DISCUSSION

Okra (*Abelmoschus esculentus* (L.) Moench) is one of the important vegetable crops of India, belongs to family Malvaceae and the genus *Abelmoschus*. India is the pioneer country in the development of high yielding hybrids of vegetables by using conventional method (hand emasculation and pollination). The basic objective of a breeding programme is to increase yield potential and fulfill requirement of ever increasing human population. Yield increase is accompanied by developing more productive plant types as a result of greater physiological efficiency. Among the various tools a breeder has to improve the productivity, the natural phenomenon of heterosis has fascinated a lot and its use in crop improvement has assumed a considerable significance in obtaining higher yield with quality produce, in many vegetables high degree of heterosis for yield and its quality component, has been reported by many workers in several crops.

Exploitation of hybrid vigour in okra also has been recognized as practical tool and some commercial F_1 hybrids were now being grown successfully. For developing promising cultivar through hybridization, choice of parent is a matter of great concern to a plant breeder. A high yield genotype may or may not transmit its superiority to its progenies therefore, the success of a breeding programme is determined by useful gene combination in the form of high combining inbreeds.

The knowledge of gene action for different traits in okra is of prime importance before starting a breeding programme. Determination of the most suitable breeding method and selection strategy for improvement of a trait would depend on the knowledge of gene actions and expressions in the breeding population. Generation mean analysis is an efficient tool to understand the nature of gene effects involved in the expression of the characters. The efficient portioning of genetic variance in to its components *viz.*, additive, dominance and epistasis gene interaction will help in formulating an effective and sound breeding programme to the plant breeder.

Okra is an important vegetable getting good price in the market. Okra needs attention to improve the yield and yield contributing characters, pest and disease resistance. The productivity of okra in Maharashtra was low because of the poor yielding local cultivars and YVM disease (Fugro and Rajput 1999). Keeping this in view, the efforts were made in present investigation to study the genetic parameters which would help in construction of selection indices for improvement in okra. The results obtained from five season (three *kharif* and two summers) data are discussed as under with suitable headings.

5.1 Analysis of variances for line x testers

5.2 Heterosis

5.3 Combining ability

5.4 Combining ability variances and gene action

5.4 Genotype x Environment (G x E) interaction/stability analysis

5.1 ANALYSIS OF VARIANCE FOR LINE X TESTERS

5.1.1 Kharif 2010 (KE_1)

Analysis of variances revealed significant differences among parents for three traits and non-significant for number of branches per plant, tender fruit length, number of seeds per fruit, number of fruits per plant and weight of fruit per plant. Genetic variability among the parents is essential as it affects the effectiveness of the selection for genetic improvement in seed yield and yield attributes. The crosses showed significant differences for all the traits except days to first flowering, number of branches per plant, tender fruit length and number of fruits per plant. The interaction between parents and crosses was found significant for characters days to 50% flowering, plant height, number of fruits per plant and weight of fruits per plant, heterosis could be exploited for those characters.

5.1.2 Kharif 2011 (KE_2)

Analysis of variances showed significant differences among parents for all the traits except tender fruit length. The crosses showed the significant differences for all the traits except number of branches per plant and tender fruit length. These findings confirm that for expression of heterosis presence of genetic variability is essential. The interaction between parents and crosses expressed significant differences for characters *viz.,* number of branches per plant, tender fruit length, number of seeds per fruit, number of fruits per plant and weight of fruits per plant, heterosis could be exploited in these characters.

5.1.3 Kharif 2012 (KE_3)

Analysis of variances revealed that two characters tender fruit length and number of seeds per fruit were recorded non-significant differences among the parents and crosses. These findings confirm that for expression of heterosis presence of genetic variability is essential. The interaction between parent and crosses recorded significant for all the characters except, characters lacking genetic variability with in parental population.

5.1.4 Summer 2011 (SE_1)

Similar results were revealed in summer season for characters days to first flowering and days to 50% flowering, whereas hybrids recorded non-significant differences for number of branches per plant and number of seeds per fruit. The interaction between parents and crosses was found significant for characters days to 50% flowering, number of fruits per plant and weight of fruits per plant, heterosis could be exploited for those characters.

5.1.5 Summer 2012 (SE_2)

Analysis of variances revealed that characters *viz.*, number of branches per plant, plant height and weight of fruits per plant were recorded non-significant differences among the parents and crosses. These findings confirm that for expression of heterosis presence of genetic variability is essential.

Significant interaction was revealed between parents and crosses for characters *viz.*, days to first flowering, days to 50% flowering, tender fruit length and number of fruits per plant, heterosis could be exploited in these characters.

Udengwu (2009) revealed significant differences for length of pod, number of seeds per pod, number of pods per plant, weight of pods per plant, plant height and days to flower opening. Weerasekara *et al.* (2008) observed significant differences for all the characters indicating presence of genetic variability. Borgaonkar *et al.* (2006b) revealed significant differences for days to 50% flowering, days to first picking, fruit length, fruit girth, number of nodes on main stem, plant height, intermodal distance and yield per plant indicating considerable genetic diversity.

5.2 HETEROSIS

The primary objective of heterosis breeding is to achieve a quantum jump in yield and quality aspects of crop plants. Earlier several workers namely Vijayranghwan and Wariar (1946), Pal *et al.* (1952), Joshi *et al.* (1975), Singh and Mandal (1993) and Dhankar *et al.* (1998) had observed appreciable heterosis value for most of the economic characters *viz.*, Plant height, fruit length and fruit yield by number and weight. Top five hybrids selected on the basis of per se performance along with *sca* effects, relative heterosis, heterobeltiosis, standard heterosis, *gca* effects of parents. Eight quantitative traits during *kharif* – 2010 (KE1), *kharif* – 2011 (KE2), *kharif* –

2012 (KE3), summer – 2011 (SE1) and summer – 2012 (SE2) presented in table (5.1 A-E)

5.2.1 Days to first flowering

5.2.1.1 Kharif 2010 (KE_1)

In present investigation negative heterosis for days to flower initiation recorded up to extent of -6.98% and -13.04% over mid parent and better parent respectively. Significant negative heterosis over mid parent and better parent recorded by four hybrids *viz.*, BO-2 x 315 (-6.98% and -13.04%), 35 x 315 (-6.56% and -12.32%), 447 x 315 (-5.79% and -11.59%) and EC-316053 x 315 (-6.51% and -11.59%). None of the hybrids was expressed negative heterosis over standard check.

5.2.1.2 Kharif 2011 (KE_2)

Heterosis was ranged from -8.87 to 7.56%, -10.69 to 5.79% and -4.24 to 8.47% over mid parent, better parent and standard check respectively. Three hybrids *viz.*, 35 x VRO-4, 35 x 410 and EC-316053 x 410 were exhibited highest significant negative relative heterosis and heterobeltiosis. None of the hybrid was shown significant negative standard heterosis.

5.2.1.3 Kharif 2012 (KE_3)

Highest extent of negative heterosis observed over mid parent (-9.16%), better parent (-11.02%) and standard check (-8.87%). Significant negative heterosis was shown by six, eight and sixteen hybrids over mid parent, better parent and standard check respectively. Six hybrids *viz.,* 447 x 410, EC-316053 x VRO-4, EC-316053 x 162, EC-316053 x 364, EC-316053 x 410 and Vaibhav x 364 were expressed significant negative heterosis over mid parent, better parent and standard check.

5.2.1.4 Summer 2011 (SE$_1$)

In the present investigation, heterosis ranged from -3.03 to 2.72%, -5.19 to 2.33% and -3.85 to 1.54% over mid parent, better parent and standard check respectively. Significant negative heterosis was shown by six, seven and two hybrids over mid parent, better parent and standard check respectively. Hybrid BO-2 x VRO-4 expressed significant negative heterosis over the mid parent, better parent and standard check.

5.2.1.5 Summer 2012 (SE$_2$)

Extent of negative heterosis over mid parent, better parent and standard check observed up to -9.96%, -11.59% and -10.29% respectively. Highest significant negative heterosis over standard check recorded by hybrid BO-2 x IIVR-11 (-10.29%), 35 x HRB-55 (-10.29%), BO-2 x 364 (-9.56%) and Vaibhav x 410 (-9.56%). Significant negative heterobeltiosis was exhibited by five hybrids. Hybrid BO-2 x IIVR-11 expressed significant negative heterosis over mid parent, better parent and standard check.

Therefore hybrids *viz.,* BO-2 x 315, 35 x 315, 447 x 315, EC-316053 x 410, EC-316053 x 315, EC-316053 x 364, BO-2 x VRO-4 and BO-2 x IIVR-

11 could be utilized for developing early flowering high yielding varieties in later segregating generations.

In present investigation, considerable heterosis is observed and similar findings are reported by Dayashankar (1994), Sivakumar (1997), Thippeswamy (2001) Rewale *et al.* (2003), Wammanda *et al.* (2010). Aggarado and Rasco (1986), Sheela *et al.* (1988) recorded significant negative heterosis. Chaudhary *et al.* (1991a) recorded significant negative heterosis over check Harbhajan. Mamidwar and Mehta (2006) reported highest heterobeltiosis in Daftari-1 x Arka Abhay.

5.2.2 Days to 50% flowering

5.2.2.1 Kharif 2010 (KE_1)

During this season, range of heterosis observed up to extent of -13.51 to 3.97%, -16.56 to 1.43% and -0.79 to 18.11% over mid parent, better parent and standard check. Highest significant negative heterobeltiosis was expressed by four hybrids *viz.*, EC-316053 x IIVR-11 (-16.53%), EC-316053 x VRO-4 (-15.23%), EC-316053 x HRB-55 (-15.23%), EC-316053 x 410 (-14.57%). None of the hybrid was shown significant superiority over standard check.

5.2.2.2 Kharif 2011 (KE_2)

Desirable negative heterosis observed up to -11.51%, -14.08% and -3.23% over mid parent, better parent and standard check. Nine and sixteen hybrids were found significant negative heterosis over mid parent and better parent. Highest significant negative heterosis over better parent recorded by four hybrids *viz.,* 447 x 410 (-14.08%), EC-316053 x 410 (-13.38%), BO-2 x 410 (-11.97%) and 35 x 410 (-11.97%). None of the hybrid was shown significant negative heterosis over standard check.

5.2.2.3 Kharif 2012 (KE_3)

Extent of heterosis over mid parent, better parent and standard check noticed up to -9.23 to 5.34 %, -13.38 5.34 % and -6.25 to 7.81 % respectively. Five hybrids *viz.,* EC-316053 x VRO-4, EC-316053 x HRB-55, EC-316053 x 162, EC-316053 x 364 and EC-316053 x 410 recorded significant negative heterosis over mid parent and better parent. None of the hybrid was exhibited significant negative standard heterosis.

5.2.2.4 Summer 2011 (SE_1)

Highest extent of negative heterosis recorded over mid parent (-3.50%), better parent (-6.12%) and standard check (-0.72%). Highest significant negative heterosis over mid parent and better parent recorded by hybrid BO-2 x 410, 35 x 410, 447 x 410, EC-316053 x 410 and Vaibhav x 410. None of the hybrid expressed significant negative heterosis over standard check.

5.2.2.5 Summer 2012 (SE_2)

Extent of heterosis ranged from -3.52 1.81%, -4.86 to 1.44% and -3.55 to 0.00% over mid parent, better parent and standard check. Three hybrids *viz.,* BO-2 x IIVR-11, BO-2 x 162 and BO-2 x 315 recorded with significant negative heterosis over mid parent, better parent and standard check. Hybrid 35 x 162 was found significant negative heterosis over better parent and standard check and non-significant negative heterosis over mid parent. Three hybrids *viz.*, EC-316053 x 410, EC-316053 x HRB-55 and EC-316053 x VRO-4 were showed negative average heterosis also substantiated the fact that the hybrids in general were early in flowering. The existence of both positive and negative heterotic effect over parents and checks suggests the presence of non-additive gene action for this trait. Swamy Rao (1997), Shukla and Gautam (1990), Dayasagar (1994) and Patil (1995), Jayprakashnarayan (2003) have also reported earliness in okra hybrids. Pathak and syamal (1997) and. Akhtar *et al.* (2010) recorded maximum heterosis (-22.86%) for days to 50% flowering.

5.2.3 Number of branches per plant

5.2.3.1 Kharif 2010 (KE_1)

Branches are the important growth parameters contributing to productivity. The extent of positive heterosis recoded over mid parent (11.63%), better parent (6.67%) and standard check (20.00%). Highest positive non-significant standard heterosis registered by EC-316053 x 364 (20.00%), EC-316053 x 410 (15.56%) and Vaibhav x 315 (13.33%). None of the hybrid showed significant positive heterosis over mid parent, better parent and standard check.

Table: 5.1 Top five hybrids on basis of *per se* performance for quantitative traits in kharif- 2010 (KE_1)

Character	Crosses	Mean	SCA	RH	Hb	SH	*gca* of parents
Days to first flowering	BO-2 x 315	40.00	-0.886	-6.98 **	-13.04 **	0.00	H x L
	EC-316053 x 364	40.00	-0.048	-1.64	-2.44	0.00	H x H
	VAIBHAV x VRO- 4	40.00	-0.314	-0.83	-0.83	0.00	L x H
	VAIBHAV x IIVR- 11	40.00	-0.314	-0.41	-0.83	0.00	L x H
	VAIBHAV x 364	40.00	-0.381	-0.83	-0.83	0.00	L x H
Days to 50% flowering	BO-2 x 410	42.00	-1.724	-5.26	-5.26	-0.79	H x H
	35 x HRB- 55	42.00	-0.895	-7.01	-9.35 *	-0.79	L x H
	447 x HRB- 55	42.00	0.390	-4.55	-4.55	-0.79	H x H
	447 x 410	42.00	-0.343	-4.91	-5.26	-0.79	H x L
	EC-316053 x IIVR- 11	42.00	-1.714	-12.80 **	-16.56 **	-0.79	H x L
Number of branches	EC-316053 x 364	1.80	0.172	10.20	3.85	20.00	H x H
	447 x 162	1.67	0.119	6.38	6.38	11.11	H x L
	447 x IIVR-11	1.67	0.139	6.38	6.38	11.11	H x M
	Vaibhav x VRO-4	1.67	0.092	0.00	-3.85	11.11	L x H
	Vaibhav x 315	1.70	0.192	0.00	-5.56	13.33	L x H
Plant height (cm)	BO-2 x VRO-4	86.10	6.093	29.41 *	29.02	-14.81	M x M
	35 x VRO-4	91.80	11.589	33.37 *	28.69	-9.17	M x M
	35 x IIVR-11	80.47	9.082	7.12	1.99	-20.38	M x M
	447 x HRB-55	80.63	15.300	28.67	19.99	-20.22	L x L
	EC-316053 x 162	89.00	9.398	50.85 **	40.60 *	-11.94	L x M
Tender fruit length	BO-2 x 162	10.40	0.218	2.80	1.30	1.30	L x H
	35 x 315	10.30	0.168	3.00 *	2.32	0.32	H x L
	EC-316053 x HRB-55	10.30	0.139	0.00	-0.32	0.32	H x L
	EC-316053 x 162	10.37	0.132	2.13	0.32	0.97	H x H
	EC-316053 x 364	10.30	0.112	0.82	-0.32	0.32	H x M
Number of seeds per fruit	BO-2 x HRB-55	71.00	8.838	26.79	23.12	21.02	M x M
	35 x 315	69.33	5.067	30.00 *	18.86	18.18	M x M
	447 x 162	67.67	6.476	5.73	-2.87	15.34	L x M
	EC-316053 x 364	67.33	-17.362	36.03 *	23.93	14.77	L x L
	Vaibhav x 315	66.00	0.590	24.14	13.14	12.50	M x M
Number of fruits per plant	BO-2 x IIVR-11	16.47	1.568	27.65	19.32	5.11	M x L
	BO-2 x 410	16.07	0.594	11.57	7.11	2.55	M x M
	35 x 162	16.47	0.621	22.28	16.51	5.11	M x M
	EC-316053 x HRB-55	16.40	2.314	23.93	14.95	4.68	L x L
	Vaibhav x 315	17.13	2.949	62.66 **	51.18 *	9.36	L x M
Weight of fruits per plant	BO-2 x 315	177.3	-3.414	24.51	23.27	14.32	M x M
	35 x VRO-4	160.1	8.664	26.97	24.02	3.22	M x L
	35 x 315	169.2	-13.910	28.18 *	20.06	9.11	M x M
	EC-316053 x HRB-55	172.9	28.698	31.84 *	12.05	11.52	L x L
	Vaibhav x 315	216.9	46.205	82.39 **	53.88 **	39.85 **	L x M

*, ** significance at 5% and 1% level respectively
RH=Relative heterosis, Hb =Heterobeltiosis and SH=Standard heterosis

Table: 5.2 Top five hybrids on basis of *per se* performance for quantitative traits in kharif-2011 (KE_2)

Character	Crosses	Mean	SCA	RH	Hb	SH	*gca* of parents
Days to first flowering	BO-2 x HRB-55	37.67	-1.019	-2.16	-3.42	-4.24	H x H
	35 x VRO-4	37.67	-0.352	-8.87 **	-8.87 **	-4.24	H x H
	35 x IIVR-11	38.33	0.381	-4.17	-7.26 **	-2.54	H x H
	35 x 364	38.33	-0.086	-3.77	-7.26 **	-2.54	H x H
	447 x VRO-4	38.33	-0.352	-4.17	-7.26 **	-2.54	H x H
Days to 50% flowering	BO-2 x IIVR-11	40.33	-0.867	0.00	0.00	-2.42	H x L
	BO-2 x HRB-55	40.33	-0.067	-0.41	-0.82	-2.42	H x H
	35 x VRO-4	40.33	-0.114	-6.56 **	-6.92 **	-2.42	H x H
	447 x 162	40.00	-1.324	-2.44	-3.23	-3.23	H x H
	EC-316053 x VRO-4	40.00	-1.162	-9.43 **	-11.76 **	-3.23	L x H
Number of branches	35 x VRO-4	2.23	0.216	9.84	8.06	11.67	L x H
	EC-316053 x VRO-4	2.13	0.169	11.30	6.67	6.67	L x H
	Vaibhav x VRO-4	2.20	-0.031	6.45	3.13	10.00	H x H
	Vaibhav x 162	2.30	0.222	8.66	7.81	15.00	H x M
	Vaibhav x 315	2.13	0.269	10.34	0.00	6.67	H x L
Plant height (cm)	35 x VRO-4	150.4	9.575	31.11 *	17.38	16.98	M x M
	447 x 364	151.7	3.679	19.95	11.14	17.99	M x M
	Vaibhav x VRO-4	149.0	2.204	16.13	15.98	15.89	M x M
	Vaibhav x HRB-55	147.0	9.964	17.89	14.45	14.36	M x M
	Vaibhav x 364	152.6	3.350	24.65 *	18.81	18.72	M x M
Tender fruit length	BO-2 x VRO-4	10.07	0.167	4.50 *	4.14	-0.33	H x H
	BO-2 x 162	9.93	0.087	2.41	2.05	-1.65	H x H
	447 x 364	10.10	0.291	3.06	2.71	0.00	H x L
	EC-316053 x HRB-55	9.93	0.128	2.58	1.71	-1.65	M x H
	EC-316053 x 410	9.97	0.201	3.64	3.46	-1.32	M x L
Number of seeds per fruit	BO-2 x 315	75.00	10.971	53.58 **	46.10 **	52.03 **	L x M
	EC-316053 x 162	60.00	4.019	40.63 *	16.88	21.62	M x M
	EC-316053 x 315	59.67	-5.648	16.23	16.23	20.95	M x M
	Vaibhav x 162	60.33	2.448	40.86 *	16.77	22.30	M x M
	Vaibhav x 315	73.00	5.781	41.75 **	41.29 **	47.97 **	M x M
Number of fruits per plant	447 x VRO-4	21.07	1.789	19.02 *	15.75	25.90 *	M x H
	EC-316053 x VRO-4	20.13	2.636*	25.83 **	17.05	20.32 *	L x H
	Vaibhav x 162	19.67	0.920	0.85	-1.01	17.53	H x L
	Vaibhav x 315	21.40	2.933*	12.24	7.72	27.89 **	H x L
	Vaibhav x 410	22.07	1.693	26.82 **	11.07	31.87 **	H x H
Weight of fruits per plant	447 x VRO-4	276.1	21.720	16.53 *	9.84	31.88 **	M x M
	EC-316053 x VRO-4	262.6	35.06**	26.11 **	18.04	25.45 *	L x M
	Vaibhav x HRB-55	266.1	5.956	6.21	0.03	27.13 *	M x L
	Vaibhav x 315	313.0	42.37**	26.01 **	17.64 *	49.52 **	M x M
	Vaibhav x 410	289.6	18.330	22.63 **	8.84	38.34 **	M x M

*, ** significance at 5% and 1% level respectively

RH=Relative heterosis, Hb =Heterobeltiosis and SH=Standard heterosis

Table: 5.3 Top five hybrids on basis of *per se* performance for quantitative traits in kharif-2012 (KE_3)

Character	Crosses	Mean	SCA	RH	Hb	SH	*gca* of parents
Days to first flowering	447 x 410	37.67	-1.190	-6.22 *	-8.87 **	-8.87 **	H x L
	EC-316053 x VRO-4	38.00	-0.476	-8.43 **	-10.24 **	-8.06 **	H x H
	EC-316053 x 162	37.67	-1.076	-7.38 **	-11.02 **	-8.87 **	H x L
	EC-316053 x 410	38.00	-1.143	-9.16 **	-10.24 **	-8.06 **	H x L
	Vaibhav x 364	37.67	-0.838	-7.00 **	-7.38 *	-8.87 **	H x H
Days to 50% flowering	BO-2 x VRO-4	40.67	-0.276	-4.31	-6.15	-4.69	H x H
	447 x VRO-4	40.00	-0.324	-6.25	-7.69 *	-6.25	H x H
	447 x IIVR-11	40.67	0.076	-2.79	-3.17	-4.69	H x H
	447 x HRB-55	40.67	0.343	-2.01	-3.17	-4.69	H x H
	EC-316053 x 364	41.00	-0.743	-9.23 **	-13.38 **	-3.91	L x H
Number of branches	35 x 315	2.63	0.290	17.04	16.18	-20.20 *	H x H
	EC-316053 x VRO-4	2.60	0.150	22.83	14.71	-21.21 *	H x M
	EC-316053 x HRB-55	2.50	0.030	18.11	10.29	-24.24 **	H x H
	EC-316053 x 162	2.47	-0.090	16.54	8.82	-25.25 **	H x H
	EC-316053 x 410	2.67	0.203	24.03 *	17.65	-19.19 *	H x H
Plant height (cm)	EC-316053 x IIVR-11	97.60	7.022	32.19 *	28.48	0.07	M x M
	EC-316053 x HRB-55	98.87	7.909	29.83 *	22.66	1.37	M x M
	EC-316053 x 410	94.80	5.355	29.24 *	26.40	-2.80	M x M
	Vaibhav x VRO-4	97.53	7.589	48.08 **	32.34 *	0.00	M x M
	Vaibhav x 162	96.67	6.789	43.85 **	26.58	-0.89	M x M
Tender fruit length	BO-2 x VRO-4	10.43	0.336	7.38	4.68	2.62	H x L
	BO-2 x 162	10.30	0.110	9.38	8.80	1.31	H x M
	BO-2 x 315	10.53	0.336	7.85	4.64	3.61	H x M
	BO-2 x 364	10.40	0.143	9.86	9.86	2.30	H x M
	35 x HRB-55	10.33	0.676	5.62	2.31	1.64	L x L
Number of seeds per fruit	BO-2 x IIVR-11	77.00	12.581	33.91 *	30.51	45.28 *	M x M
	35 x VRO-4	66.67	7.419	7.24	2.04	25.79	L x M
	447 x IIVR-11	68.33	5.343	33.12	22.02	28.93	M x M
	447 x 162	73.33	10.010	35.80 *	19.57	38.36 *	M x M
	EC-316053 x 315	69.00	9.067	17.61	13.11	30.19	L x M
Number of fruits per plant	BO-2 x 162	20.67	1.061	17.87	16.10	-8.01	M x M
	BO-2 x 410	20.93	1.741	23.14 *	17.60	-6.82	M x M
	35 x 162	20.67	1.109	23.51 *	19.69	-8.01	M x M
	EC-316053 x VRO-4	20.67	1.158	22.05 *	17.42	-8.01	M x M
	EC-316053 x 410	20.47	0.865	21.10 *	16.29	-8.90	M x M
Weight of fruits per plant	BO-2 x 315	238.9	3.600	11.81	10.89	-4.78	L x M
	447 x 315	249.7	14.390	28.78 *	15.91	-0.48	L x M
	EC-316053 x HRB-55	236.9	15.678	24.19	22.05	-5.58	M x M
	Vaibhav x 315	267.6	20.895	38.18 **	24.23	6.67	M x M
	Vaibhav x 364	242.5	29.735	43.40 **	41.06 *	-3.32	M x L

*, ** significance at 5% and 1% level respectively

RH=Relative heterosis, Hb =Heterobeltiosis and SH=Standard heterosis

Table: 5.4 Top five hybrids on basis of *per se* performance for quantitative traits in summer-2011 (SE_1)

Character	Crosses	Mean	SCA	RH	Hb	SH	*gca* of parents
Days to first flowering	BO-2 x VRO-4	41.67	-0.914*	-2.72 **	-3.10 **	-3.85 **	L x H
	BO-2 x 410	42.67	-0.181	-3.03 **	-5.19 **	-1.54	L x H
	35 x VRO-4	42.00	-0.438	-1.95	-2.33 *	-3.08 **	H x H
	35 x HRB-55	42.67	-0.038	-0.78	-0.78	-1.54	H x H
	35 x 364	42.67	-0.371	-0.39	-0.78	-1.54	H x L
Days to 50% flowering	BO-2 x VRO-4	46.00	-0.105	-0.36	-0.72	0.00	H x H
	BO-2 x HRB-55	46.00	0.095	-0.72	-0.72	0.00	H x H
	447 x IIVR-11	45.67	-0.410	-1.08	-1.44	-0.72	H x H
	447 x 315	45.67	-0.610	-2.14 *	-2.84 **	-0.72	H x L
	EC-316053 x HRB-55	45.67	-0.238	-1.79 *	-2.14 *	-0.72	H x H
Number of branches	35 x HRB-55	1.53	0.043	5.75	4.55	0.00	H x M
	35 x 410	1.60	0.103	20.00	9.09	4.35	H x H
	447 x VRO-4	1.57	0.006	0.00	0.00	2.17	H x H
	447 x IIVR-11	1.67	0.119	13.64	6.38	8.70	H x M
	447 x HRB-55	1.57	0.019	4.44	0.00	2.17	H x M
Plant height (cm)	BO-2 x 364	50.33	4.406	13.75	0.07	10.22	L x M
	35 x IIVR-11	51.97	5.717	29.97 *	21.61	13.80	M x M
	35 x 162	47.97	1.573	21.59	12.25	5.04	M x M
	Vaibhav x HRB-55	47.60	2.442	30.29	15.25	4.23	M x M
	Vaibhav x 364	49.73	2.415	21.20	-1.13	8.91	M x M
Tender fruit length	BO-2 x 364	10.37	0.410	9.31 **	9.12 *	2.30	H x L
	447 x 364	10.23	0.414	5.32	3.02	0.99	L x L
	Vaibhav x IIVR-11	10.17	0.154	5.72	5.17	0.33	H x M
	Vaibhav x HRB-55	10.23	0.281	5.14	3.37	0.99	H x L
	Vaibhav x 410	10.17	0.201	5.72	5.17	0.33	H x L
Number of seeds per fruit	BO-2 x 410	46.67	7.076	-1.41	-27.08	48.94	L x L
	EC-316053 x IIVR-11	48.67	1.800	37.74	22.69	55.32	M x M
	EC-316053 x 315	58.00	4.867	70.59 **	56.76 *	85.11 **	M x M
	Vaibhav x IIVR-11	49.67	4.705	49.75	25.21	58.51	L x M
	Vaibhav x 315	50.00	-1.229	57.07 *	35.14	59.57	L x M
Number of fruits per plant	BO-2 x 410	15.60	1.316	42.25 *	25.13	-13.01	M x L
	35 x HRB-55	15.13	0.038	26.11	18.85	-15.61	M x M
	447 x HRB-55	15.80	1.162	32.40	24.08	-11.90	L x M
	EC-316053 x VRO-4	15.13	1.863	36.75 *	27.53	-15.61	M x L
	EC-316053 x HRB-55	15.93	0.876	29.54	25.13	-11.15	M x M
Weight of fruits per plant	35 x 410	170.9	13.490	36.09	33.96	-16.78	M x L
	447 x HRB-55	181.4	13.406	29.02	23.18	-11.68	L x M
	447 x 162	177.9	18.152	7.56	-9.65	-13.37	L x M
	EC-316053 x HRB-55	184.5	17.796	29.51	25.26	-10.19	L x M
	Vaibhav x HRB-55	171.1	-1.490	44.81 *	16.16	-16.72	M x M

*, ** significance at 5% and 1% level respectively
RH=Relative heterosis, Hb =Heterobeltiosis and SH=Standard heterosis

Table: 5.5 Top five hybrids on basis of *per se* performance for quantitative traits in summer-2012 (SE_2)

Character	Crosses	Mean	SCA	RH	Hb	SH	*Gca* of parents
Days to first flowering	BO-2 x IIVR-11	40.67	-1.686	-9.96 **	-11.59 **	-10.29 **	H x L
	BO-2 x 364	41.00	-1.524	-5.75	-7.52 *	-9.56 **	H x H
	35 x HRB-55	40.67	-0.924	-6.15	-7.58 *	-10.29 **	H x H
	35 x 162	41.33	-0.552	-4.98	-6.06	-8.82 *	H x H
	Vaibhav x 410	41.00	-1.248	-5.38	-6.82	-9.56 **	H x H
Days to 50% flowering	BO-2 x IIVR-11	45.67	-0.390	-2.49 *	-2.84 *	-2.84 *	H x L
	BO-2 x 162	45.33	-0.257	-2.51 *	-2.86 *	-3.55 **	H x H
	BO-2 x 315	45.67	-0.324	-3.52 **	-4.86 **	-2.84 *	H x L
	BO-2 x 364	45.67	-0.190	-1.44	-2.14	-2.84 *	H x H
	35 x 162	45.67	-0.352	-2.14	-2.84 *	-2.84 *	L x H
Number of branches	BO-2 x VRO-4	1.33	0.082	5.26	-2.44	-6.98	H x L
	35 x 364	1.33	0.095	11.11	8.11	-6.98	L x H
	447 x IIVR-11	1.37	0.141	9.33	0.00	-4.65	L x L
	Vaibhav x 162	1.33	0.037	-1.23	-4.76	-6.98	H x H
	Vaibhav x 315	1.33	0.044	2.56	-4.76	-6.98	H x H
Plant height (cm)	BO-2 x VRO-4	50.33	9.714**	39.36 **	38.79 **	39.43 **	M x M
	BO-2 x IIVR-11	37.37	-0.946	4.04	3.03	3.51	M x M
	35 x 315	37.70	1.910	2.12	0.98	4.43	L x M
	447 x IIVR-11	37.53	1.269	5.33	5.14	3.97	L x M
	Vaibhav x 315	37.83	1.653	5.98	1.34	4.80	L x M
Tender fruit length	35 x VRO-4	10.27	0.230	3.18	1.99	-3.75	M x H
	447 x 162	10.23	0.126	-2.23	-3.46	-4.06	H x H
	447 x 364	10.27	0.412	1.48	-0.65	-3.75	H x L
	Vaibhav x IIVR-11	10.30	0.166	2.49	2.32	-3.44	H x M
	Vaibhav x HRB-55	10.80	0.606*	5.88 *	4.52	1.25	H x H
Number of seeds per fruit	35 x 162	51.00	6.638	24.39	15.04	6.99	M x L
	447 x 315	64.00	9.210	40.66 *	35.21 *	34.27	L x M
	EC-316053 x IIVR-11	54.00	1.429	33.33	28.57	13.29	M x M
	EC-316053 x 162	54.00	3.829	25.10	21.80	13.29	M x L
	EC-316053 x 315	76.67	14.829*	71.64 **	61.97 **	60.84 **	M x M
Number of fruits per plant	BO-2 x VRO-4	21.53	1.722	24.95	20.97	-3.00	M x L
	35 x 162	22.00	1.160	24.29	18.28	-0.90	L x M
	EC-316053 x 364	22.27	3.910*	20.36	12.84	0.30	M x L
	EC-316053 x 410	22.40	2.390	26.32	23.08	0.90	M x M
	Vaibhav x 162	25.80	3.131	50.88 **	38.71 *	16.22	M x M
Weight of fruits per plant	BO-2 x 315	221.1	1.669	26.95	22.14	2.98	M x M
	BO-2 x 410	220.0	0.429	30.25	29.01	2.48	M x M
	EC-316053 x 364	225.5	3.910*	25.34	13.79	5.06	M x L
	Vaibhav x 162	247.3	3.131	11.08	6.55	-12.64	M x M
	Vaibhav x 315	221.5	1.545	-14.28	-18.86	-31.58 *	M x M

*, ** significance at 5% and 1% level respectively

RH=Relative heterosis, Hb =Heterobeltiosis and SH=Standard heterosis

5.2.3.2 Kharif 2011 (KE_2)

The range of relative heterosis was to the tune of -18.40 to 29.67%, heterobeltiosis -20.97 to 19.23% and standard heterosis -21.67 to 15.00% respectively. Two hybrids BO-2 x 410 and 447 x 410 were expressed significant positive heterosis over mid parent and better parent. None of the hybrid expressed significant positive heterosis over better parent and standard check. However, fourteen and thirteen hybrids registered with non-significant positive heterosis over better parent and standard check.

5.2.3.3 Kharif 2012 (KE_3)

Desirable heterosis over mid parent and better parent observed up to extent of 38.78% and 25.93 % respectively. Four hybrids *viz.*, Vaibhav x 364 (38.78%), Vaibhav x 410 (37.54%), Vaibhav x 162 (32.04%) and EC-316053 x 410 (24.03%) were shown significant relative heterosis and twenty five hybrids with non-significant positive heterobeltiosis. None of the hybrid found positive standard heterosis.

5.2.3.4 Summer 2011 (SE_1)

In summer season heterosis for number of branches per plant observed up to extent of 20.00%, 15.79% and 8.70% over parental mean, better parent and standard check. None of the hybrid recorded significant positive heterosis over mid parent, better parent and standard check; however, twenty, fifteen and seven hybrids were registered with positive mid parent, better parent and standard heterosis. Highest non-significant positive relative heterosis and standard heterosis recorded by hybrid 447 x IIVR-11.

5.2.3.5 Summer 2012 (SE_2)

The extent of mid parent and better parent heterosis ranged from -10.84 to 11.11% and -17.07 to 8.33% respectively. None of the hybrid showed significant positive heterosis over mid parent, better parent and standard check. Seventeen hybrids registered with non-significant positive heterosis over mid parent and better parent. However, hybrid 35 x 364 (11.11%) and EC-316053 x 315 (8.33%) recorded highest non-significant positive heterosis over mid parent and better parent.

Six hybrids *viz.,* BO-2 x 410, 447 x 410, Vaibhav x 364, Vaibhav x 410, and Vaibhav x 162 and EC-316053 x 410 were exhibited significant relative heterosis over the season. These hybrids could be utilized for isolative transgressive segregants in later generation of crosses.

Earlier reports of Joshi *et al.* (1958) recorded range of heterobeltiosis up to extent of 1.2 to 25.3%. Elangovan *et al.* (1981) found positive heterosis over better parent. Vijay and Manohar (1986a) reported heterobeltiosis extent of (63.33%). Heterosis for number of branches per plant was also reported by Ahmed *et al.* (1999) and Akhtar *et al.* (2010). Kachhadia *et al.* (2011) reported maximum heterosis over better parent of (66.87%) in the hybrid Pant Bhendi x HRB-55 for number of branches per plant. Kumar (2011) found highest magnitude of heterosis in cross Pusa A4 x Punjab Padmini (14.81 and 52.44%) for number of branches per plant over better parent and Sakthi. Bassey *et al.* (2012) found highest better parent heterosis of (131.15%) for number of branches per plant recorded from the cross Lady Finger x Jokoso.

5.2.4 Plant height

5.2.4.1 Kharif 2010 (KE_1)

Desirable heterosis over mid parent and better parent observed up to extent of 76.68% and 40.85 % respectively. Three hybrids *viz.,* Vaibhav x 315 (76.68%), EC-316053 x 162 (50.85%), Vaibhav x 162 (44.62%) were found with highest significant positive relative heterosis. However, significant positive relative heterosis and heterobeltiosis recorded by EC-316053 x 162. None of the hybrid expressed with positive standard heterosis.

5.2.4.2 Kharif 2011 (KE_2)

Heterosis for plant height observed in both directions, however positive heterosis was recorded up to extent of 68.30%, 23.40% and 18.72% over mid parent, better parent and standard check respectively. Three hybrids *viz.,* EC-316053 x 410 (68.30%), 35 x 410 (64.87%) and 447 x 410 (45.05%) were recorded significant positive heterosis over mid parent. However, twenty-one and twenty hybrids expressed with non-significant positive heterosis over better parent and standard check.

5.2.4.3 Kharif 2012 (KE_3)

The range of heterosis observed up to extent of -26.28 to 48.08%, -28.43 to 32.34% and -39.10 to 1.37% over mid parent, better parent and standard check respectively. Two hybrids Vaibhav x VRO-4 and EC-316053 x 364 were recorded significant positive heterosis over mid parent and better parent. Significant heterosis over mid parent and non-significant heterosis over better parent expressed by five hybrids *viz.*, EC-316053 x VRO-4, EC-316053 x IIVR-11, EC-316053 x HRB-55, EC-316053 x 410 and Vaibhav x 162. None of the hybrid was shown significant positive standard heterosis.

5.2.4.4 Summer 2011 (SE_1)

In summer season, extent of positive heterosis observed up to 51.90%, 32.21% and 13.80% over mid parent, better parent and standard check respectively. Three hybrids viz., Vaibhav x 410 (51.98%), 447 x 410 (35.06%) and 35 x IIVR-11 (39.57%) were exhibited significant positive heterosis over mid parent. None of the hybrid was shown significant positive heterosis over better parent and standard check. However, five hybrids were recorded with positive non-significant heterosis over mid parent, better parent and standard check.

5.2.4.5 Summer 2011 (SE_2)

Desirable heterosis over mid parent, better parent and standard check observed up to extent of 39.36%, 38.79% and 39.43% respectively. Hybrid

BO-2 x VRO-4 was recorded significant positive heterosis over mid parent, better parent and standard check. However fifteen hybrids expressed with non-significant positive heterosis over standard check.

In past studies, heterosis for plant height was reported by several workers, (Venkatramani 1952; Singh *et al.* 1975; Lal *et al.* 1975; El-Maksud *et al.* 1986; Vijay and Manohar, 1986a; Chaudhry *et al.* 1991a; Dhankar *et al.* 1996; Patil *et al.* 1996a; Wankhade *et al.* 1997; Poshiya and Vashi, 1999 and Dhankar and Dhankar, 2001; Wammanda *et al.* 2010; Akhtar *et al.* 2010) to be an important yield component as it was significantly associated with fruit yield. Many workers have reported both positive and negative heterosis values for plant height. The predominance of tallness over dwarfness, indicated tallness to be dominant character as reported by (Singh *et al.* 1975; Vijay and Manohar, 1986a; Wankhade *et al.* 1997; Dhankar *et al.* 1996; Poshiya and Vashi, 1999 and Dhankar and Dhankar, 2001, Wammanda *et al.*, 2010; Akhtar *et al.*, 2010). On the contrary Sheel *et al.* 1988; Patil, 1995; Laxmi prasanna, 1996; Dhankar *et al.*, 1996; Borgaonkar *et al.*, 2006b and Hoshmani *et al.*, 2008 reported significant negative heterosis for this trait.

5.2.5 Tender fruit length

5.2.5.1 Kharif 2010 (KE_1)

Positive heterosis over parental mean, better parent and standard check recorded up to extent of 3.00%, 2.35% and 1.30% respectively. Significant positive heterosis showed by hybrid 35 x 315 over mid parent and three hybrids *viz.,* BO-2 x 162, EC-316053 x 162 and Vaibhav x VRO-4 expressed with non-significant positive heterosis over mid parent, better parent and standard check. None of the hybrid showed significant heterosis over better parent and standard check.

5.2.5.2 Kharif 2011 (KE_2)

Heterosis observed in both directions. Extent of positive heterosis was 4.50%, 4.14% and 0.00% over mid parent, better parent and standard check. Hybrid BO-2 x VRO-4 recorded significant heterosis over mid parent. None of the hybrid showed significant positive heterosis over better parent and standard check. However hybrid 447 x 364 expressed non-significant positive heterosis over mid parent, better parent and standard check.

5.2.5.3 Kharif 2012 (KE_3)

None of the hybrid recorded significant positive heterosis and the extent of positive heterosis expressed as 9.86%, 9.86% and 3.61% respectively over mid parent, better parent and standard check. Six hybrids *viz.,* BO-2 x VRO-4, BO-2 x 162, BO-2 x 315, BO-2 x 364, 35 x HRB-55 and 447 x 364 were exhibited non-significant positive heterosis over mid parent, better parent and standard check.

5.2.5.4 Summer 2011 (SE_1)

In summer season, extent of heterosis ranged from -4.64 to 9.31%, -8.70 to 9.12% and -7.57 to 2.30% over mid parent, better parent and standard check respectively. Two hybrids BO-2 x VRO-4 and BO-2 x 364 recorded significant positive heterosis over mid parent, only one hybrid BO-2 x 364 exhibited significant positive heterosis over better parent. None of the hybrid was shown significant positive heterosis over standard check.

5.2.4.5 Summer 2012 (SE_2)

Heterosis observed in both directions. Extent of positive heterosis was 5.88%, 4.52% and 1.25% over mid parent, better parent and standard check respectively. None of the hybrid showed significant positive heterosis over better parent and standard check. However, hybrid Vaibhav x HRB-55 was recorded significant positive heterosis over mid parent.

Four hybrids *viz.*, 35 x 315, BO-2 x VRO-4, BO-2 x 364 and HRB-55 were exhibited significant relative heterosis over the season. These hybrids could be utilized for isolative transgressive segregants in later generation of crosses.

The positive average heterosis also substantiated the fact that the hybrids in general were longer fruit length. Shukla and Gautam (1990), Patil (1995), Laxmi prasanna (1996), Thippeswamy (2001) and Borgaonkar *et al.* (2006) observed the simillar results. Significant heterobeltiosis for tender fruit length were reported by Singh *et al.* (1977), Sharma and Mahajan (1978), Singh and Singh (1979a), Vijay and Manohar (1986a), Pathak and Syamal (1997) and Singh *et al.* (2002). Akhtar *et al.* (2010) observed heterosis (37.83%) for tender fruit length in okra. Patel *et al.* (2010) reported positive and significant heterobeltiosis in KS-404 x HRB-108-2.

5.2.6 Number of seeds per fruit

5.2.6.1 Kharif 2010 (KE_1)

Heterosis for number of seeds per fruit observed in both directions, however positive heterosis was recorded up to extent of 36.03%, 31.25% and 21.02% over mid parent, better parent and standard check respectively. Three hybrids *viz.,* EC-316053 x 364 (36.03%), Vaibhav x 364 (35.97%) and 35 x 315 (30.00%) were recorded significant positive heterosis over mid parent. However, sixteen hybrids expressed with non-significant positive heterosis over better parent.

5.2.6.2 Kharif 2011 (KE_2)

Heterosis observed in both directions. Extent of positive heterosis was 53.58%, 46.10% and 52.03% over mid parent, better parent and standard check respectively. Two hybrids BO-2 x 315 and Vaibhav x 315 were expressed with significant positive heterosis over mid parent, better parent and standard check. Three hybrids *viz.,* Vaibhav x 162, EC-316053 x 162 and 447 x 162 recorded significant positive relative heterosis and non-significant positive heterobeltiosis and standard heterosis.

5.2.6.3 Kharif 2012 (KE_3)

Relative heterosis, heterobeltiosis and standard heterosis ranged from -18.68 to 35.80%, -24.49 to 30.51% and -6.29 to 45.28% respectively. Significant positive relative and standard heterosis recorded by 447 x 162 and BO-2 x IIVR-11. None of the hybrid showed significant positive heterobeltiosis. However, seventeen hybrids showed non-significant positive heterobeltiosis.

5.2.6.4 Summer 2011 (SE_1)

Wide range of heterosis observed in this season and positive of relative heterosis, heterobeltiosis and standard heterosis recorded up to extent of 70.59%, 56.76% and 85.11% respectively. Two hybrids EC-316053 x 315 and Vaibhav x 315 were recorded significant relative heterosis. However, significant positive relative heterosis, heterobeltiosis and standard heterosis recorded by hybrid EC-316053 x 315.

5.2.6.5 Summer 2012 (SE_2)

Positive heterosis over parental mean, better parent and standard check recorded up to extent of 71.64%, 61.97% and 60.84% respectively. Hybrid EC-316053 x 315 registered significant positive heterosis over mid parent, better parent and standard check. Significant positive heterosis over mid parent and better parent was recorded by hybrid 447 x 315.

Hybrid EC-316053 x 315 was expressed significant positive heterosis over mid parent, better parent and standard check over all the summer seasons. These hybrids could be exploited for isolating transgressive segregants in later generations of crosses for improving number of seeds per fruit.

Vijay and Manohar (1986b), Ahmed *et al.* (1999) observed range of heterobeltiosis up to extent of 1.58 to 52.06% and -25.6 to 36.59% respectively. Akhtar *et al.* (2010) recorded maximum heterosis (34.50%) for number of seeds per fruit.

5.2.7 Number of fruits per plant

5.2.7.1 Kharif 2010 (KE_1)

Number of fruits per plant showed heterosis in both the directions; however the extent of positive heterosis of 62.66%, 51.18% and 9.36% over mid parent, better parent and standard check respectively. Significant positive heterosis over mid parent and better parent was recorded by hybrid Vaibhav x 315. However, hybrid 447 x 315 registered with significant positive relative heterosis and non-significant positive heterobeltiosis. None of the hybrid showed significant positive standard heterosis.

5.2.7.2 Kharif 2011 (KE_2)

Positive heterosis over parental mean, better parent and standard check recorded up to extent of 26.82%, 20.98% and 31.87% respectively. Three hybrids *viz.,* 447 x VRO-4, EC-316053 x VRO-4 and Vaibhav x 410 showed significant positive heterosis over mid parent and standard check. Significant positive heterosis showed by EC-316053 x 410 over mid parent and non-significant positive heterosis over better parent and standard check. None of the hybrid showed significant positive heterobeltiosis.

5.2.7.3 Kharif 2012 (KE_3)

The extent of mid parent and better parent heterosis ranged from -16.89 to 32.11% and -17.98 to 30.32% respectively. None of the hybrid showed positive standard heterosis. Five hybrids *viz.,* Vaibhav x 364 (32.11%), 35 x 162 (23.51%), BO-2 x 410 (23.14%), EC-316053 x VRO-4 (22.05%) and EC-316053 x 410 (21.10%) recorded significant positive heterosis over mid parent. However, only one hybrid Vaibhav x 364 (30.32%) showed significant positive heterosis over better parent.

5.2.7.4 Summer 2011 (SE_1)

In summer season, the extent of heterosis over mid parent and better parent ranged from 69.88% and 54.93%. None of the hybrid showed positive standard heterosis. Hybrid Vaibhav x 410 expressed significant positive heterosis over mid parent and better parent. Five hybrids *viz.,* Vaibhav x 364, BO-2 x 410, 35 x 410, Vaibhav x HRB-55 and EC-316053 x VRO-4 were exhibited significant positive heterosis over mid parent and non-significant positive heterosis over better parent.

5.2.7.5 Summer 2012 (SE_2)

Heterosis were observed in both directions, however positive heterosis over mid parent, better parent and standard check recorded up to extent of 50.85%, 38.71% and 16.22% respectively. Two hybrids Vaibhav x 162 (50.88%) and Vaibhav x 315 (33.89%) were expressed significant positive heterosis over mid parent. However, only one hybrid Vaibhav x 162 (38.71) was recorded significant positive heterosis over better parent. None of the hybrid showed significant positive heterosis over standard check.

The positive average heterosis also substantiated the fact that the hybrids in general had higher fruit number. five hybrids Vaibhav x 315, 447 x VRO-4, EC-316053 x VRO-4, Vaibhav x 410, Vaibhav x 364 recorded significant positive relative heterosis over the kharif season and two hybrids Vaibhav x 410 and Vaibhav x 162 showed significant positive heterosis over mid parent and better parent during the summer season. None of the hybrid found significant over all the season.

In okra, the first report on hybrid vigour in respect of fruit number was made by Vijayranghwan and Wariar (1946). Venkatramani (1952) noticed increase yield range from (5.4 to 14.5%) over better parent. Joshi *et al.* (1958)

recorded relative heterosis range from (9.68 to 62.12%). Singh *et al.* (1975) observed significant heterosis range from (0.73 to 38.03%). Lal *et al.* (1975) observed significant heterosis (15.38%). Sharma and Mahajan (1978) reported significant heterobeltiosis. Singh and Singh (1979a) found singificant heterobeltiosis up to extent of (71.46%). Pratap and Dhankar (1980) recorded significant heterobeltiosis range from (23.33 to 23.94%). Thaker *et al.* (1982) found significant positive heterosis for number of fruits per plant. El-maksud *et al.* (1986) observed extent of heterosis up to (149.20%). Sivagmasundhari *et al.* (1992) observed higher positive heterosis. Dayasagar (1994) reported significantly heterosis in cross Pusa Sawani x Parbhani Kranti (95.98%). Patil *et al.*(1996a) observed significant heterotic effect over better parent up to extent of (121.7%).Singh *et al.*(1996a) reported heterosis to the extent of (83.33%). Pathak and Syamal (1997) reported significant heterobeltiosis up to extent of (28.83%). Panda and Singh (1998) recorded extent of heterosis was (45.62%) for number of fruits per plant in okra. Ahmed *et al.*(1999) recorded maximum heterosis (74.77%) for number of fruits per plant in okra. Singh *et al.* (2002) found heterobeltiosis range up to extent of (185%).Dhankar and Dhankar (2001), Thippeswamy (2001), Mamta Rani *et al.*(2002), Rewale *et al.*(2003) and Akhter *et al.*(2010) also observed heterosis for increase in number of fruits per plant in okra. Patel *et al.* (2010) reported significant and positive heterosis in KS-404 x HRB-108-2 and VRO-5 x GO-2. Vachhani *et al.* (2011) reported high magnitude of heterotic effect for number of fruits per plant. Kumar (2011) found highest magnitude of heterosis in cross Pusa A4 x Punjab Padmini (13.52 and 29.78%) for number of fruits per plant over better parent and Sakthi.

5.2.8 Weight of fruits per plant

5.2.8.1 Kharif 2010 (KE_1)

Heterosis for weight of fruits per plant observed in both positive and negative directions, however positive heterosis revealed up to extent of 83.39%, 53.88% and 39.85% over mid parent, better parent and standard check respectively. Significant positive heterosis over mid parent, better parent and standard check was recorded by hybrid Vaibhav x 315. Two hybrids EC-316053 x HRB-55 and 35 x 315 showed significant positive heterosis over mid parent and non-significant positive heterosis over better parent and standard check.

5.2.8.2 Kharif 2011 (KE_2)

Significant positive heterosis was expressed by five, one and seven hybrids over parental mean, better parent and standard check respectively with extent of 26.11%, 18.04% and 49.52% respectively. Four hybrids *viz.*, BO-2 x 364, 447 x VRO-4, EC-316053 x VRO-4 and Vaibhav x 410 were exhibited significant positive heterosis over mid parent and standard check. Significant positive heterosis over mid parent, better parent and standard check was recorded by hybrid Vaibhav x 315.

5.2.8.3 Kharif 2012 (KE_3)

Relative heterosis, heterobeltiosis and standard heterosis ranged from -16.02 to 43.40%, -20.86 to 41.06% and -33.17 to 6.67% respectively. Three hybrids *viz.,* Vaibhav x 364, Vaibhav x 315 and 447 x 315 were exhibited significant positive heterosis over mid parent. Significant positive relative heterosis and heterobeltiosis recorded by Vaibhav x 364. None of the hybrid showed significant positive standard heterosis.

5.2.8.4 Summer 2011 (SE_1)

The extent of mid parent and better parent heterosis ranged from -11.08 to 54.41% and -22.95 to 33.96% respectively. None of the hybrid showed positive standard heterosis. Three hybrids *viz.,* Vaibhav x 410, Vaibhav x 364 and Vaibhav x HRB-55 were exhibited significant positive heterosis over mid parent. However, twenty four hybrids were recorded with non-significant positive heterosis over better parent.

5.2.8.5 Summer 2012 (SE_2)

Desirable heterosis over mid parent, better parent and standard check observed up to extent of 51.40%, 40.53% and 15.22% respectively. Vaibhav x 162 was recorded significant positive heterosis over mid parent and better parent. None of the hybrid showed significant positive heterosis over standard check. However, five hybrids expressed with non-significant positive heterosis over standard check.

The fruit weight of a genotype serves as an indicator of fruit yield as it is an important character contributing to yield. The positive average heterosis also substantiated the fact that the hybrids in general had higher fruit weight. Four hybrids *viz.*, BO-2 x 364, 447 x VRO-4, EC-316053 x VRO-4 and Vaibhav x 410 were expressed with significant positive mid parent and standard heterosis over the season. However hybrid, Vaibhav x 315 recorded significant performance over mid parent better parent and standard check over the season. These hybrids could be utilized for isolating high yielding transgressive segregants in later generation of crosses.

The most important trait is tender fruit yield. In present study, heterosis for fruit yield was observed to the extent of 82.39%. Vijayraghwan and Warior (1946) observed increase in fruit weight. Singh *et al.* (1975) observed heterosis range up to extent of (6.62 to 52.27%). Lal *et al.* (1975) recorded heterosis range of (13.64%). Sharma and Mahajan (1978) reported significant heterobeltiosis. Pratap and Dhankar (1980) recorded significant heterobeltiosis range from (-21.34 to 16.63%). El-Maksud *et al.* (1986) observed extetn of heterosis to the extent of (124.93%) for weight of fruits in okra. Chaudhary *et al.* (1991a) recorded significant heterosis over check Harbhajan. Veerarangavathatham and Irulappn (1991) recorded highest yielder 317g/plant in AE-974 x Pusa Sawani. Sivagmasundhari *et al.* (1992) observed higher positive heterosis. Singh *et al.* (1996a) reported heterosis to the extent of (21.64%). Ahmed *et al.* (1999) recorded significant heterobeltiosis (42.50%).

Singh *et al.* (2002) found maximum (67.51%) beneficial heterobeltiosis in okra. Bhalekar *et al.* (2004) observed highest heterosis over better parent up to extent of (19.29%). Senthilkumar *et al.* (2007) found highest standard heterosis of (86.80%) in Punjab Padmini x Parbhani Kranti. It indicates that there is immense scope for exploitation of hybrid vigour in okra.

5.3 COMBINING ABILITY

5.3.1 Analysis of variances for combining ability

Analysis of variances for combining ability provides information about the variability in crosses, lines, testers and interaction between line and testers. The estimates of variances due to general combining ability and specific combining ability revealed nature of non-allelic gene interaction and the appropriate breeding methods to be adopted for genetic improvement of quantitative traits.

5.3.1.1 Kharif 2010 (KE_1)

Significant differences among the crosses indicate presence of variability among the crosses for all the characters except number of branches per plant, tender fruit length and number of fruits per plant. Testers have more diversity than lines for all the traits except number of branches per plant, tender fruit length and number of fruits per plant. The significance of variances due to line x tester interaction revealed the specific combining ability for all the traits except number of branches per plant, plant height, number of fruits per plant and weight of fruits per plant.

5.3.1.2 Kharif 2011 (KE_2)

All character except number of branches per plant and tender fruit length were revealed significant differences among the crosses. Testers were having more diversity than lines for all the traits except number of branches per plant, tender fruit length, number of fruits per plant and weight of fruits per plant. These differences between lines and testers may result into heterosis in specific cross combinations when dispersed genes complement in positive directions. Variances due to line x tester interaction were significant for days to 50% flowering, number of fruits per plant and weight of fruits per plant, indicate high specific combining ability.

5.3.1.3 Kharif 2012 (KE_3)

Significant differences among the crosses indicate presence of variability among the crosses for all the characters except days to 50% flowering, number of branches per plant, plant height, tender fruit length, number of seeds per fruit, number of fruits per plant and weight of fruits per plant. Lines were have more diversity than testers for the traits days to first flowering, days to 50% flowering, number of branches per plant and tender fruit length. These differences in diversity among lines and testers for different quantitative traits may be resulted into dispersion of genes in parents.

5.3.1.4 Summer 2011 (SE_1)

In summer season, characters number of branches, plant height, number of seeds per fruit and number of fruits per plant were revealed significant differences among the testers. Testers were have more diversity than line for the traits days to first flowering, days to 50% flowering, plant height, number of seeds per fruit, number of fruits per plant and weight of fruits per plant. These differences between lines and testers may result into heterosis in specific cross combinations when dispersed genes complement in positive directions.

5.3.1.5 Summer 2012 (SE_2)

Significant differences among the crosses indicate presence of variability among the crosses for all the characters except days to first flowering, days to 50% flowering, number of branches per plant, plant height, tender fruit length, number of fruits per plant and weight of fruits per plant. The variances due to lines were significant for all the traits except number of branches per plant, plant height, tender fruit length, number of seeds per fruit, number of fruits per plant and weight of fruits per plant. Lines were having more diversity than testers for all the characters except number of branches per plant. These differences in diversity among lines and testers for different quantitative traits may be resulted into dispersion of genes in parents.

Kumar and Pathania (2011) revealed significant differences among lines for all the characters except, node at which first flower bud appears, whereas none of the tester exhibited significant differences for the characters.

5.3.2 GENERAL AND SPECIFIC COMBINING ABILITY STUDIES

The capacity or ability of an inbred line to transmit superior performance to its progeny or crosses is referred as combining ability; it helps in the selection of suitable good general combiner parents for hybridization through the estimation of general combining ability (*gca*) effects, and identification of superior cross combinations for commercial exploitation of heterosis through estimation of specific combining ability (*sca*) effects. The *gca* is considered as the intrinsic genetic value of the parent for trait which is due to additive genetic effects and is fixable. The estimates of *sca* represent dominance and epistatic gene action. Combining ability analysis also provides information about gene action involved in the expression of quantitative character and breeding procedures to be followed for genetic improvement of trait.

5.3.2.1 Days to First Flowering

5.3.2.1.1Kharif 2010 (KE_1)

In kharif season all lines shown significant negative *gca* effects except one line, highest negative *gca* effects shown by BO-2 (-0.114) and 35 (-0.114), followed by 447 (-0.067) and EC-316053 (0.019). Whereas six tester *viz.*,

VRO-4 (-0.162), IIVR-11 (-0.162), HRB-55 (-0.162), 410 (-0.162), 162 (-0.095) and 364 (-0.095) shown significant negative *gca* effects. One line and one tester Vaibhav and 315 were expressed significant positive *gca* effects. These parents are good combiners for earliness. Highest *sca* effects was exhibited by BO-2 x 315 (-0.886), followed by 35 x 315 (-0.552) and Vaibhav x 364 (-0.381). These hybrids were shown high relative heterosis and consist of parents with high x low, high x high and low x high *gca* effects, additive x non-additive, additive x additive and non-additive x additive type of gene action.

5.3.2.1.2 Kharif 2011 (KE_2)

Combining ability study revealed that three lines 35 (-0.714), 447 (-0.524) and BO-2 (-0.048) were shown significant negative *gca* effects. Whereas Vaibhav (1.00) and EC-316053 (0.286) expressed significant positive *gca* effects. Four testers *viz.*, IIVR-11 (-0.667), VRO-4 (-0.660), HRB-55 (-660) and 364 (-0.200) were good combiner for days to first flowering, whereas 315 (1.667) shown significant positive *gca* effects. Hybrid 35 x 315 (-1.619) and 447 x 315 (-1.619) was exhibited significant negative *sca* effects. Whereas seventeen hybrids recorded with non-significant negative *sca* effects. These hybrids involve parents with high x high *gca* effects. Thus additive x additive type of gene action might be responsible for high *sca* effects.

5.3.2.1.3 Kharif 2012 (KE_3)

Significant negative *gca* effects were exhibited by three lines *viz.,* 447 (-0.810), EC-316053 (-0.524) and Vaibhav (-0.429), whereas significant positive *gca* effects shown by 35 (1.381). Four testers HRB-55 (-0.457), 364 (-0.257), VRO-4 (-0.190) and IIVR-11 (-0.190) expressed significant negative *gca* effects, whereas positive *gca* effects expressed by 315 (0.543), 410 (0.476) and 162 (0.076). Hybrids 35 x HRB-55 (-1.448), 35 x IIVR-11 (-1.381), 447 x 410 (-1.190), EC-316053 x 410 (1.143) and EC-316053 x 162 (-1.076) were exhibited high *sca* effects. These hybrids were involve parents with high x low and high x high *gca* effects, indicates that the involvement of additive x non-additive and additive x additive gene action in expressing of high *sca* effects.

5.3.2.1.4 Summer 2011 (SE_1)

In summer season two lines 35 (-0.095) and 447 (-0.095) and four testers *viz.,* VRO-4 (-0.419), HRB-55 (-0.152), 410 (-0.152) and 162 (-0.019) were good combiner having significant negative *gca* effects for days to first flowering. Whereas, parents with significant positive *gca* effects registered by EC-316053 (0.095), 315 (0.381), IIVR-11 (0.181) and 364 (0.181). Hybrid BO-2 x VRO-4 (-0.914) was shown significant negative *sca* effects. Nineteen hybrids expressed with non-significant negative *sca* effects. These hybrids involves at least one parent with high *gca* effects, indicates the role of additive gene action.

5.3.2.1.5 Summer 2012 (SE_2)

Significant negative *gca* effects were exhibited by three lines *viz.,* Vaibhav (-0.619), 35 (-0.476) and BO-2 (-1.048), whereas significant positive *gca* effects shown by 447 (1.619). Four testers 364 (-0.495), HRB-55 (-0.429), 162 (-0.362) and 410 (-0.229) expressed significant negative *gca* effects, whereas testers VRO-4 (0.705), 315 (0.505) and IIVR-11 (0.305) recorded with positive *gca* effects. Good specific combining ability were shown by BO-2 x IIVR-11 (-1.686), 35 x HRB-55 (-1.524), 447 x HRB-55 (-1.286) and Vaibhav x 410 (-1.284). These hybrids involve parents with high x low and high x high *gca* effects, indicates that additive x non-additive and additive x additive gene action in expressing of high *sca* effects.

Five parents *viz.,* 447, VRO-4, IIVR-11, HRB-55 and 364 were shown good combining ability over all the kharif season. Whereas one parent HRB-55 expressed good combining ability over all the kharif and summer season. Six hybrids *viz.,* BO-2 x 315, 35 x 315, 447 x 315, 35 x HRB-55, BO-2 x VRO-4 and BO-2 x IIVR-11 were good specific combiner over the season.

Rao and Ramu (1979), Sivkumar *et al.* (1995), Panda and singh (1995), Poshiya and vashi (1999a) and Thippeswamy (2001) reported that the magnitude of *gca* was more for days to first flowering indicating the role of additive gene action. Whereas inheritance of non-additive gene action for days to first flowering reported by many workers Sharma and Mahajan (1978), Shukla *et al.* (1989), Chaudhry *et al.* (1991), Singh *et al.* (1996b), Naphade *et al.* (2006), Jaiprakshnarayan (2003) and Dabhi *et al.* (2010). Both additive and non-additive gene action inheritance were reported by Wankhede *et al.* (1995), Laxmi Prasanna (1996), Nichal (2000) and Liou-Minli (2002). Rajendra *et al.* (2005) reported that the cultivar AB-2 was a good general combiner for days to first flowering.

5.3.2.2 Days to 50% Flowering

5.3.2.2.1Kharif 2010 (KE_1)

Six parents *viz.*, 447 (0.590), EC-316053 (-0.352), BO-2 (-0.210), HRB-55 (-1.867), 410 (-1.133) and 364 (-1.200) were good combiner for early flowering. Hybrids BO-2 x 315 (-1.724), EC-316053 x IIVR-11 (-1.714), Vaibhav x 410 (-1.390) and 447 x 315 (-1.343) were exhibited high *sca* effects. These hybrids involve parent with high x high, low x high and high x low *gca* effects, indicates that additive x additive, non-additive x additive and additive x non-additive type of gene action.

5.3.2.2.2Kharif 2011 (KE_2)

Parents *viz.*, BO-2 (-0.467), 35 (-0.419), 447 (-0.276), VRO-4 (-0.743), HRB-55 (-0.743), 364 (-0.543), 162 (-0.010) and 410 (-0.010) were good combiner for days to 50% flowering. Two hybrid 35 x 315 (-1.484) and Vaibhav x IIVR-11 (-1.533) were shown significant *sca* effects. However, seventeen hybrids were expressed with non-significant *sca* effects. These hybrids had parents with high x low, high x high and low x high *gca* effects, indicates that additive x non-additive, additive x additive and non-additive x additive gene action in expression of high *sca* effects.

5.3.2.2.3Kharif 2012 (KE_3)

Significant negative *gca* effects were exhibited by two lines *viz.,* 447 (-0.810), and BO-2 (-0.190), whereas significant positive *gca* effects shown by 35 (0.810). Four testers VRO-4 (-0.581), HRB-55 (-0.581), IIVR-11 (-0.314) and 364 (-0.114) expressed significant negative gca effects. Hybrids 35 x 315 (-1.410), Vaibhav x 410 (-1.181), 35 x HRB-55 (-0.943) and EC-316053 x 410 (-0.943) were exhibited with high *sca* effects. These hybrids involves parents with high x high *gca* effects, indicates that additive x additive type of gene action.

5.3.2.2.4 Summer 2011 (SE_1)

Seven parents *viz.,* 447 (-0.124), BO-2 (-0.029), EC-316053 (-0.029), HRB-55 (-0.286), VRO-4 (-0.086), 162 (-0.086) and IIVR-11 were good combiner for days to 50% flowering. Good specific combining ability were shown by 447 x 315 (-0.610), 447 x IIVR-11 (-0.410), BO-2 x 410 (-0.371) and EC-316053 x 364 (-0.305). These hybrids involves at least one parent with high *gca* effects, indicates the role of additive gene action.

5.3.2.2.5 Summer 2012 (SE_2)

Significant negative *gca* effects were exhibited by five parents *viz.*, BO-2 (-0.410), Vaibhav (-0.171), 162 (-0.314), HRB-55 (-0.181) and 364 (-0.048). Highest *sca* effects was exhibited by EC-316053 x 410 (-0.467), followed by BO-2 x IIVR-11 (-0.390), 35 x 162 (-0.352) and BO-2 x 315 (-0.324). These hybrids were shown high relative heterosis and consist of parents with high x low, high x high and low x high *gca* effects, additive x non-additive, additive x additive and non-additive x additive type of gene action.

Two parents *viz.*, BO-2 and HRB-55 were exhibited good combining ability over all the kharif and summer season. Five hybrids *viz.*, BO-2 x 315, 35 x 315, Vaibhav x 410, 447 x 315 and EC-316053 x 410 were good specific combiner over the season.

Pratap and Dhankar (1980) reported that the ratio of genetic components indicated the additive genetic effects for days to 50% flowering. Poshiya and Shukla (1986b) observed both general and specific combining ability effects were significant; Pusa Sawani and Pegrin were good general combiner. Chavandhal and Malkhandale (1994) reported that days to 50% flowering were governed by additive gene action. Weerasekara *et al.* (2008) identified that the parents KAO-52, KAO-61, KAO-10, KAO-25 and KAO-35 were good general combiner for days to 50% flowering. Khanpara *et al.* (2009) noticed that the gene action was predominantly additive for days to 50% flowering. Reddy *et* *al.* (2012) observed that the preponderance of non-additive gene action involved in the inheritance of days to 50% flowering.

5.3.2.3 Number of branches per plant

5.3.2.3.1 Kharif 2010 (KE_1)

Four parents *viz.*, EC-316053 (0.061), Vaibhav (0.028), 364 (0.032) and 162 (0.019) were good combiner for number of branches per plant. Hybrid Vaibhav x 315 (0.192), Vaibhav x 410 (0.188), 447 x 410 (0.188), EC-316053 x 364 (0.172) and 447 x IIVR-11 (0.139) were shown high *sca* effects. These hybrids had parents with high x high, low x high and high x medium *gca* effects and both additive and non-additive gene actions were important in these hybrids.

5.3.2.3.2 Kharif 2011 (KE_2)

For number of branches per plant, Vaibhav (0.171), VRO-4 (0.160) and 364 (0.032) were shown positive *gca* effects. Highest *sca* effects was exhibited by BO-2 x HRB-55 (0.281), Vaibhav x 315 (0.269), Vaibhav x 162 (0.222) and 35 x VRO-4 (0.216). These hybrids involves parents with low x high, high x medium and high x high *gca* effects, indicates non-additive x additive, additive x additive and additive x additive gene action might be responsible for high *sca* effects.

5.3.2.3.3 Kharif 2012 (KE_3)

Significant positive *gca* effects shown by seven parents *viz.*, EC-316053 (0.230), 35 (0.050), Vaibhav (0.030), 162 (0.138), 315 (0.105), HRB-55 (0.051) and 410 (0.045). Hybrids 35 x 315 (0.290), followed by Vaibhav x 364 (0.203) and EC-316053 x 410 were exhibited high positive sca effects. These hybrids involves at least one parent with high *gca* effects, indicates the role of additive gene action.

5.3.2.3.4 Summer 2011 (SE_1)

In summer season, six parents *viz.*, 447 (0.108), 35 (0.050), 162 (0.030), 364 (0.030), VRO-4 (0.023) and 410 (0.016) were good combiner for number of branches per plant. Highest positive *sca* effects were exhibited by EC-316053 x 162 (0.137), 447 x IIVR-11 (0.119), EC-316053 x VRO-4 (0.110) and 35 x 410 (0.103). These hybrids involves at least one parent with high *gca* effects, indicates the role of additive gene action.

5.3.2.3.5 Summer 2012 (SE_2)

Five parents *viz.*, Vaibhav (0.016), BO-2 (0.011), 162 (0.030), 315 (0.023) and 364 (0.010) were exhibited significant positive *gca* effects. Hybrids 447 x IIVR-11 (0.141), 35 x 364 (0.095) and BO-2 x VRO-4 (0.082) were expressed high *sca* effects. These hybrids involves parents with low x low, low x high and high x low *gca* effects, indicates non-additive x non-additive, non-additive x additive and additive x non-additive gene action could be responsible for high *sca* effects .

Two parents 162 and 364 were shown good combining ability over all the summer season. Whereas one parent Vaibhav expressed good combining abiity over all the kharif season. Two hybrids, 447 x IIVR-11 and EC -316053 x 364 were exhibited positive specific combining ability effects over all the kharif and summer season.

Elangovan *et al.* (1981) revealed that the tester AE 108 and AE 1068 were good general combiner for number of branches per plant. Panda and Singh (1995) reported that non-significant general combining ability effects for this trait. Dhankar *et al.* (1996) noticed that variances due to *sca* were significant for number of branches per plant. Naphade *et al.* (2006) identified that sca variances were higher than *gca* variances for number of branches per plant indicating predominant role of non-additive gene action. Khanpara *et al.* (2009) reported the gene action for number of branches per plant was predominantly additive. Reddy *et al.* (2012) noticed that the preponderance of non-additive gene action involved in the inheritance of number of branches per plant.

5.3.2.4 Plant height

5.3.2.4.1Kharif 2010 (KE_1)

Five parents *viz.*, 35 (1.725), BO-2 (1.520), 162 (10.811), VRO-4 (9.445) and IIVR-11 (0.618) were good combiner for increasing plant height, whereas 447 (-2.913), 315 (-12.715), 410 (-5.229) and 364 (-2.135) were good combiner for reducing plant height. Hybrids 447 x HRB-55(15.300), 35 x VRO-4 (11.589), EC-316053 x 162 (9.398) and 35 x IIVR-11 (9.082) were exhibited high *sca* effects and high relative heterosis. These hybrids had parents with medium x medium, low x medium and low x low *gca* effects, indicates additive x additive, non-additive x additive and non-additive x non-additive type of gene action.

5.3.2.4.2 Kharif 2011 (KE_2)

Parents *viz.*, Vaibhav (8.410), 447 (7.148), 35 (2.438), 364 (12.492), VRO-4 (9.445), IIVR-11 (0.879), HRB-55 (0.279) and 410 (0.266) were good combiner for increasing plant height. Top five hybrids on the basis of *per se* performance were consisting of parent with medium *gca* effects. Hybrids EC-316053 x 410 (19.239), 35 x 315 (17.249), Vaibhav x 315 (16.110) and EC-316053 x IIVR-11 were shown high *sca* effects. These hybrids had parents with low x medium and medium x low *gca* effects, indicates that non-additive x additive and additive x no-additive gene action might be responsible for high *sca* effects.

5.3.2.4.3 Kharif 2012 (KE_3)

Eight parents *viz.* EC-316053 (6.498), Vaibhav (2.865), VRO-4 (4.226), 162 (4.159), 364 (4.092), IIVR-11 (1.226), HRB-55 (1.606) and 410 (0.092) were good combiner for increasing plant height, whereas BO-2 (-4.611)), 35 (-3.978), 447 (-0.773) and 315 (-2.135) should be utilized for reducing the plant height. Hybrids EC-316053 x HRB-55 (7.909), Vaibhav x VRO-4 (7.589) and Vaibhav x 162 (6.789) were exhibited high *sca* effects. These hybrids involve parents with medium x medium *gca* effects indicates that additive x additive type of gene action.

5.3.2.4.4 Summer 2011 (SE_1)

In summer season, seven parents *viz.*, 447 (2.430), 35 (1.283), Vaibhav (1.078), 364 (4.094), 162 (3.001), IIVR-11 (2.821) and HRB-55 (1.934) were good combiner for increasing plant height. Good specific combining ability were shown by hybrids EC-316053 x VRO-4 (5.926), 35 x IIVR-11 (5.717), BO-2 x 364 (4.406) and 447 x 315 (4.383). These hybrids had parents with low x low, medium x medium and low x medium *gca* effects, indicates non-additive x non-additive, additive x additive and non-additive x additive gene action could be responsible for high *sca* effects.

5.3.2.4.5 Summer 2012 (SE_2)

Parents BO-2 (1.892), VRO-4 (2.490), 315 (0.237) and IIVR-11 (0.184) were good combiner for increasing plant height, whereas EC-316053 (-0.760), 35 (-0.684), Vaibhav (-0.293), 447 (-0.155), HRB-55 (-1.203), 410 (-0.833), 162 (-0.416) and 364 (-0.410) should be used for reducing plant height. Significant positive sca effects was shown by BO-2 x VRO-4 (9.714). Top five hybrids on the basis of *per se* performance consist of at least one parent with medium *gca* effects, indicates additive type of gene action.

Parent IIVR-11 was shown positive *gca* effects over all the kharif and summer season, whereas VRO-4 exhibited positive gca effects over all the kharif season. Three hybrids EC-316053 x 410, Vaibhav x HRB-55 and Vaibhav x 315 were exhibited positive sca effects over all the kharif season. Whereas, four hybrids viz., BO-2 x VRO-4, 35 x 162, 447 x 410 and Vaibhav x 410 were expressed positive sca effects over all the summer season.

Rao & Ramu (1979), Sharma and Mahajan (1978) noticed that sca variances was more for plant height indicating role of non-additive gene action. Chavandhal and Malkhandale (1994) revealed the ratio of *gca*/*sca* was less than unity indicating the preponderance of non-additive gene action for plant height. Panda and Singh (1995) reported significant specific combining ability effects and identified HRB-9-2 with high general combining ability effects for plant height. Shinde *et al.* (1995) noticed significant mean sum of squares due to both general and specific combining effects for plant height. Sivakumar *et al.* (1995) reported variances due to *sca* were highly significant for this trait. Singh *et al.* (1996) revealed that *gca* and *sca* variances were highly significant for plant height. Nichal (2000) observed importance of both additive and non-additive genetic components of variation for plant height. Rewale *et al.* (2003) identified two hybrids NK-01 x Ankur-40 and JNOO-5 x Arka Anamika were showed best performance for plant height. Rajendra *et al.* (2005) revealed that Parbhani Kranti was a good general combiner for plant height. Khanpara *et al.* (2009) and Dabhi *et al.* (2010) reported that plant height was governed by predominant additive gene action. Reddy *et al.* (2012) noticed that the preponderance of non-additive gene action involved in the inheritance of plant height.

5.3.2.5 Tender fruit length

5.3.2.5.1 Kharif 2010 (KE_1)

Parents 35 (0.052), EC-316053 (0.048), VRO-4 (0.053), 162 (0.053) and IIVR-11 (0.00) were good combiner for increasing tender fruit length. Whereas, parents 447 (-0.067), Vaibhav (-0.029), BO-2 (-0.005), 315 (-0.053), 410 (-0.040) and HRB-55 (-0.020) should be used for reducing tender fruit length. Hybrid 447 x 315 (0.220), BO-2 x 162 (0.218), Vaibhav x 410 (0.169) and 35 x 315 (0.168) were shown positive *sca* effects. These hybrids had parents with low x low, low x high and high x low *gca* effects, indicates non-additive x non-additive, non-additive x additive and additive x non-additive type of gene action.

5.3.2.5.2 Kharif 2011 (KE_2)

Significant positive *gca* effects were exhibited by five parents *viz.*, BO-2 (0.060), 447(0.055), VRO-4 (0.086), HRB-55 (0.039) and 162 (0.032). Whereas Vaibhav (-0.097), 35 (-0.030), 315 (-0.134), IIVR-11 (-0.021), 364 (-0.001) and 410 (-0.001) expressed with significant negative *gca* effects. Good specific combining ability effects were shown by hybrids 447 x 364 (0.291), EC-316053 x 410 (0.201), BO-2 x VRO-4 (0.167), Vaibhav x IIVR-11 (0.164) and 35 x 364 (0.144). These hybrids involves parents with high x high , medium x low and low x low *gca* effects, indicates additive x additive, additive x non-additive and non-additive x non-additive gene action might be responsible for high *sca* effects.

5.3.2.5.3 Kharif 2012 (KE_3)

Four parents *viz.*, BO-2 (0.410), 364 (0.129), 162 (0.062) and 315 (0.069) were good combiner for increasing tender fruit length. Top five hybrids selected on the basis of *per se* performance were mostly consist of parents with high x low, high x medium and low x low gca effects. Hybrids 35 x HRB-55 (0.676) was good combiner and involved parents with low x low *gca* effects, indicating the non-additive x non-additive type of gene action.

5.3.2.5.4 Summer 2011 (SE_1)

In summer season, five parents *viz.*, BO-2 (0.084), Vaibhav (0.079), VRO-4 (0.043), IIVR-11 (0.036) and 162 (0.030) were good combiner for increasing tender fruit length. Hybrids 447 x 364 (0.414), BO-2 x 364 (0.410), Vaibhav x HRB-55 (0.281) and 35 x 162 (0.209) were good combiners and consist of parents with low x low, high x low and low x medium gca effects, indicates non-additive x non-additive, additive x non-additive and non-additive x additive gene action could be responsible for high *sca* effects.

5.3.2.5.5 Summer 2012 (SE_2)

Parents *viz.,* Vaibhav (0.134), 447 (0.034), 162 (0.093), HRB-55 (0.080) and VRO-4 (0.047) were exhibited significant positive *gca* effects. Hybrid Vaibhav x HRB-55 (0.606) was shown significant positive *sca* effects. Top five hybrids selected on the basis of *per se* performance consist of parents with medium x high, high x low and high x high *gca* effects, indicates additive x additive, additive x non-additive and additive x additive type of gene action.

Parent 162 was shown positive *gca* effects over all the kharif and summer season. Whereas, parent Vaibhav expressed significant positive gca effects over all the summer season. Hybrid 35 x HRB-55 was registered with positive *sca* effects over all the kharif and summer season.

Sharma and Mahajan (1978) recorded that *sca* effects was higher for fruit length indicating predominance of non-additive gene action. Singh and Singh (1978) observed high estimate of variances due to specific combining ability effects. Elangovan *et al.* (1981) identified tester AE 108 and Line 1068 were good general combiners for this trait. Poshiya and Shukla (1986b) observed both general and specific combining ability effects were significant and AE-91and Pegrin were good general combiner for fruit length. Chavandhal and Malkhandale (1994) observed the ratio of *gca*/*sca* was less than unity indicating the preponderance of non-additive gene action. Panda and Singh (1995) reported significant specific combining ability effects. Shinde *et al.* (1995) noticed significant mean sum of squares due to both general and specific combining effects. Sivakumar *et al.* (1995) reported that non-additive gene action was important for fruit length. Dhankar *et al.* (1996) observed variances due to *sca* were highly significant. Nichal (2000) observed importance of both additive and non-additive genetic components for fruit length. Rajendra *et al.* (2005) identified that Parbhani Kranti was a good general combiner for fruit length. Naphade *et al.* (2006) reported that *sca* were higher than *gca* variances for fruit length indicating predominant role of non-additive gene action. Srivastava *et al.* (2008) and Khanpara *et al.* (2009) reported that the ratio of *gca*/*sca* indicated the predominance of additive gene action. Dabhi *et al.* (2010) revealed that preponderance of non-additive gene action is important in expression of tender fruit length.

5.3.2.6 Number of seeds per fruit

5.3.2.6.1 Kharif 2010 (KE_1)

Parents Vaibhav (3.476), 35 (2.333) and BO-2 (2.429), 162 (8.286), 315 (5.219) and HRB-55 (3.019) were good combiner for number of seeds per fruit. None of the hybrid recorded significant positive *sca* effects, however 447 x IIVR-11 (9.743), BO-2 x HRB-55 (8.383) and EC-316053 x 410 (7.429) were shown high *sca* effects. Top five hybrids on the basis of *per se* performance involved parents with medium x medium, low x medium and low x low *gca* effects, indicating importance of both additive and non-additive gene action.

5.3.2.6.2 Kharif 2011 (KE_2)

Positive *gca* effects were recorded by parents *viz.*, EC-316053 (0.648), Vaibhav (2.552), 315 (12.505) and 162 (3.171). Highest positive *sca* effects exhibited by BO-2 x 315 (10.971), followed by 447 x IIVR-11 (6.486), Vaibhav x 315 (5.781) and 35 x 364 (5.143). These hybrids had parents with low x medium, medium x medium and low x low *gca* effects, indicating the non-additive x additive, additive x additive and non-additive x non-additive gene action might be responsible for high *sca* effects.

5.3.2.6.3 Kharif 2012 (KE_3)

Six parents *viz.*, BO-2 (2.219), 447 (0.790), 162 (2.705), IIVR-11 (2.371), 315 (0.171) and VRO-4 (1.105) were good combiner for increasing number of seeds per fruit. Seventeen hybrids exhibited with positive *sca* effects and BO-2 x IIVR-11(12.581) revealed highest, followed by 447 x 162 (10.010), EC-316053 x 315 (9.067) and BO-2 x 364 (7.648). These hybrids had parents with medium x medium, low x medium and medium x low *gca* effects, indicates additive x additive, non-additive x additive and additive x non-additive type of gene action.

5.3.2.6.4 Summer 2011 (SE_1)

In summer season, parents EC-316053 (4.467), Vaibhav (2.562), BO-2 (1.324), 315 (9.800) and IIVR-11 (3.533) were recorded with positive *gca* effects. None of the hybrid exhibited significant positive *sca* effects, however hybrid 35 x HRB-55 (13.248), Vaibhav x 364 (9.105), 447 x VRO-4 (8.305) and 447 x 162 (7.505) were shown high *sca* effects. These hybrids involved parents with low x low and medium x low *gca* effects, indicating the importance of non-additive gene action.

5.3.2.6.5 Summer 2012 (SE_2)

Four parents *viz.*, EC-316053 (6.438), 35 (0.629), 315 (10.600) and IIVR-11 (1.333) were good combiner for increasing number of seeds per fruit. Hybrid EC-316053 x 315 (14.829) was shown significant positive *sca* effects. Top five hybrids selected on the basis of *per se* performance involved parents with medium x low, low x medium and medium x medium *gca* effects, indicates additive x non-additive, non-additive x additive and additive x additive gene action should be responsible for high *sca* effects.

Parent 315 was shown positive *gca* effects over all the kharif and summer season. However, positive *gca* effects over all the kharif season exhibited by parent 162; parents EC-316053 and IIVR-11 over all the summer season. Hybrid BO-2 x 410 was expressed with positive *sca* effects over all the kharif and summer season.

Many workers, Rao and Ramu (1979), Patel *et al.* (1994), Rewale *et al.* (2003) and Naphade *et al.* (2006) reported that magnitude of *sca* variances were higher than *gca* variances for number of seeds per fruit indicating predominant role of non-additive gene action. Weerasekara *et al.* (2008) identified that parents KAO-16, KAO-61, KAO-52 and KAO-AA were good general combiners for number of seeds per fruit.

5.3.2.7 Number of fruits per plant

5.3.2.7.1 Kharif 2010 (KE_1)

Five parents *viz.*, 35 (1.059), BO-2 (0.792), 315 (1.009), 162 (0.512) and 410 (0.406) were good combiner for increasing number of fruits per plant. Whereas, parents Vaibhav (-1.189), 447 (-0.655), EC-316053 (-0.008), 364 (-1.634), HRB-55 (-0.181), IIVR-11 (-0.168) and VRO-4 (-0.034) expressed significant negative *gca* effects. None of the hybrid recorded significant positive *sca* effects, however Vaibhav x 315 (2.949), EC-316053 x HRB-55 (2.314), Vaibhav x 364 (1.815) and EC-316053 x 162 (1.154) were shown high *sca* effects. Top five hybrids selected on the basis of per se performance involved parents with low x low, low x medium and medium x medium *gca* effects, indicating non-additive x non-additive, non-additive x additive and additive x additive type of gene action.

5.3.2.7.2 Kharif 2011 (KE_2)

Significant positive *gca* effects were recorded by parents *viz.,* Vaibhav (1.307), VRO-4 (1.211) and 410 (1.211). Whereas EC-316053 (-1.570), 35 (-0.027), IIVR-11 (-0.815), 315 (-0.695), 162 (-0.415), 364 (-0.269) and HRB-55 (-0.229) revealed significant negative *gca* effects. Two hybrids Vaibhav x 315 (2.933) and EC-316053 x VRO-4 (2.636) were exhibited significant positive sca effects. Top five hybrids selected on the basis of per se performance involves parents with high x low, low x high and medium x high *gca* effects, indicating additive x non-additive, non-additive x additive and additive x additive gene action involved in expression of high *sca* effects.

5.3.2.7.3 Kharif 2012 (KE_3)

Parents EC-316053 (0.549), BO-2 (0.139) and 35 (0.091), 162 (0.825), HRB-55 (0.531), 410 (0.411), VRO-4 (0.318) and 315 (0.051) were exhibited with positive *gca* effects. None of the hybrids recorded with significant positive *sca* effects, whereas 447 x IIVR-11 (5.343), Vaibhav x 364 (1.825), 447 x 315 (1.368) and Vaibhav x 315 (1.225) were shown positive *sca* effects. There is no agreement between *per se* performance and *sca*. Top five hybrids selected on the basis of *per se* performance involve parents with medium x medium *gca* effects, indicating additive type of gene action.

5.3.2.7.4 Summer 2011 (SE_1)

In summer season, parents viz., BO-2 (0.217), 35 (0.122), EC-316053 (0.084), HRB-55 (1.352), 162 (0.739) and 410 (0.446) were good combiner for increasing number of fruits per plant. Hybrids EC-316053 x VRO-4 (1.863), 35 x IIVR-11 (1.465), BO-2 x 410 (1.316) and 447 x HRB-55 (1.162) were shown positive *sca* effects. These hybrids had parents with medium x low, medium x medium and low x medium *gca* effects, indicates additive x non-additive, additive x additive and non-additive x additive gene action might be responsible for high *sca* effects.

5.3.2.7.5 Summer 2012 (SE_2)

Positive *gca* effects were recorded by six parents *viz.*, Vaibhav (1.162), BO-2 (0.838) and EC-316053 (0.343), 162 (2.383), 410 (0.543) and HRB-55 (0.210). Significant positive *sca* effect was exhibited by EC-316053 x 364 (3.910). Good specific combining ability effects were shown by hybrids Vaibhav x 162 (3.131), EC-316053 x 410 (2.390) and 447 x 315 (2.250). These hybrids involves parents with, medium x low, medium x medium and low x low *gca* effects, indicates additive x non-additive, additive x additive and non-additive x non-additive type of gene action.

Two parents BO-2 and 410 were exhibited good combining ability over all the kharif and summer season. Whereas, EC-316053, HRB-55 and 162 expressed positive *gca* effects over all the summer season. Three hybrids *viz.*, 35 x IIVR-11, 447 x IIVR-11 and EC-316053 x HRB-55 were shown good positive *sca* effects over all the kharif and summer season.

Rao and Ramu (1979) revealed that magnitude of *gca* was more for number of fruits per plant indicating the role of additive gene action.Sharma and Mahajan (1978) recorded that *sca* effects were higher indicating predominance of non-additive gene action for number of seeds per fruit. Elangovan *et al.* (1981) identified tester AE 108 and line AE 1068 were good general combiners. Poshiya and Shukla (1986b) observed both general and specific combining ability effects were significant. Chaudhari *et al.* (1991b) identified that Pusa Makhmali was good general combiner and cross Pusa Sawani x P-7 had shown highest sca effects for number of fruits per plant. Sundhari *et al.* (1992) and Chavandhal and Malkhandlae (1994) found *gca*/sca ratio were less than unity indicating the role of non-additive gene action for number of fruits per plant. Panda and Singh (1995) identified HRB-9-2 with high *gca* effects for number of seeds per fruit. Sivakumar *et al.* (1995) reported non-additive gene action was important and Punjab-7 was best general combiner for number of fruits per plant. Nichal (2000) and Liou-Minli (2002) reported that number of fruits per plant was controlled by both additive and non-additive genes. Rajendra *et al.* (2005) reported cultivar AB-2 was a good general combiner. Naphade *et al.* (2006) observed that *gca* variances were higher than *sca* variances for number of fruits per plant indicating the role of non-additive gene action. Dabhi *et al.* (2010) revealed that additive type of gene action was predominant in expression of number of fruits per plant. Reddy *et al.* (2012) noticed that the preponderance of non-additive gene action involved in the inheritance of number of fruits per plant.

5.3.2.8 Weight of fruits per plant

5.3.2.8.1 Kharif 2010 (KE_1)

Three parents *viz.*, 35 (7.856), BO-2 (5.428) and 315 (29.110) were good combiner for increasing weight of fruits per plant. A significant positive sca effect was recorded by Vaibhav x 315 (46.205). Eighteen hybrids exhibited positive *sca* effects and EC-316053 x HRB-55 (28.698) revealed highest, followed by Vaibhav x 364 (17.525) and BO-2 x IIVR-11 (11.239). These hybrids had parents with low x medium low x low, medium x low *gca* effects, indicating non-additive x additive, non-additive x non-additive and additive x non-additive gene action could be responsible for high *sca* effects.

5.3.2.8.2 Kharif 2011 (KE_2)

Two hybrids Vaibhav x 315 (42.370) and EC-316053 x VRO-4 (35.006) were exhibited significant positive *sca* effects. Positive *gca* effects were shown by six parents *viz.*, Vaibhav (24.697), 447 (1.440), 35 (1.421), VRO-4 (14.328), 410 (7.994) and 315 (7.354). Top five hybrids selected on the basis of *per se* performance involved parents with medium x medium, low x medium and medium x low *gca* effects, revealed that additive x additive , non-additive x additive and additive x non-additive type of gene action.

5.3.2.8.3 Kharif 2012 (KE_3)

Positive *gca* effects were shown by five parents *viz.*, Vaibhav (8.665), EC-316053 (4.655), 315 (26.562), HRB-55 (5.055) and 162 (2.229). None of the hybrid recorded significant positive *sca* effects, whereas Vaibhav x 364 (29.735) revealed highest, followed by 447 x IIVR-11 (25.577) and BO-2 x 162 (24.533) were expressed positive *sca* effects. Top five hybrids selected on the basis of *per se* performance involved parents with low x medium, medium x medium and medium x low *gca* effects, expressing non-additive x additive, , additive x additive and additive x non-additive type of gene action.

5.3.2.8.4 Summer 2011 (SE_1)

Five parents *viz.*, 35 (2.884), Vaibhav (2.303), BO-2 (0.655), HRB-55 (15.670) and 162 (7.457) were good combiner for weight of fruits per plant. None of the hybrid recorded significant positive *sca* effects. Hybrid EC-316053 x VRO-4 (24.143), 35 x IIVR-11 (20.103), 447 x 162 (18.152) and EC-316053 x HRB-55 (17.796) were shown high positive *sca* effects. Top five hybrids on basis of *per se* performance mostly involved parents with medium x low, low x medium and medium x medium *gca* effects, expressing both additive and non-additive type of gene action.

5.3.2.8.5 Summer 2012 (SE_2)

Positive *gca* effects were expressed by seven parents *viz.*, Vaibhav (15.299), BO-2 (14.318), EC-316053 (0.156), 162 (18.383), 315 (5.583), HRB-

55 (1.423) and 410 (1.170). Significant positive *sca* effect was recorded by EC-316053 x 364 (50.470). Top five hybrids on basis of *per se* performance mostly involved at least one parent with medium *gca* effect. Hybrid Vaibhav x 162 (30.474), 447 x 315 (22.779) and EC-316053 x 410 (22.430) were shown high positive *sca* effects. These hybrids had parents with medium x medium and low x medium *gca* effects, indicating additive x additive and non-additive x additive gene action might be responsible for high *sca* effects.

None of the parent was recorded with positive *gca* effects over all the kharif and summer season. Whereas, one parent 315 exhibited positive *gca* effects over all the kharif season and four parents *viz.*, BO-2, Vaibhav, HRB-55 and 162 expressed positive *gca* effects over all the summer season. Two hybrids 35 x IIVR-11 and 447 x IIVR-11 were registered positive sca effects over all the kharif and summer season.

Rao and Ramu (1979) observed magnitude of *gca* was more indicating the role of additive gene action for weight of fruits. Sharma and Mahajan (1978) recorded that *sca* effects were higher indicating predominance of non-additive gene effects. Sharma and Mahajan (1978) identified the tester Pusa Sawani to be a poor combiner of this trait. Pratap and Dhankar (1980) revealed the importance of both additive and non-additive effects for this trait. Singh and Singh (1984) observed that the variances due to *sca* effects were high indicating predominance of non-additive genetic varaince. Chaudhari *et al.*

(1991b) identified the Pusa Makhamali was a good combiner for fruit weight. Chavandhal and Malkhandale (1994) noticed that the ratio of *gca*/*sca* was less than unity indicating the preponderance of non-additive gene action. Shinde *et al.* (1995) observed significant sum of squares due to both general and specific combining effects. Liou-Minli (2002) identified that weight of fruits per plant was controlled by both additive and non-additive genes. Naphade *et al.* (2006) reported that *sca* variances were higher than *gca* variances indicating the predominant role of non-additive gene effects. Srivastava *et al.* (2008) revealed that the ratio of *gca*/*sca* for this trait indicating predominance of additive genes.

5.4 COMBINING ABILITY VARIANCES AND GENE ACTION

5.4.1. Kharif 2010 (KE_1)

Higher estimates of general combining ability (GCA) variances than specific combing ability (SCA) variances for all the characters except days to 50% flowering, number of branches and number of seeds per fruit, indicates the majority of variation among these characters was due to predominance of additive gene action therefore, selection could be effective. The additive variances were found higher than dominance variances for all the traits except days to 50% flowering, number of branches per plant, tender fruit length and number of seeds per fruit. Therefore selection of segregating generation should be utilized to exploit additive gene action. The ratio of GCA mean sum of square to *sca* mean sum of square was less than unity for characters namely days to 50% flowering, tender fruit length, number of seeds per fruit and number of fruits per plant. These characters were predominantly governed by non-additive gene action; selection should be delayed to later segregating generations.

5.4.2. Kharif 2011 (KE_2)

The relative estimates of variances due to GCA were higher than variances due to SCA for all the characters except plant height and number of fruits per plant, indicates the majority of variation among these characters was due to predominance of additive gene action. The additive variances were found higher than dominance variances for all the traits except days to 50% flowering and number of fruits per plant. Therefore selection in early segregating generation could be utilized to exploit additive gene action. The ratio of GCA mean sum of square to *sca* mean sum of square was more than unity for all the characters except days to 50% flowering, tender fruit length and number of fruits per plant. Whereas, for rest of the characters with predominance of non-additive gene action delayed selection could be effective.

5.4.3. Kharif 2012 (KE_3)

All characters except number of seeds per fruit and number of fruits per plant, with higher estimates of general combining ability (GCA) variances than specific combing ability (SCA) variances indicates predominance of additive gene action. The additive variances were found higher than dominance variances for all the traits except number of seeds per fruit and number of fruits per plant. Therefore selection of segregating generation should be utilized to exploit additive gene action. The ratio of GCA mean sum of square to *sca* mean sum of square was less than unity for characters namely tender fruit length, number of fruits per plant and weight of fruits per plant, indicates predominance of non-additive gene action. Thereforef, bi-parental mating or diallel selective mating should be utilized.

5.4.4 Summer 2011 (SE_1)

Only days to first flowering recorded higher variances due to specific combing ability (SCA) than variances due to general combining ability (GCA) indicates the majority of characters showed predominance of additive gene action. The additive variances were found higher than dominance variances for all the traits except days to first flowering. The ratio of GCA mean sum of square to *sca* mean sum of square was less than unity for all the characters except number of seeds per fruit therefore hybrid vigour could be exploited for those characters.

5.4.5 Summer 2012 (SE_2)

Characters *Viz.,* plant height, number of seeds per fruit and number of fruits per plant, expressed higher estimates of specific combing ability (SCA) variances, indicates predominance of non-additive gene action and selection could be delayed to later segregating generations. The additive variances were found higher than dominance variances for all the traits except plant height, number of seeds per fruit and number of fruits per plant, therefore selection could be effective for these characters. The ratio of GCA mean sum of square to *sca* mean sum of square was less than unity for all the characters except days to first flowering and weight of fruits per plant; indicates predominance of non-additive gene action and bi-parental mating or diallel selective mating should be utilized along with delayed selection.

These results are in agreement with those previously reported by Reddy *et al.* (2012), Dhakae and Bangar (2006), Jindal and Ghai (2005), Rewlae *et al.* (2003) and Liou-Minli *et al.* (2002).

5.5 GENOTYPE X ENVIRONMENT (G X E) INTERACTION (STABILITY ANALYSIS)

5.5.1 Analysis of variances for kharif season.

Varieties recorded highly significant MSS for characters days to first flowering, days to 50% flowering, plant height, no. of fruits per plant and weight of fruits per plant when tested against both pooled deviation and pooled error. Where as MSS for no. of branches and no. of seeds per fruit were significant when tested against pooled error. However tender fruit weight recorded non significant MSS. Env.+(Var* ENV.) Recorded significant MSS for characters for all characters when tested against pooled deviation and pooled error, whereas character days to first flowering and no. of seeds per fruit were recorded significant MSS when tested against pooled error only. Environments recorded significant MSS for all characters when tested against pooled error and pooled deviation. Environments (Lin.) recorded significant MSS for all characters when tested against both pooled error and pooled deviation. Characters viz. days to 50% flowering, plant height recorded significant MSS for var.*Env. (Lin.) when tested against both pooled error and pooled deviation, whereas characters tender fruit length, no. of fruits/plant and weight of fruits per plant were non significant.MSS for pooled deviation was significant for characters days to first flowering, no. of branches, no. of seed/ fruit and no. of fruits/plant.

5.5.2 Analysis for kharif and summer season.

Analysis of variance revealed that varieties recorded significant MSS for all characters when tested against pooled deviation. MSS for Env.+(Var*Env.) recorded significant MSS for all characters when tested against polled deviation and pooled error. MSS due to environments were highly significant for all characters when tested against pooled deviation and pooled error. MSS for var*Env. were found significant for characters viz., days to first flowering, days to 50% flowering, no. of branches, plant height and no. of seeds/fruit. All characters were recorded significant MSS for Environment (Lin.). Except characters tender fruit length, no of fruit/plant and weight of fruits/plant recorded significant MSS when tested against either pooled deviation or pooled error. Characters viz., days to first flowering, days to 50% flowering, no. of branches, plant height and no. of seeds/plant recorded significant MSS for pooled deviation.

Adetunji and Chheda (1989) evaluated five established varieties in eight different environments (Planting at different times for 3 consecutive years) reported that there were significant variations for seed yield between environments, even though the trials were all at the same site. Ariyo (1990) found that the branches per plant were under strong genotypic influence and most genotypes were unstable for the characters studied. Poshiya and Vashi (1997) revealed that the variances due to genotype (G), environment (E) and G x E interactions was highly significant. Both the linear and non-linear components of G x E interactions were significant. Kanwar *et al.* (2006) found that linear and non-linear components equally contributed G x E interactions in number of seeds per pod, seed weight per pod, seed yield per hectare and seed germination. Jindal *et al.* (2009) revealed that parents and hybrids were stable for fruit length under unfavourable environments but their performance cannot be predicted with greater accuaracy due to significant deviation from regression. Senthil Kumar (2011) revealed that the significant pooled deviation for all the traits except fruit length indicated predominance of non-linear component. No genotypes were stable for all the traits. C. C. Nwangburuka *et* *al.* (2011) found that the significant environmental effects for all the characters. However, significant varietal x environmental interaction effects on all the characters except for mature pod width.

5.5.3 Stability analysis of genotypes for the quantitative characters

After the pooled analysis of variances stability of genotypes studied for the characters those recorded significant genotype x environment interaction. The ability of genotype to produce a narrow range of phenotype in different environments can be called as stable (Lewis, 1954). Eberhart and Russell (1966) defined a stable genotype as the one which showed high mean, regression co-efficient (bi) around unity and deviation from regression near to zero. Accordingly, the mean and deviation from regression of each genotype were considered for stability, whereas linear regression used for testing the varietal response or sensitivity to environmental changes. Genotypes with high mean, bi = 1 with non-significant δ2di are suitable for general adaptation, *i.e.*, suitable over all environmental conditions and they are considered as stable genotypes. Genotypes with high mean, bi > 1 with non-significant δ2di are highly sensitive to changing environments and considered as below average in stability. Such genotypes tend to respond favourably to better environments but give poor yield in unfavourable environments; hence, they are suitable for favourable environments. Genotypes with low mean, bi < 1 with non-significant δ2di do not respond favourably to improved environmental conditions and hence, it could be regarded as specifically adapted to poor environments; however if accompanied with high mean suitable to unfavourable environment or stress condition. Genotypes with any bi value with significant δ2di are unstable and performance could not be predicted. On the basis of above stability parameters stability of genotypes was discussed herewith for quantitative traits.

5.5.3.1 Days to first flowering

5.5.3.1.1 Kharif season

Environmental indices for character days to first flowering ranged from -2.287 to 0.553. Parent IIVR-11 and three hybrids *viz.*, 447 x IIVR-11, 447 x HRB-55, 447 x 410 were sensitive for fluctuation in environmental condition and will not suitable for unfavorable environmental condition, however they will respond favorably to better environments. Parent BO-2 and eleven hybrids *viz.*, BO-2x HRB-55, 35 x VRO-4, 35 x 162, 35 x 315, 35 x 364, 35 x 410, EC-316053 x 162, EC-316053 x 315, Vaibhav x 162, Vaibhav x 315 and Vaibhav x 364 were unstable genotype and performance could not be predicted.

5.5.3.1.2 Kharif and summer season

Environment varied for this trait as observed from range of environmental indices (-1.659 to 2.228). Parent HRB-55 and three hybrids *viz.*, BO-2 x HRB-55, 447 x HRB-55, and EC-316053 x 410 were stable genotypes and suitable for general adaptation. Two hybrids BO-2 x VRO-4 and 35 x HRB-55 were above average stable and not suitable for favourable environments, however were specifically adapted to poor environments.

Parents VRO-4, 315 and 410 and five hybrids *viz.,* BO-2 x IIVR-11, BO-2 x 364, 35 x 410, Vaibhav x 315 and Vaibhav x 364 were unstable gentoypes and performance could not be predicted.

Senthil Kumar (2011) reported that the genotypes namely PK x PP, PP x PK, PK were found to be stable and suitable for all the environment for days to first flowering.

5.5.3.2 Days to 50% flowering

5.5.3.2.1 Kharif season

Environments varied with regards to days to 50% flowering as revealed from range of environmental indices (-1.042 to 1.858). Parent HRB-55 and hybrid BO-2 x VRO-4 were stable genotypes and suitable for general adaptation. Sixteen hybrids *viz.,*BO-2 x HRB-55, BO-2 x 410, 35 x VRO-4, 35 x HRB-55, 35 x 364, 447 x HRB-55, 447 x 162, 447 x 364, 447 x 410, EC-316053 x VRO-4, EC-316053 x HRB-55, EC-316053 x 364, EC-316053 x 410, Vaibhav x HRB-55, Vaibhav x 364 and Vaibhav x 410 were above average stable and not suitable for favourable environments, however were specifically adapted to poor environments. Hybrid BO-2 x IIVR-11 was highly sensitive for change in environments, however they tend to early in favourable environments. Parents 410 and 315 and two hybrids 35 x 410 and Vaibhav x 315 were unstable genotypes and performance could not be predicted.

5.5.3.2.2 Kharif and summer season

Environmental indices for this trait ranged from -2.436 to 2.144. Nine hybrids *viz.,* BO-2 x HRB-55, BO-2 x 410, 35 x VRO-4, 35 x HRB-55, 447 x HRB-55, EC-316053 x HRB-55, EC-316053 x 364, EC-316053 x 410 and Vaibhav x HRB-55 were stable genotypes for earliness and suitable for general adaptation. Parent HRB-55 and six hybrids *viz.*, BO-2 x VRO-4, BO-2 x IIVR-11, 447 x 162, 447 x 364, 447 x 410 and EC-316053 x VRO-4 were highly sensitive for change in environments, however they tend to early in favourable environments. Hybrid EC-316053 x 315 was revealed above average stable genotype and will not respond to favourable environment and specifically adapted to poor environments.

Mandal and Dana (1994) studied the stability and found that strain 6316 and Pusa Sawani was the most stable genotypes for days to 50% flowering.

5.5.3.3 Number of branches per plant

5.5.3.3.1 Kharif season

Environmental indices for number of branches ranged from -0.315 to 0.294. Hybrid Vaibhav x 315 was stable genotype and suitable for general adaptation. Two hybrids EC-316053 x VRO-4 and Vaibhav x 162 were sensitive for fluctuation in environmental condition and will not suitable for unfavourable environmental condition, however they will respond favourably to better environments. Hybrid EC-316053 x 364 was above average stable genotype and will not respond to favourable environment and specifically adapted to poor environments. Parents Vaibahv and 410 and hybrid EC-316053 x 410 and check Avantika and Syngenta-152 were unstable genotypes and performance could not be predicted.

5.5.3.3.2 Kharif and summer season

The range of environmental indices varied from -0.402 to 0.502. Four hybrids *viz.*, EC-316053 x VRO-4, EC-316053 x 364, Vaibhav x 162 and Vaibhav x 315 were highly sensitive to changes in environments and tend to respond better in favourable environment. Two parents Vaibahv and 410, hybrid 35 x 315 and check Avantika were unstable gneotypes and performance could not be predicted.

Ariyo (1990) observed that branches per plant were under strong genotypic influence and most genotypes were unstable. Senthil Kumar (2011) found that the genotypes Pusa A_4 x PP, PP x VU and PP were stable for number of branches per plant.

5.5.3.4 Plant height

5.5.3.4.1 Kharif season

Environmental indices for character plant height ranged from -23.321 to 33.777. Five hybrids *viz.*, 447 x HRB-55, 447 x 162, EC-316053 x VRO-4, EC-316053 x IIVR-11 and EC-316053 x 364 were stable genotypes and suitable over diverse environments. Hybrids 35 x IIVR-11, EC-316053 x 162 and Vaibhav x 162, check; Avantika and Syngenta-152 were above average stable genotypes and specifically adapted for stress or unfavourable environments, however may not perform in rich environment. Five hybrids *viz.,* 447 x 364, EC-316053 x 410, Vaibahv x VRO-4, Vaibhav x HRB-55 and Vaibhav x 364 were highly sensitive to changes in environments and tend to respond better in favourable environment. Parent 315 and hybrid 35 x VRO-4 were unstable genotypes and performance could not be predicted.

5.5.3.4.2 Kharif and summer season

Environment varied for this trait as observed from range of envorinmental indices (-34.472 to 54.717). Six hybrids *viz.,* 35 x IIVR-11, 447 x IIVR-11, 447 x HRB-55, 447 x 162, EC-316053 x VRO-4 and Vaibhav x 162 and check; Syngenta-152 were stable genotypes and suitable for general adaptation. Hybrids 447 x 364, Vaibahv x VRO-4, Vaibhav x HRB-55 and Vaibhav x 364 were below average stable genotypes and highly sensitive to change in environment, however tend to respond favourably to better environments but poor performer in unfavourable or stress condition. Hybrid BO-2 x VRO-4 was above average stable genotype and specifically adapted for stress or unfavourable environments, however may not perform in rich environment. Three parents Vaibhav, 315 and 410, two hybrids; 35 x VRO-4 and EC-316053 x HRB-55 and check Avantika were unstable genotypes and performance could not be predicted.

Mandal and Dana (1994) studied the stability and found that strain 7116 was the most stable genotype for plant height. Senthil Kumar

(2011) found that the genotype PP x UV and PK x PP were stable for plant height.

5.5.3.5 Tender fruit length

5.5.3.5.1 Kharif season

Environmental indices for tender fruit length ranged from -0.148 to 0.262. Hybrid EC-316053 x 162 was stable genotype for tender fruit length and suitable for general adaptation. Check Parbhani Kranti and five hybrids *viz.*, BO-2 x VRO-4, BO-2 x 162, BO-2 x 364, 35 x HRB-55 and 447 x 364 were above average stable and not suitable for favourable environments, however were specifically adapted to poor environments. Hybrid BO-2 x 315 was unstable genotype as shown significant (S^2di).

5.5.3.5.2 Kharif and summer season

Environment varied for this trait as observed from range of environmental indices (-0.189 to 0.221). Parent HRB-55 was stable genotype and suitable for all environments. Parent 315, check; Parbhani Kranti and Avantika, six hybrids *viz.*, BO-2 x VRO-4, BO-2 x 162, BO-2 x 315, BO-2 x 364, 35 x HRB-55 and 447 x 364 were above average stable and not suitable for favourable environments, however were specifically adapted to poor environments. Parent EC-316053 was below average stable genotype and highly sensitive to change in environment, however tend to respond favourably to better environments but poor performer in unfavourable or stress environment. Parent 162 and hybrid Vaibhav x HRB-55 were unstable genotypes and performance could not be predicted.

Jindal *et al.* (2009) studied G x E interaction and found that all the parents and hybrids were stable for fruit length under unfavourable environments but their performance cannot be predicted with greater accuracy due to significant deviation from regression. Senthil Kumar (2011) found that the genotype PP x UV and PK x PP were stable for tender fruit length.

5.5.3.6 Number of seeds per fruit

5.5.3.6.1 Kharif season

Environmental indices for character number of seeds per fruit ranged from -3.998 to 3.196. Three hybrids *viz.*, 35 x 315, EC-316053 x 162 and Vaibhav x 162 were above average stable and specifically adapted to poor or stress environments. Hybrids BO-2 x 315, 447 x 162 and Vaibahv x 315 were suitable for favourable or rich environments, however poor performer in unfavourable or stress environment. Parents 162 and 410 , Check; Parbhani Kranti and hybrids BO-2 x HRB-55, 447 x 364, EC-316053 x VRO-4 and EC-316053 x IIVR-11 were unstable genotypes as shown significant (S^2di).

5.5.3.6.2 Kharif and summer season

The extent of environmental indices for this trait ranged from -11.731 to 8.916. Hybrid 35 x 315 was stable genotype and suitable for wider adaptation. Check Parbhani Kranti and two hybrids 447 x 315 and Vaibhav x 315 were above average stable genotypes and specifically adapted to poor or stress environments. Two hybrids 447 x 162 and EC-316053 x 162 were highly sensitive to change in environment, however tend to perform favourably in better or rich environment. Two parents 162 and 410, six hybrids *viz.*, BO-2 x IIVR-11, BO-2 x HRB-55, BO-2 x 315, 447 x 364, EC-316053 x IIVR-11 and EC-316053 x 315 were unstable genotypes as revealed significant mean square deviation (S^2di) from zero.

Kanwar *et al.* (2006) reported that linear and non-linear components equally contributed G x E interaction in number of seeds per pod. Punjab-8 and Punjab Padmini were stable for all characters.

5.5.3.7 Number of fruits per plant

5.5.3.7.1 Kharif season

Environment varied for this trait as observed from range of environmental indices (-2.729 to 1.663). Hybrid BO-2 x 410 was stable genotype and suitable for wide range of environment. Three hybrids *viz.*, 35 x VRO-4, 35 x 162 and Vaibahav x 315 were above average stable genotypes and specifically adapted to unfavourable or stress environment, however may not respond better in rich or favourable environment. Hybrid EC-316053 x VRO-4 was highly sensitive to change in environment, however tend to perform favourably in better or rich environments. Parent Vaibhav, Check; Avantika and three hybrids *viz.*, EC-316053 x HRB-55, EC-316053 x 162 and Vaibahv x 410 were unstable genotypes and performance could not be predicted.

5.5.3.7.2 Kharif and summer season

Environmental indices for character number of fruits per plant ranged from -3.082 to 2.382. Five hybrids *viz.,* BO-2 x VRO-4, BO-2 x 162, BO-2 x 315, BO-2 x 410 and Vaibhav x 410 were stable genotype and suitable for general adaptation. Parent 162 and three hybrids 35 x HRB-55, EC-316053 x VRO-4 and EC-316053 x HRB-55 were above average stable genotypes and specifically adapted to poor or stress environments. Three hybrids *viz.,* 35 x 162, EC-316053 x 410 and Vaibhav x 315 were suitable for favourable environment, however poor performer in unfavourable environment. Parent Vaibahv, check; Avantika and two hybrids Vaibahv x 162 and BO-2 x IIVR-11 were unstable genotype as shown significant (S^2di).

Senthil Kumar (2011) found that the genotypes Pusa A_4 x PP, PP x VU and PP were stable and considered as the best adapted genotype for favourable environment for number of fruits per plant.

5.5.3.8 Weight of fruits per plant

5.5.3.8.1 Kharif season

Environmental indices for character weight of fruits per plant ranged from -51.965 to 40.664. Four hybrids *viz.,* 35 x 162, 447 x 315, Vaibhav x 315 and Vaibhav x 364 were stable genotypes and suitable for wide range of environment. Two hybrids BO-2 x 315 and 35 x 315 were above average stable genotypes and specifically adapted to unfavourable environment, however may not respond better in favourable environment. Two Hybrids EC-316053 x

VRO-4 and Vaibahv x 410 were highly sensitive to change in environment, however tend to perform favourably in better environemt. Hybrid BO-2 x IIVR-11 and check; Avantika were unstable genotypes and performance could not be predictable.

5.5.3.8.2 Kharif and summer season

Environment varied for this trait as observed from range of environmental indices (41.026 to 51.603). Four hybrids *viz.,* BO-2 x 315, 35 x 162, 447 x 315 and Vaibhav x 364 were stable genotypes and suitable for all environment. Two hybrids BO-2 x 410 and EC-316053 x HRB-55, check; Avantika were specifically adapted to unfavorable environment, however may not respond better in favourable environment. Two hybrids EC-316053 x VRO-4 and Vaibahv x 410 were below average stable genotypes and highly sensitive to change in environment, however tend to perform better in favourable environment. Three hybrids *viz.,* EC-316053 x 364, Vaibahv x 162 and Vaibahv x 315 were unstable genotype as shown significant (S^2di).

Paiva and Costa (1994) found that highest stability was shown by cv. Santa Cruz 47 and hybrids Santa cruz 47 x Piranema, BGH4888 x Santa Cruz 47 and Clempson Spineless x Santa Cruz 47 for average yield (184-286 g/plant) but had significant low stability. Poshiya and Vashi (1977) reported that the genotypes Gujarat Okra-1 and two hybrids Parbhani Kranti x Padra 18-6 and Gujarat Okra-1 x Perkins Long Green exhibited best stability in the environments. Overall, hybrids had higher yields and stability than their parents. Kanwar *et al.* (2006) reported that genotypes Punjab-8 and Punjab Padmini were stable for fruit yield per plant. Jindal *et al.* (2009) observed that the cross NDO-10 x S-2 was found stable for fruit weight. Dabhi *et al.* (2010) reported that non-linear component also played an important role for fruit weight. Ramya and SenthilKumar (2010) observed that the genotypes Pusa $A_{4,}$ Parbhani Kranti, Varsha Uphar, Punjab Padmini, Hissar Unnat, PB 266, CO-1, Harbhajan, Arka Abhay and AOL-03-01 were significantly higher regression coefficient along with desirable mean value for pod yield per plant. Kacchadia *et al.* (2011) observed that the fruit yield per plant indicated difficulty in predicting the performance of genotypes over environments. Kumar (2011) reported that the parent Punjab Padmini and the hybrids, Punjab Padmini x Varsha Uphar and Parbhani Kranti x Punjab Padmini were found to have significantly higher regression coefficient along with desirable mean value for fruit yield per plant. Alake and Ariyo (2012) found that NGAE-96-0060 and NGAE-96-0063 were found as stable genotypes.