.09
IC-117236 x P-8	-5.56	-3.32	-4.38	12.40	5.44	8.96	-6.90	-14.79	-8.78	-6.84	-4.53	-5.63
IC-128061 x Arka Abhay	-3.33	1.88	-0.71	12.40	-1.36	4.48	-36.48*	-22.66*	-28.11*	-12.85	-21.64*	-17.87*
IC-128061 x Varsha Uphar	-4.11	-0.47	-0.73	9.09	-4.76	1.49	-28.60*	-3.21	-14.88*	-2.04	-3.10	-2.68
IC-128061 x P-8	0.48	-6.79	0.61	14.88*	-6.80	2.99	35.66*	-11.75	-22.83*	-11.73	-11.77	-11.80
IC-128099 x Arka Abhay	1.90	-4.44	1.73	18.18*	2.72	9.70	-44.43*	-14.19*	-28.15*	-18.16	14.88	0.36
IC-128099 x Varsha Uphar	5.60	-0.63	2.19	14.05*	6.80	10.45*	-21.40*	-5.41	-12.79*	15.71	26.57*	21.81*
IC-128099 x P-8	1.02	-8.46	-4.16	9.09	-2.04	2.99	-33.36*	-40.54*	-37.23*	-1.94	-20.45*	-12.33
EC-169476 x Arka Abhay	-6.41	-0.45	-0.71	8.26	0.68	4.48	10.42	22.71*	17.19*	17.14	24.34*	21.18*
EC-169476 x Varsha Uphar	1.26	4.48	2.96	10.74	5.44	8.20	12.75	-0.64	6.68	15.82	-0.56	6.61
EC-169476 x P-8	-4.52	2.47	-0.83	4.96	3.40	3.73	-6.36	23.04*	11.25	-3.78	22.99*	11.17
EC-169513 x Arka Abhay	-1.98	-0.22	-1.10	23.14*	2.72	11.94*	-20.77*	-10.08	-15.60*	16.63	-3.26	5.36
EC-169513 x Varsha Uphar	-12.75*	-2.87	-7.82	9.09	0.00	3.73	-21.60*	-32.25*	-26.75*	15.41	-27.13*	-8.58
EC-169513 x P-8	-14.51*	-2.65	-5.95	7.44	5.44	5.97	-17.05*	3.33	-7.19	22.14	11.14	15.91*
EC-305644 x Arka Abhay	-5.02	-7.02	-6.11	24.79*	20.41*	22.39*	-2.02	-24.65*	-14.18*	3.98	-23.63*	-11.61
EC-305644 x Varsha Uphar	-20.71*	-12.98*	-16.51*	4.13	12.24	8.96	13.24	-13.62	-2.28	6.12	-13.52	-5.00
EC-305644 x P-8	-16.11*	-14.56*	-15.27*	10.74	10.20	10.45*	3.50	1.88	2.59	3.57	1.91	2.59
EC-329356 x Arka Abhay	-9.98	-7.56	-7.77	4.13	0.00	1.49	-6.71	4.46	-0.46	-0.31	10.42	5.72
EC-329356 x Varsha Uphar	-2.43	-2.31	-2.36	10.74	5.44	8.21	1.65	-2.18	-0.49	8.67	3.42	5.63
EC-329356 x P-8	-1.94	-8.40	-5.41	11.57	-1.36	4.48	-16.42	-6.97	-11.14	-10.61	-1.67	-5.63
EC-329424 x Arka Abhay	-3.49	-8.50	-6.07	14.05*	-4.76	3.73	-6.86	15.56	4.73	26.53*	30.95*	28.95*
EC-329424 x Varsha Uphar	-10.47	-5.01	-7.65	5.79	-1.36	2.24	8.99	11.02	10.04	48.06*	25.78*	35.48*
EC-329424 x P-8	-6.05	-10.68	-8.44	11.57	-6.80	1.49	4.28	3.44	3.85	41.63*	17.18	27.88*
EC-7194 x Arka Abhay	-2.61	-11.87	-5.88	13.22*	-0.68	5.22	12.18	1.90	6.55	34.39*	15.12	23.50*
EC-7194 x Varsha Uphar	4.70	-7.85	-2.22	16.53*	4.08	9.70	2.21	0.40	1.22	22.45	13.44	17.34*
EC-7194 x P-8	-2.97	-1.21	-2.00	8.26	11.56	9.70	4.03	-9.98	-3.64	24.59*	1.67	11.71
LB Local x Arka Abhay	-15.82*	-3.36	-9.26*	5.79	10.88	8.21	-21.99*	20.25*	1.27	-17.24	21.88*	4.74
LB Local x Varsha Uphar	-18.24*	8.30	-4.27	2.49	24.49*	14.18*	-13.68	16.11	3.54	-19.08	16.23	0.71
LB Local x P-8	-3.74	-2.57	-3.12	20.66*	11.56	15.67*	-11.39	23.07*	7.97	-11.33	23.07*	7.95
SE (d) ±	0.08	0.10	0.07	0.08	0.10	0.07	1.13	1.21	0.83	1.13	1.21	0.83

*Significant at P = 0.05

Table 6. Heterosis for fruit yield per plant and average fruit weight at Akrot (E_1), Palampur (E_2) and pooled over environment (E_3)

Crosses	Fruit yield per plant						Average fruit weight					
	Better Parent			Standard Check			Better Parent			Standard Check		
	E_1	E_2	E_3	E_1	E_2	E_3	E_1	E_2	E_3	E_1	E_2	E_3
IC-117236 x Arka Abhay	-16.93*	-21.14*	-15.22*	-4.05	-4.10	-4.09	-1.08	-7.36	-4.41	8.41	1.13	4.64
IC-117236 x Varsha Uphar	1.71	-20.02*	-9.77	9.08	-2.75	2.09	-4.81	-8.48	-5.06	8.31	-0.09	3.90
IC-117236 x P-8	-8.68	-5.42	-6.61	-7.81	15.00	5.66	-10.08*	2.00	-3.67	-1.38	11.34*	5.38
IC-128061 x Arka Abhay	-30.41*	-12.27	-20.71*	-3.43	-12.59	-8.84	1.82	8.88	7.91*	10.39	10.99*	10.76*
IC-128061 x Varsha Uphar	-29.31*	3.54	-12.69*	-1.90	1.97	0.38	-12.00*	2.83	1.05	0.10	4.80	2.69
IC-128061 x P-8	-31.19*	-4.16	-16.77*	-4.51	-4.16	-4.31	6.72	5.42	6.03	7.91	7.42	7.70*
IC-128099 x Arka Abhay	-23.95*	-21.85*	-21.31*	-12.16	2.15	-3.72	-1.28	-3.47	-2.11	7.02	2.79	4.82
IC-128099 x Varsha Uphar	5.73	1.80	3.25	16.68	33.06*	26.35*	-12.11*	-0.27	-3.49	0.00	6.20	3.34
IC-128099 x P-8	-15.66	-17.42	-16.77*	-6.94	7.94	1.84	-10.54*	-7.38	-8.87*	-3.66	-1.40	-2.41
EC-169476 x Arka Abhay	10.20	26.91*	19.46*	27.29*	26.45*	26.79*	0.15	0.18	0.32	8.61	-2.11	2.97
EC-169476 x Varsha Uphar	11.26	2.85	6.64	19.33*	-6.28	4.21	-9.42	5.54	2.00	3.07	3.14	3.15
EC-169476 x P-8	10.29	22.95*	18.43*	11.91	22.95	18.43*	16.92*	-0.74	-7.56*	16.91*	-0.70	7.61*
EC-169513 x Arka Abhay	-35.62*	8.30	-15.35*	15.55	7.90	11.03	-18.88*	13.16*	0.00	-0.40	10.30	5.29
EC-169513 x Varsha Uphar	-37.42*	-16.03	-28.01*	12.33	-17.98	-5.58	-20.12*	23.66*	-0.23	-1.98	11.17*	5.01
EC-169513 x P-8	-30.82*	1.12	-15.71*	24.16*	1.12	10.55	-17.38*	-10.09	-9.44*	1.38	-10.03	-4.64
EC-305644 x Arka Abhay	-16.94*	-27.62*	-23.44*	0.10	-6.07	-3.55	-26.98*	11.89*	-8.27*	-3.17	21.47*	10.02*
EC-305644 x Varsha Uphar	-6.44	-18.05*	-13.50*	12.75	6.36	8.97	-20.29*	12.03*	-4.73	5.74	21.64*	14.19*
EC-305644 x P-8	-5.74	-14.39	-11.00*	13.59	11.10	12.11	-17.28*	-0.80	-9.35*	9.69	7.68	8.72*
EC-329356 x Arka Abhay	-18.40*	-9.88	-5.14	-5.74	9.28	3.13	-12.74*	-11.34*	-8.77*	-5.44	-1.83	-3.43
EC-329356 x Varsha Uphar	21.06*	5.06	11.81*	29.82*	15.84	21.56*	4.61	-0.11	8.31*	18.99*	10.65*	14.66*
EC-329356 x P-8	-22.28*	-2.73	-10.57	-17.22	7.25	-2.77	-7.54	-7.96	-7.77*	-7.42	1.92	-2.41
EC-329424 x Arka Abhay	-11.29	25.96*	8.54	32.15*	48.07*	41.55*	-3.87	9.23	2.86	5.74	11.87*	9.09*
EC-329424 x Varsha Uphar	-1.91	12.52	5.77	46.12.*	32.28*	27.94*	-13.50*	1.36	-4.40	-1.58	3.84	1.39
EC-329424 x P-8	-2.00	3.66	1.01	45.99*	21.87	31.73*	-6.78	0.51	-3.03	2.47	2.97	2.78
EC-7194 x Arka Abhay	9.46	6.07	7.56	64.74*	40.84*	50.62*	-2.04	3.70	0.91	21.96*	20.68*	21.34*
EC-7194 x Varsha Uphar	-10.64	14.41	3.38	34.49*	51.92*	44.78*	-11.02*	13.92*	1.81	10.78*	32.64*	22.45*
EC-7194 x P-8	-9.42	-16.96	-13.64*	36.32*	10.27	20.93*	-12.02*	-8.37	-10.41*	9.50	6.63	8.07*
LB Local x Arka Abhay	-23.48*	27.66*	10.72	-11.62	37.71*	17.51*	-13.25*	2.75	-5.23	6.43	11.87*	9.37*
LB Local x Varsha Uphar	-18.60*	27.88*	13.15*	-12.72	37.95*	17.21*	-12.45*	8.39	-2.00	7.42	18.06*	13.08*
LB Local x P-8	2.23	31.53*	21.30*	2.23	41.89*	25.65*	-2.63	4.70	1.05	19.39*	14.05*	16.60*
SE (d) ±	9.70	16.91	9.75	9.70	16.91	9.75	0.55	0.61	0.41	0.55	0.61	0.41

*Significant at P = 0.05

Table 7. Heterosis for nodes per plant and plant height at Akrot (E_1), Palampur (E_2) and pooled over environment (E_3)

Crosses	Nodes per plant						Plant height					
	Better Parent			Standard Check			Better Parent			Standard Check		
	E_1	E_2	E_3	E_1	E_2	E_3	E_1	E_2	E_3	E_1	E_2	E_3
IC-117236 x Arka Abhay	-18.61*	-17.96*	-15.32*	-12.86	-2.07	-7.39	-13.33	-0.13	-4.83	-6.85	-3.57	-4.66
IC-117236 x Varsha Uphar	-4.68	-13.42*	-9.52	-5.61	3.32	-1.08	3.93	0.91	3.29	5.11	-3.28	-0.50
IC-117236 x P-8	-9.71	-10.20	-9.58	-9.69	7.17	-1.14	-5.39	-10.90	-8.72	-4.31	-10.90	-8.72
IC-128061 x Arka Abhay	-32.08*	-20.31*	-23.81*	-19.74*	-14.17	-16.95*	-39.12*	5.81	-8.79	-29.01*	2.17	-8.18
IC-128061 x Varsha Uphar	-23.73*	-6.65	-12.94*	-9.87	-0.41	-5.11	-30.25*	9.91	-3.28	-18.67*	5.34	-2.63
IC-128061 x P-8	-31.02*	-7.83	-20.22*	-18.53*	-7.65	-13.04*	-31.38*	7.63	-2.20	-19.98*	7.63	-1.54
IC-128099 x Arka Abhay	-20.33*	-9.87	-14.66*	-8.17	19.74*	6.01	-22.21*	-5.82	-11.60*	-6.62	2.97	-0.22
IC-128099 x Varsha Uphar	-5.73	-2.07	-3.74	8.65	30.11*	19.53*	-6.63	-4.44	-5.21	12.08	4.48	6.99
IC-128099 x P-8	-13.99**	-30.08*	-22.72*	-0.85	-7.11	-4.03	-20.96*	-7.87	-12.49*	-5.12	0.72	-1.22
EC-169476 x Arka Abhay	-2.73	20.01	9.66	10.18	29.28*	19.83*	-0.53	5.47	3.51	11.21	20.72*	17.56*
EC-169476 x Varsha Uphar	-2.15	-0.35	-0.69	10.85	6.34	8.53	-0.38	-7.57	-5.22	11.38	5.80	7.64
EC-169476 x P-8	-18.92*	19.92*	0.08	-8.17	26.44*	9.38	-15.23*	-6.33	-9.44*	-5.23	7.20	3.08
EC-169513 x Arka Abhay	-19.90*	-11.34	-15.64*	-5.24	1.19	-1.98	-33.61*	0.32	-12.86*	-3.23	14.34*	8.50
EC-169513 x Varsha Uphar	-17.87*	-24.50*	21.17*	-2.86	-13.81*	-8.41	-36.47*	-6.69	-18.26*	-7.40	6.35	1.78
EC-169513 x P-8	-14.15*	-0.61	-7.41	1.58	13.46*	7.57	-28.31*	1.78	-9.90*	4.50	16.01*	12.18*
EC-305644 x Arka Abhay	-3.38	-17.89*	-10.56*	3.41	-11.14	-3.97	-2.75	1.26	-0.17	4.52	-2.23	7.88
EC-305644 x Varsha Uphar	16.93*	-14.55*	-0.24	8.41	-7.53	0.36	17.89*	12.04	14.00*	14.70	7.39	9.81
EC-305644 x P-8	-1.67	-4.44	0.34	-1.65	3.43	0.90	-3.76	-5.76	-5.10	-3.76	-5.76	-5.10
EC-329356 x Arka Abhay	-14.67*	2.63	-6.00	-2.23	15.06*	6.01	-15.69*	-1.34	-6.40	1.60	8.33	6.17
EC-329356 x Varsha Uphar	-12.85*	-5.57	-9.18	-1.10	5.87	2.46	-14.75*	-8.60	-10.77*	2.73	0.47	1.21
EC-329356 x P-8	-19.42*	-9.45	-14.39*	-8.53	1.48	-3.43	-8.64	-5.09	-6.35	10.10	4.32	6.23
EC-329424 x Arka Abhay	-7.61	13.01	2.72	4.08	24.24*	14.30*	-6.01	4.26	0.62	10.86	11.20	11.00*
EC-329424 x Varsha Uphar	2.11	14.52*	8.33	15.05*	25.90*	20.55*	3.78	4.54	4.27	22.15*	11.51	15.03*
EC-329424 x P-8	-0.47	3.81	1.67	12.13	14.11*	13.16*	2.07	5.58	4.34	20.13*	12.61	15.11*
EC-7194 x Arka Abhay	7.84	6.63	7.23	18.22*	15.65*	16.89*	18.54*	7.56	12.17*	29.52*	3.86	12.37*
EC-7194 x Varsha Uphar	4.34	3.73	4.03	14.38*	12.51	13.46*	12.84	13.43	16.88*	23.29*	8.72	13.55*
EC-7194 x P-8	-3.48	-2.11	-2.79	5.79	6.16	6.01	4.07	3.31	6.76	13.71	3.31	6.75
LB Local x Arka Abhay	-17.65*	8.68	-4.26	-11.82	17.07*	2.82	-20.81*	10.92	-0.37	-14.88	7.11	-0.20
LB Local x Varsha Uphar	-10.43	6.89	-1.04	-17.00*	14.05*	-1.26	-28.87*	7.00	-4.57	-29.47*	2.55	-8.08
LB Local x P-8	-3.92	17.34*	7.70	-3.90	19.03*	7.69	-7.51	7.29	2.38	-7.51	7.28	2.37
SE (d) ±	1.19	1.34	0.90	0.34	1.34	0.90	6.77	11.66	6.74	1.68	11.66	6.74

*Significant at P = 0.05

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