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Genetic Analysis of Yield and Yield Contributing Traits in Okra (*Abelmoschus esculentus* L. Moench)

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A B S T R A C T

The generation mean analysis involving six generations (P_1, P_2, F_1, F_2, B_1 and B_2) was carried out to study the nature and magnitude of gene effects for seventeen characters in okra. The study was conducted at Departmental Farm of Department of Agricultural Botany, College of Agriculture, VNMKV Parbhani during *Kharif*-17 season. The Mather's individual scaling tests and Cavalli's joint scaling tests were used to detect the presence or absence of the epistatic interactions. The results obtained showed the importance of additive, dominance and all three types of epistatic interactions for most of the crosses and characters viz., plant height, days to first flowering, number of branches per plant, fruit length, fruit weight, number of fruiting nodes per plant, number of fruits per plant, internodal length and yield per plant. For majority of crosses and characters duplicate epistasis was observed while for some crosses complementary epistasis was observed.

Introduction

Okra (*Abelmoschus esculentus* L. Moench) is considered as one of the most popular vegetable crop grown in the tropical, subtropical, low altitude region of Asia, Africa, America and warmer region of tropical Mediterranean basin. It is grown commercially in most of the states of India as *Kharif* as well as summer season crop with area 532.66 thousand hectare production 6346 thousand metric tonnes and productivity 12 tonnes/ha (Anonymous, 2018).

In this crop all the characters of economical importance are qualitatively inherited and are dependent on nature and magnitude of heritable variations. Yield ultimately is the

final product is the result of complex of several yield contributing traits and being govern by polygenes are highly influence by environmental fluctuations.

Therefore, a breeder should have information on the mode of inheritance and genetic makeup of yield and it's yield contributing traits. Information of gene actions thus enables the breeder to decide the suitable breeding methodology and selection strategy approach for crop improvement programme.

Partitioning the heritable variations in to components is useful to provide information on inheritance of these quantitative traits. Most widely used approach for understanding the nature of gene action is growing the different generations to carry out the generation mean analysis. Although, it is widely used in several crops, very little information on these aspects is available in the literature on okra crop.

Materials and Methods

The present investigation entitled "Generation mean analysis studies in okra (*Abelmoschus esculents* L. Moench)" consist six basic sets of generations (along with check Pusa Sawani and Mahyco Bhindi No.10) viz., P_1, P_2, F_1, F_2, B_1 and B_2 were derived from four crosses involving five genotypes of okra. These six generations of four crosses viz., Parbhani Kranti × VROR-159, Parbhani Kranti × Kashi Pragati, Kashi Satadhari × VROR-159 and Kashi Satadhari × BO-2 were produced and grown in Randomised Block Design with three replications during Kharif season of 2017 at Botany farm, College of Agriculture, VNMKV, Parbhani.

The parental genotypes and F_1s were grown in four line, the F_2s were grown in eight lines and each backcross in four lines each of net 10 plants. The row to row and plant to plant distance was kept as 60 cm and 30 cm, respectively

The data was recorded on five plants for parents and F1s, ten plants for backcrosses and twenty plants for F2s in each replication. The observations were recorded on Plant height (cm), Internodal length (cm), Number of nodes on main stem, Number of branches per plant, Days to first flowering.

Days to 50% flowering, First fruiting node. Fruit length (cm), Fruit diameter (cm), Fruit weight (gm), Number of ridges per fruit, Number of fruits per plant, Marketable fruit yield per plant (gm) Yield per plot (Kg), Fruit yield (q/ha.), Incidence of Fruit and shoot borer (%) and Incidence of Yellow vein mosaic (%).

Individual scaling tests (A, B, C and D) and their variances were computed for each trait and cross for testing their deviations of segregation from the additive-dominance model of gene effects according to Mather and Jinks (1982). The joint scaling test was also implemented for confirmation of adequacy of additive-dominance model as provided by Cavelli (1952).

The cases where the model was adequate i.e. no epistasis was present, three parameter model of Jinks and Jones (1958) was used for estimation of genetic components. When the scaling tests were significant i.e. inter allelic interactions were present six parameter model suggested by Hayman (1958), Jinks and Jones (1958) was used for estimation of genetic components of variation.

Results and Discussion

Analysis of variance for yield and yield components showed highly significant differences among the crosses studied for all the character except for days to flowering in a

cross Kashi Satadhari × VROR-159 and Kashi Satadhari × BO-2 and 50% flowering in Kashi Satadhari × BO-2 which indicated the presence of substantial variability in the material under study (Table-1).

Mean performance of six generation of each of four crosses revealed that among the parents, Parbhani Kranti was found superior for plant height, fruit weight, marketable fruit yield per plant, fruit yield per plot and Fruit yields per hectare, Parent VROR-159 was found superior for number of branches per plant, number of nodes on main stem, internodal length, fruit length, days to first flowering and days to 50% flowering, parent Kashi Pragati was superior in Incidence of yellow vein mosaic and Incidence of fruit and shoot borer, parent BO- 2 was superior in first fruiting nodes and fruit diameter, parent kashi Satadhari superior in number of ridges per fruit. Whereas, check Mahyco Bhindi No 10 was superior for plant height, Internodal length and Pusa Sawani for earliness.

However, cross Parbhani kranti x VROR -159 was found better in Fruit weight, Number of fruit per plant, Marketable fruit yield per plant, Fruit yield per plot and Fruit yield per hectare, Number of branches per plant, Number of nodes on main stem, Fruit length and Incidence of yellow vein mosaic (%), the cross kashi Satadhari x VROR -159 was found superior for plant height, first fruiting nodes and incidence of fruit and shoot borer.

whereas, cross Kashi Satadhari x BO-2 was found superior for earliness, fruit diameter and incidence of fruit and shoot borer. While cross Parbhani Kranti x Kashi Pragati superior for days to 50% flowering and internodal length (Table-2).

Individual Scaling Test for most of the characters and crosses were significant for one or more crosses for all the characters. Inadequacy of additive-dominance model was evident by the significance of one or more scaling tests A, B, C and D as given by Mather (1949) indicating presence of non-allelic gene action in most of the crosses for various characters under studied. Joint scaling test was significant for all traits except for number of ridges per fruit.

The individual scaling test and joint scaling test behaves in accordance with each other and confirm the presence of inter allelic gene interaction. The accordance of individual and joint scaling tests was earlier reported by kumar *et al.*, (2013).

The individual scaling tests indicated that the simple additive dominance model was unable to explain the total genetic variability in all the crosses and presence of epistasis was observed for all the seventeen characters studied estimation of main as well as digenic interaction effects by six parameter models revealed the significance of both main and digenic interaction component for various characters.

However magnitude of dominant and epistasis components was greater than additive components in most of the characters. The magnitude of dominance (h) component was higher than additive component in characters indicating its predominant occurrence in the inheritance of these characters.

The prevalence of duplicate type of epistasis in all the characters over one or more crosses except number of nodes on main stem showing complementary epistasis further confirms the prevalence of dominance gene action. Among the digenic gene component, the dominance × dominance (l) component in general had enhancing effect in the expression of the characters. The additive × additive (d) gene effect was also evident in most of the characters (Table-3).

Table.1 Analysis of variance of the six generation four crosses

Characters	Treatment df	Error df	Mean square(MS)			
			Parbhani Kranti x VROR-159,	Parbhani Kranti x Kashi Pragati, $_2$	Kashi Satadhari X VROR-159	Kashi Satadhari x BO
Plant height (cm)	5	10	255.63*	755.42**	1304.65**	691.91**
Internodal length (cm)	5	10	1.09**	1.78**	1.53**	1.79**
Number of nodes on main stem,	5	10	17.60**	16.85**	19.62**	21.44**
Number of branches per plant	5	10	0.44**	0.36**	1.07**	0.30**
Days to first flowering	5	10	8.62**	4.10**	1.650 ^{NS}	1.55 ^{NS}
Days to 50% flowering	5	10	7.12**	6.48**	4.35**	1.94 ^{NS}
First fruiting node.	5	10	0.98**	0.66**	1.94**	0.704**
Fruit length (cm)	5	10	2.25*	2.52*	4.70**	2.62*
Fruit diameter (cm)	5	10	0.027**	0.018*	0.020**	0.039**
Fruit weight (gm)	5	10	27.05**	14.76**	15.68**	21.03**
Number of ridges per fruit	5	10	0.027**	0.07**	3.50**	3.77**
Number of fruits per plant	5	10	2.17**	2.40**	6.23**	1.97**
Marketable fruit yield per plant (gm)	5	10	896.07**	984.32**	1454.60**	1992.71**
Yield per plot (Kg),	5	10	1.64**	1.57**	2.44**	2.90**
fruit yield (q/ha.),	5	10	315.77**	303.43**	470.49**	560.35**
Incidence of Fruit and shoot borer (%)	5	10	3.08**	5.09**	9.61**	2.06**
Incidence of Yellow vein mosaic (%).	5	10	123.48**	52.82**	352.92**	192.24**

*and**significant at 5% and 1% respectively

Table.2 Mean performance of six generation in four crosses for 17 characters

Crosses	P_1	P_2	F_1	F_2	BC_1	BC_2	Pusa sawani	Mahyco Bhindi No. 10
Plant height (cm)								
C1 (Parbhani Kranti × VROR-159)	155.66±1.21	151.40±1.46	170.26±0.51	151.00±0.19	143.23±0.30	160.60±0.22	115.73±1.20	163.60±1.05
C2 (Parbhani Kranti × Kashi pragati)	155.66±1.21	116.46±0.61	160.80±0.55	144.81±0.16	153.23±0.30	141.20±0.30	115.73±1.20	163.60±1.05
C3 (Kashi Satadhari × VROR-159)	110.93±0.81	151.40±1.46	170.80±0.55	136.70±0.13	124.30±0.31	139.56±0.37	115.73±1.20	163.60±1.05
C4 (Kashi Satadhari × BO2)	110.93±0.81	131.40±1.41	151.80±0.55	137.55±0.25	126.50±0.22	146.73±0.38	115.73±1.20	163.60±1.05
Internodal length (cm)								
C1 (Parbhani Kranti × VROR-159)	6.74±0.10	6.88±0.08	6.31±0.09	6.58±0.03	5.22±0.05	6.64±0.06	5.15±0.6	6.93±0.12
C2 (Parbhani Kranti × kashi pragati)	6.74±0.10	4.91±0.06	5.75±0.07	5.24±0.02	5.87±0.04	6.81±0.06	5.15±0.6	6.93±0.12
C3 (Kashi Satadhari × VROR-159)	6.09±0.14	6.88±0.085	6.86±0.084	7.73±0.03	7.05±0.05	5.73±0.02	5.15±0.6	6.93±0.12
C4 (Kashi Satadhari × BO2)	6.093±0.14	5.51±0.08	5.94±0.07	4.40±0.03	6.73±0.03	5.67±0.02	5.15±0.6	6.93±0.12
Number of nodes on main stem								
C1 (Parbhani Kranti × VROR-159)	17.93±0.35	18.80±0.24	24.53±0.22	20.25±0.12	18.50±0.17	20.96±0.28	14.73±0.24	18.60±0.16
C2 (Parbhani Kranti × kashi pragati)	17.93±0.22	16.33±0.35	23.33±0.18	20.25±0.07	19.53±0.14	20.13±0.24	14.73±0.24	18.60±0.16
C3 (Kashi Satadhari × VROR-159)	13.26±0.42	18.80±0.24	20.93±0.19	16.85±0.11	16.43±0.15	17.50±0.19	14.73±0.24	18.60±0.16
C4 (Kashi Satadhari × BO2)	13.26±0.42	16.00±0.28	21.13±0.21	18.48±0.10	16.46±0.19	18.30±0.14	14.73±0.24	18.60±0.16
Number of branches per plant								
C1 (Parbhani Kranti × VROR-159)	2.86±0.05	3.60±0.04	3.66±0.025	3.91±0.013	3.30±0.03	3.80±0.03	3.00±0.05	3.47±0.06
C2 (Parbhani Kranti × kashi pragati)	2.86±0.05	2.46±0.06	3.40±0.04	3.03±0.02	2.90±0.01	2.50±0.04	3.00±0.05	3.47±0.06
C3 (Kashi Satadhari × VROR-159)	2.60±0.04	3.60±0.04	2.80±0.04	4.20±0.01	3.00±0.01	3.53±0.03	3.00±0.05	3.47±0.06
C4 (Kashi Satadhari × BO2)	2.60±0.04	3.2±0.04	2.60±0.04	2.56±0.01	3.23±0.02	2.63±0.02	3.00±0.05	3.47±0.06
Days to flowering								
C1 (Parbhani Kranti × VROR-159)	43.66±0.12	39.66±0.25	41.66±0.12	43.33±0.06	44.33±0.08	42.00±0.15	40.00±0.23	43.67±0.18
C2 (Parbhani Kranti × kashi pragati)	43.66±0.12	41.33±0.25	40.66±0.12	41.66±0.06	41.33±0.08	40.33±0.08	40.00±0.23	43.67±0.18
C3 (Kashi Satadhari × VROR-159)	40.33±0.33	39.66±0.25	40.33±0.12	41.66±0.06	41.00±0.15	41.33±0.17	40.00±0.23	43.67±0.18
C4 (Kashi Satadhari × BO2)	40.33±0.33	41.66±0.12	40.00±0.21	41.00±0.10	41.33±0.17	41.00±0.15	40.00±0.23	43.67±0.18
Days to 50% flowering								
C1 (Parbhani Kranti × VROR-159)	46.66±0.33	43.00±0.21	44.33±0.12	47.00±0.10	46.00±0.15	44.66±0.31	42.67±21	45.67±16
C2 (Parbhani Kranti × Kashi Pragati)	46.66±0.33	44.33±0.12	43.00±0.21	45.00±0.10	45.00±0.15	42.66±0.08	42.67±21	45.67±16
C3 (Kashi Satadhari × VROR-159)	46.00±0.21	43.00±0.21	43.66±0.25	45.66±0.06	43.66±0.08	44.66±0.23	42.67±21	45.67±16
C4 (Kashi Satadhari × BO2)	46.00±0.21	44.66±0.12	43.66±0.12	44.33±0.12	44.66±0.23	44.33±0.08	42.67±21	45.67±16
First fruiting nodes								
C1 (Parbhani Kranti × VROR-159)	3.80±0.07	3.40±0.04	2.40±0.04	3.95±0.03	3.23±0.05	3.80±0.03	4.67±0.06	3.13±0.04
C2 (Parbhani Kranti × Kashi Pragati)	3.80±0.07	3.00±0.08	3.00±0.04	2.73±0.01	3.86±0.03	3.50±0.03	4.67±0.06	3.13±0.04
C3 (Kashi Satadhari × VROR-159)	3.80±0.04	3.40±0.04	1.93±0.06	4.00±0.01	4.13±0.03	3.23±0.038	4.67±0.06	3.13±0.04
C4 (Kashi Satadhari × BO2)	3.80±0.04	2.86±0.02	2.40±0.04	2.90±0.02	3.20±0.03	2.66±0.04	4.67±0.06	3.13±0.04

Fruit length (cm)								
C1 (Parbhani Kranti × VROR-159)	13.80±0.29	15.60±0.28	14.22±0.23	12.91±0.06	13.66±0.10	13.40±0.13	11.76±16	14.87±12
C2 (Parbhani Kranti × Kashi Pragati)	13.80±0.29	14.09±0.23	13.80±0.16	13.92±0.10	14.00±0.19	11.66±0.11	11.76±16	14.87±12
C3 (Kashi Satadhari × VROR-159)	14.31±0.22	15.60±0.28	13.42±0.15	12.39±0.03	12.46±0.10	14.45±0.15	11.76±16	14.87±12
C4 (Kashi Satadhari × BO2)	14.31±0.22	12.08±0.30	13.16±0.21	13.33±0.07	11.69±0.11	12.97±0.10	11.76±16	14.87±12
Fruit weight (gm)								
C1 (Parbhani Kranti × VROR-159)	23.53±0.19	23.20±0.15	23.60±0.08	21.41±0.06	17.20±0.13	17.46±0.17	18.47±0.14	21.47±0.16
C2 (Parbhani Kranti × Kashi Pragati)	23.53±0.19	20.13±0.26	22.60±0.20	19.36±0.09	17.96±0.15	18.70±0.12	18.47±0.14	21.47±0.16
C3 (Kashi Satadhari × VROR-159)	21.93±0.33	23.20±0.15	23.33±0.13	21.41±0.06	17.16±0.17	20.33±0.23	18.47±0.14	21.47±0.16
C4 (Kashi Satadhari × BO2)	21.93±0.33	19.86±0.33	21.60±0.11	18.65±0.06	18.13±0.18	14.73±0.16	18.47±0.14	21.47±0.16
Fruit diameter (cm)								
C1 (Parbhani Kranti × VROR-159)	1.87±0.02	2.07±0.01	1.85±0.01	1.85±0.012	1.83±0.01	1.82±0.01	1.96±0.03	1.98±0.08
C2 (Parbhani Kranti × Kashi Pragati)	1.87±0.017	2.04±0.012	1.93±0.013	1.90±0.004	1.82±0.009	1.84±0.011	1.96±0.03	1.98±0.08
C3 (Kashi Satadhari × VROR-159)	2.04±0.01	2.07±0.01	1.87±0.02	1.97±0.005	1.88±0.008	2.00±0.009	1.96±0.03	1.98±0.08
C4 (Kashi Satadhari × BO2)	2.04±0.01	2.14±0.02	2.05±0.01	2.02±0.006	1.94±0.01	1.80±0.007	1.96±0.03	1.98±0.08
No of ridges per fruit								
C1 (Parbhani Kranti × VROR-159)	5.00±0.00	5.00±0.00	5.06±0.02	5.20±0.005	5.20±0.01	5.16±0.008	5.00±00	5.20±0.01
C2 (Parbhani Kranti × Kashi Pragati)	5.00±00	5.40±0.04	5.00±00	5.10±0.005	5.20±0.01	5.00±0.00	5.00±00	5.20±0.01
C3 (Kashi Satadhari × VROR-159)	7.73±0.06	5.00±0.00	7.00±0.04	7.16±0.01	8.1±0.03	6.73±0.02	5.00±00	5.20±0.01
C4 (Kashi Satadhari × BO2)	7.73±0.06	5.00±0.00	6.86±0.05	6.72±0.01	8.10±0.03	6.10±0.04	5.00±00	5.20±0.01
Fruit yield per plant (gm)								
C1 (Parbhani Kranti × VROR-159)	280.60±2.42	260.60±3.31	313.40±3.03	275.56±0.37	280.76±1.36	279.80±2.27	252.67±1.46	264.93±1.12
C2 (Parbhani Kranti × Kashi Pragati)	280.60±2.42	277.13±1.79	283.20±3.41	247.93±0.82	266.33±1.94	239.90±1.56	252.67±1.46	264.93±1.12
C3 (Kashi Satadhari × VROR-159)	255.46±1.06	260.60±3.31	294.40±0.74	276.15±2.31	228.50±1.14	259.10±0.98	252.67±1.46	264.93±1.12
C4 (Kashi Satadhari × BO2)	255.46±1.06	239.00±1.37	293.80±1.98	263.81±0.63	282.30±1.37	227.00±1.01	252.67±1.46	264.93±1.12
Fruit yield per plot (Kg)								
C1 (Parbhani Kranti × VROR-159)	11.17±0.10	10.15±0.14	12.47±0.10	11.04±0.01	11.25±0.05	11.19±0.08	10.11±0.12	10.60±0.15
C2 (Parbhani Kranti × Kashi Pragati)	11.17±0.10	11.08±0.07	11.36±0.15	9.91±0.03	10.66±0.07	9.60±0.06	10.11±0.12	10.60±0.15
C3 (Kashi Satadhari × VROR-159)	10.14±0.03	10.15±0.14	11.75±0.04	11.11±0.10	9.13±0.04	10.36±0.04	10.11±0.12	10.60±0.15
C4 (Kashi Satadhari × BO2)	10.14±0.03	9.45±0.04	11.78±0.08	10.52±0.02	11.29±0.05	9.33±0.07	10.11±0.12	10.60±0.15
Fruit yield per hectare (q)								
C1 (Parbhani Kranti × VROR-159)	155.18±1.50	141.00±1.95	173.14±1.51	153.42±0.18	156.27±0.74	155.46±1.23	140.37±1.46	147.18±1.24

C2 (Parbhani Kranti × Kashi Pragati)	155.18±1.50	153.96±0.99	157.85±2.09	137.63±0.47	148.09±1.06	133.35±0.89	140.37±1.46	147.18±1.24
C3 (Kashi Satadhari × VROR-159)	140.96±0.51	141.00±1.95	163.25±0.59	154.34±1.48	126.83±0.64	143.88±0.59	140.37±1.46	147.18±1.24
C4 (Kashi Satadhari × BO2)	140.96±0.51	131.29±0.60	163.70±1.10	146.13±0.40	156.85±0.77	129.55±1.04	140.37±1.46	147.18±1.24
Number of fruits per plant								
C1 (Parbhani Kranti × VROR-159)	16.40±0.20	15.26±0.20	17.86±0.15	16.00±0.02	16.53±0.07	16.26±0.11	15.00±0.15	16.20±0.13
C2 (Parbhani Kranti × Kashi Pragati)	16.40±0.20	16.46±0.17	16.53±0.21	15.46±0.05	16.33±0.12	14.26±0.10	15.00±0.15	16.20±0.13
C3 (Kashi Satadhari × VROR-159)	13.80±0.13	15.26±0.20	16.73±0.06	16.00±0.02	13.06±0.12	13.80±0.05	15.00±0.15	16.20±0.13
C4 (Kashi Satadhari × BO2)	13.80±0.13	15.36±0.20	16.20±0.11	14.51±0.03	15.26±0.08	15.20±0.12	15.00±0.15	16.20±0.13
Incidence of Shoot and Fruit Borer (%)								
C1 (Parbhani Kranti × VROR-159)	17.59±0.24 (24.78)	21.02±0.20 (27.27)	19.41±0.10 (26.13)	20.67±0.03 (27.03)	18.16±0.05 (25.21)	18.47±0.09 (25.44)	19.69±0.36 (26.32}	21.54±0.25 (27.62)
C2 (Parbhani Kranti × Kashi Pragati)	17.59±0.24 (24.78)	15.82±0.13 (23.42)	18.19±0.17 (25.23)	19.41±0.05 (26.13)	18.40±0.10 (25.39)	21.06±0.10 (27.30)	19.69±0.36 (26.32}	21.54±0.25 (27.62)
C3 (Kashi Satadhari × VROR-159)	16.69±0.12 (24.10)	21.02±0.20 (27.27)	17.93±0.05 (25.05)	18.35±0.14 (25.34)	23.02±0.14 (28.66)	21.75±0.05 (27.79)	19.69±0.36 (26.32}	21.54±0.25 (27.62)
C4 (Kashi Satadhari × BO2)	16.69±0.12 (24.10)	18.41±0.22 (25.39)	18.53±0.09 (25.49)	18.75±0.02 (25.65)	19.67±0.07 (26.32)	19.77±0.11 (26.39)	19.69±0.36 (26.32}	21.54±0.25 (27.62)
Incidence of Yellow Vein Mosaic (%)								
C1 (Parbhani Kranti × VROR-159)	35.16±1.14 (36.27)	19.00±0.58 (25.77)	16.33±0.64 (23.74)	18.83±0.16 (25.69)	35.83±1.16 (36.58)	14.16±0.46 (21.99)	48.67±1.36 (44.22)	18.17±0.35 (25.20)
C2 (Parbhani Kranti × Kashi Pragati)	35.16±1.14 (36.27)	17.66±1.05 (24.62)	21.83±0.61 (27.78)	22.50±0.25 (28.26)	18.00±0.36 (25.04)	22.00±0.45 27.89)	48.67±1.36 (44.22)	18.17±0.35 (25.20)
C3 (Kashi Satadhari × VROR-159)	19.33±0.37 (26.05)	19.00±0.58 (25.77)	24.33±0.52 (29.51)	21.41±0.22 (27.52)	63.33±0.68 (52.78)	16.30±0.47 24.11)	48.67±1.36 (44.22)	18.17±0.35 (25.20)
C4 (Kashi Satadhari × BO2)	19.33±0.37 (26.05)	27.66±0.35 (31.71)	15.33±0.52 (22.98)	13.5±0.36 (21.41)	45.33±0.92 (42.27)	14.66±0.31 22.46)	48.67±1.36 (44.22)	18.17±0.35 (25.20)

Table.3 Scaling test and gene effects of yield and its attributing characters in okra crosses, following six parameter model following Jinks and Jones (1958)

Cross	Scale				Genetic component						Epistasis
	A	B	C	D	m	d	h	i	j	l	
Plant height (cm)											
C1	-39.46**±1.45	-0.46^{NS}±1.61	-40.93**±2.30	-0.50^{NS}±0.55	151**±0.19	-17**±0.38	17**±1.54	1.00^{NS}±1.10	-19.5**±1.05	38.93**±2.76	complementary
C2	-10.00**±1.47	5.13**±1.03	-14.46**±1.88	-4.8**±0.55	144.81**±0.17	12.03**±0.43	34.33**±1.41	9.60**±1.10	-7.56**±0.80	-4.73^{NS}±2.56	duplicate
C3	-33**±1.17	-43**±1.73	-57**±2.08	9.5**±0.56	136.70**±0.13	-15**±0.49	20**±1.51	-19.06**±1.13	4.96**±0.97	95.26**±2.87	complementary
C4	-9.73**±1.09	10.26**±1.70	4.26^{NS}±2.22	1.86**±0.67	137.55**±0.25	-20.23**±0.44	26.90**±1.67	-3.73**±1.35	-10.00**±0.93	3.20**±2.85	complementary
Internodal length (cm)											
C1	-2.607**±0.18	0.093^{NS}±0.17	0.100^{NS}±0.26	1.30**±0.10	6.58**±0.03	-1.42**±0.08	-3.11**±0.24	-2.613**±0.21	-1.350**±0.10	5.127**±0.42	duplicate
C2	-0.74**±0.15	2.96**±0.15	-2.20**±0.21	-2.21**±0.08	5.24**±0.02	-0.94**±0.07	4.35**±0.19	4.42**±017	-1.85**±0.09	-6.65**±0.36	duplicate
C3	1.15**±0.19	-2.28**±0.12	4.24**±0.27	2.68**±0.08	7.73**±0.03	1.32**±0.05	-4.99**±0.20	-5.36**±0.16	1.71**±0.10	6.49**±0.35	duplicate
C4	1.43**±0.18	-0.113^{NS}±0.11	-5.86**±0.25	-3.5**±0.07	4.40**±0.03	1.06**±0.04	7.31**±0.19	7.78**±0.15	0.77**±0.09	-8.50**±0.30	duplicate
Number of nodes on main stem,											
C1	-5.46**±0.54	-1.40*±0.66	-4.80**±0.80	1.03*±0.42	20.25**±0.12	-2.46**±0.33	4.10**±0.89	-2.06*±0.84	-2.03**±0.39	8.93**±1.56	complementary
C2	-0.60 ^{NS} ±0.41	-1.00 ^{NS} ±0.62	0.06 ^{NS} ±0.62	0.83*±0.13	20.25**±0.07	-0.60*±0.28	4.53**±0.69	-1.66**±0.63	0.20**±0.35	3.26**±1.29	complementary
C3	-1.33**±0.55	-4.73**±0.50	-6.53**±0.77	-0.23±0.34	16.85**±0.11	-1.06**±0.25	5.36**±0.74	0.46**±0.68	1.70**±0.35	5.60*±1.26	complementary
C4	-1.46**±0.61	-0.53**±0.46	2.40**±0.80	2.40**±0.32	18.48**±0.11	-1.83**±0.24	2.10**±0.73	-4.40**±0.65	-0.46**±0.35	6.40**±1.26	complementary
Number of branches per plant											
C1	0.067ns±0.08	0.33**±0.07	1.86**±0.09	0.73**±0.05	3.91**±0.01	-0.50**±0.04	-1.03**±0.10	-1.46**±0.10	-0.13*±0.05	1.06**±0.19	duplicate
C2	-0.46**±0.07	-0.86**±0.11	0.00±0.14	0.66**±0.06	3.03**±0.02	0.40**±0.04	-0.60**±0.13	-1.33**±0.12	0.20**±0.06	2.66**±0.22	duplicate
C3	0.60**±0.06	0.66**±0.08	5.00**±0.13	1.86**±0.05	4.20**±0.01	-0.53**±0.03	-4.03**±0.11	-3.73**±0.10	-0.03 ^{NS} ±0.04	2.46**±0.19	duplicate
C4	1.26**±0.07	-0.53**±0.07	-0.73**±0.12	-0.73**±0.04	2.56**±0.01	0.60**±0.03	1.16**±0.10	1.46**±0.09	0.90**±0.04	-2.20**±0.18	duplicate
Days to first flowering											
C1	3.33**±0.25	2.66**±0.41	6.66**±0.45	0.33 ^{NS} ±0.21	43.33**±0.06	2.33**±0.17	-0.66 ^{NS} ±0.46	-0.66 ^{NS} ±0.42	0.33 ^{NS} ±0.22	-5.33**±0.83	complementary
C2	-1.66**±0.25	-1.33**±0.33	0.33± ^{NS} 0.45	1.66**±0.17	41.66**±0.06	1.00**±0.12	-5.16**±0.39	-3.33**±0.34	-0.1 ^{NS} 6±0.18	6.33**±0.67	duplicate
C3	1.33**±0.46	2.66**±0.44	6.00**±0.54	1.00**±0.26	41.66**±0.06	-0.33ns±0.23	-1.66**±0.57	-2.00**±0.52	-0.66*±0.31	-2.00 ^{NS} ±1.07	complementary
C4	2.33**±0.53	0.33 ^{NS} ±0.39	2.00**±0.70	-0.33 ^{NS} ±0.31	41.00**±0.10	0.33 ^{NS} ±0.23	-0.33 ^{NS} ±0.68	0.66 ^{NS} ±0.62	1.00**±0.29	-3.33**±1.16	complementary
Days to 50% flowering											
C1	1.00*±0.46	2.00**±0.68	9.66**±0.63	3.33**±0.41	47.00**±0.10	1.33**±0.35	-7.16**±0.85	-6.66**±0.81	-0.50^{NS}±0.46	3.66**±1.53	duplicate
C2	0.33±0.50	-2.00**±0.30	3.00**±0.70	2.33**±0.27	45.00**±0.10	2.33**±0.17	-7.16**±0.61	-4.66**±0.55	1.16**±0.25	6.33**±0.99	duplicate
C3	-2.33**±0.37	2.66**±0.57	6.33**±0.64	3.00**±0.27	45.66**±0.06	-1.00**±0.24	-6.83**±0.62	-6.00**±0.55	-2.50**±0.29	5.66**±1.17	duplicate
C4	-0.33 ^{NS} ±0.52	0.33 ^{NS} ±0.25	-0.66 ^{NS} ±0.60	-0.33 ^{NS} ±0.34	44.33**±0.12	0.33 ^{NS} ±0.24	-1.00 ^{NS} ±0.72	0.66 ^{NS} ±0.69	-0.33 ^{NS} ±0.27	-0.66 ^{NS} ±1.16	complementary
First fruiting node.											
C1	0.26 ^{NS} ±0.13	1.80**±0.08	3.80**±0.17	0.86**±0.08	3.95**±0.03	-0.56**±0.06	-2.93**±0.18	-1.73**±0.17	-0.76**±0.07	-0.33±0.30	complementary
C2	0.933**±0.11	1.00**±0.11	-1.867**±0.15	-1.90**±0.05	2.73**±0.01	0.36**±0.04	3.40**±0.13	3.80**±0.11	-0.03±0.07	-5.73**±0.11	duplicate
C3	2.53**±0.11	1.13**±0.11	4.93**±0.16	0.63**±0.06	4.00**±0.01	0.90**±0.05	-2.93**±0.14	-1.26**±0.12	0.70**±0.06	-2.40**±0.26	complementary
C4	0.20*±0.08	0.06 ^{NS} ±0.10	0.13 ^{NS} ±0.13	-0. ^{NS} 6±0.07	2.90**±0.02	0.53**±0.05	-0.80**±0.14	0.133±0.14	0.06±0.06	-0.40±0.25	complementary
Fruit length (cm)											
C1	-0.71 ^{NS} ±0.43	-3.013**±0.45	-6.20**±0.66	-1.24**±0.19	12.91**±0.05	0.25 ^{NS} ±0.17	2.00**±0.50	2.48**±0.39	1.15**±0.26	1.24 ^{NS} ±0.94	complementary
C2	0.40 ^{NS} ±0.51	-4.50**±0.37	0.18 ^{NS} ±0.64	2.14**±0.30	13.92**±0.10	2.30**±0.22	-4.43**±0.65	-4.28**±0.60	2.45**±0.29	8.38**±1.11	duplicate
C3	-2.8**±0.34	-0.12 ^{NS} ±0.45	-7.20**±0.49	-2.13**±0.19	12.39**±0.03	-1.99**±0.18	2.73**±0.45	4.26**±0.39	-1.34**±0.26	-1.31 ^{NS} ±0.89	duplicate
C4	-4.08**±0.38	0.70 ^{NS} ±0.42	0.63 ^{NS} ±0.65	2.00**±0.22	13.33**±0.07	-1.27**±0.15	-4.05**±0.52	-4.01**±0.44	-2.39**±0.24	7.39**±0.90	duplicate
Fruit diameter (cm)											
C1	-0.057 ^{NS} ±0.03	-0.283**±0.03	-0.24**±0.04	0.05*±0.02	1.85**±0.06	0.01 ^{NS} ±0.01	-0.22**±0.04	-0.10*±0.04	0.13**±0.02	0.44**±0.08	duplicate
C2	-0.147**±0.02	-0.293**±0.02	-0.173**±0.03	0.133**±0.01	1.90**±0.01	-0.013 ^{NS} ±0.01	-0.293**±0.03	-2.67**±0.03	0.07**±0.01	0.70**±0.07	duplicate

C3	-0.16**±0.02	0.06^{NS}±0.03	0.03^{NS}±0.05	0.06**±0.01	1.97**±0.01	-0.12**±0.01	-0.31**±0.04	-0.13**±0.03	-0.11**±0.01	0.23**±0.07	duplicate
C4	-0.21**±0.02	-0.58**±0.03	-0.20**±0.04	0.29**±0.02	2.02**±0.01	0.133**±0.01	-0.63**±0.04	-0.58**±0.03	0.18**±0.02	1.38**±0.07	duplicate
Fruit weight (gm)											
C1	-12.73**±0.35	-11.86**±0.38	-8.26**±0.40	8.16**±0.25	21.41**±0.06	-0.26 ^{NS} ±0.22	-16.10**±0.53	-16.33**±0.50	-0.43 ^{NS} ±0.25	40.93**±0.96	duplicate
C2	-10.20**±0.42	-5.33**±0.42	-11.40**±0.65	2.06**±0.28	19.36**±0.09	-0.73**±0.20	-3.36**±0.62	-4.13**±0.57	-2.43**±0.26	19.66**±1.04	duplicate
C3	-10.93**±0.49	-5.86**±0.51	-6.13**±0.52	5.33**±0.32	21.41**±0.06	-3.16**±0.29	-9.90**±0.67	-10.66**±0.64	-2.53**±0.34	27.46**±1.28	duplicate
C4	-7.26**±0.51	-12.00**±0.48	-10.40**±0.58	4.43**±0.28	18.65**±0.06	3.40**±0.24	-8.16**±0.62	-8.86**±0.56	2.36**±0.34	28.13**±1.15	duplicate
Number of ridges per fruit											
C1	0.33**±0.03	0.26**±0.03	0.66**±0.05	0.03**±0.02	5.2**±0.00	0.033 ^{NS} ±0.01	0.53**±0.04	-0.06 ^{NS} ±0.04	0.03 ^{NS} ±0.01	-0.53**±0.08	duplicate
C2	0.40**±0.03	-0.40**±0.04	00 ^{NS} ±0.04	--	5.1**±0.01	0.20**±0.01	-0.2**±0.04	--	0.4**±0.02	--	--
C3	1.46**±0.01	1.46**±0.06	1.93**±0.12	-0.50**±0.04	7.16**±0.01	1.36**±0.03	1.63**±0.10	1.00**±0.09	0.00**±0.05	-3.933**±0.19	duplicate
C4	1.60**±0.10	0.33**±0.10	0.42**±0.13	-0.75**±0.05	6.72**±0.01	2.00**±0.05	2.00**±0.13	1.50**±0.11	0.63**±0.06	-3.44**±0.25	duplicate
Number of fruits per plant											
C1	-1.20**±0.29	-0.60 ^{NS} ±0.34	-3.40**±0.43	-0.80**±0.14	16.00**±0.02	0.26ns±0.13	3.63**±0.35	1.60**±0.28	-0.30ns±0.19	0.20ns±0.68	complementary
C2	-0.26 ^{NS} ±0.93	-4.46**±0.34	-4.06**±0.56	0.33 ^{NS} ±0.20	15.46**±0.05	2.06**±0.16	-0.56ns±0.47	-0.66**±0.40	2.10ns±0.21	1.39**±0.86	duplicate
C3	-4.4**±0.28	-4.4**±0.24	1.46**±0.29	5.13**±0.14	16.00**±0.02	-0.73**±0.13	-8.06**±0.31	-10.26**±0.28	0.00ns±0.18	19.06**±0.60	duplicate
C4	0.53*±0.24	-1.06**±0.33	-3.40**±0.36	-1.43**±0.16	14.51**±0.03	0.06ns±0.14	4.53**±0.36	2.86**±0.32	0.80**±0.19	-2.33**±0.69	duplicate
Marketable fruit yield per plant (gm)											
C1	-32.40**±4.76	-14.40*±6.40	-65.73**±7.52	-9.43**±2.75	275.56**±0.37	0.96 ^{NS} ±2.65	61.66**±6.63	18.86**±5.51	-9.03**±3.35	28.00*±13.00	complementary
C2	-31.13**±5.72	-80.53**±4.97	-132.40**±8.16	-10.36**±2.99	247.93**±0.82	26.43**±2.50	25.06**±7.06	20.73**±5.91	24.70**±2.92	90.93**±12.91	duplicate
C3	-92.86**±2.63	-36.80**±3.92	-0.26 ^{NS} ±9.99	64.70**±4.86	276.15**±2.31	-30.60**±1.50	-93.03**±9.91	-129.40**±9.72	-28.03**±2.30	259.06**±11.66	complementary
C4	15.33**±3.55	-78.80**±3.15	-26.80**±5.03	18.33**±2.12	263.81**±0.63	55.30**±1.70	9.90*±4.77	-36.66**±4.25	47.06**±1.91	100.13**±8.47	complementary
Yield per plot (Kg)											
C1	-1.14**±0.18	-0.227 ^{NS} ±0.25	-2.08**±0.28	-0.35**±0.10	11.04**±0.01	0.05 ^{NS} ±0.10	2.52**±0.25	0.71**±0.21	-0.45**±0.13	0.65 ^{NS} ±0.50	complementary
C2	-1.213**±0.24	-3.25**±0.21	-5.35**±0.35	-0.44**±0.12	9.91**±0.03	1.06**±0.10	1.11**±0.29	0.88**±0.24	1.01**±0.11	3.57**±0.53	complementary
C3	-3.63**±0.10	-1.18**±0.17	0.64 ^{NS} ±0.45	2.73**±0.22	11.11**±0.10	-1.227**±0.06	-3.58**±0.45	-5.46**±0.44	-1.225**±0.09	10.29**±0.52	duplicate
C4	0.65**±0.14	-2.58**±0.17	-1.08**±0.20	0.42**±0.11	10.52**±0.03	1.96**±0.09	1.14**±0.23	-0.84**±0.22	1.61**±0.09	2.77**±0.42	complementary
Fruit yield (q/ha.),											
C1	-15.77**±2.60	-3.22 ^{NS} ±3.50	-28.77**±3.98	-4.88**±1.49	153.42**±0.18	0.81 ^{NS} ±1.44	34.82**±3.56	9.76**±2.98	-6.27**±1.90	9.23 ^{NS} ±7.01	complementary
C2	-16.84**±3.35	-45.11**±2.92	-74.32**±4.94	-6.18**±1.68	137.63**±0.47	14.74**±1.39	15.64**±4.07	12.36**±3.37	14.13**±1.65	49.59**±7.44	complementary
C3	-50.55**±1.52	-16.48**±2.36	8.89^{NS}±6.37	37.96**±3.09	154.34**±1.48	-17.05**±0.87	-53.65**±6.29	-75.93**±6.18	-17.03**±1.34	142.97**±7.27	duplicate
C4	9.03**±1.97	-35.89**±2.44	-15.11**±2.85	5.87**±1.53	146.13**±0.40	27.29**±1.30	15.83**±3.28	-11.74**±3.06	22.46**±1.36	38.59**±5.93	complementary
Incidence of Fruit and shoot borer (%)											
C1	-0.48^{NS}±0.29	-2.52**±0.30	3.82**±0.40	3.41**±0.13	27.03**±0.03	-0.23^{NS}±0.11	-6.73**±0.32	-6.83**±0.26	1.01**±0.19	9.85**±0.61	duplicate
C2	0.76*±0.36	5.95**±0.30	5.85**±0.49	-0.43*±0.18	26.13**±0.05	-1.91**±0.14	1.99**±0.42	0.86*±0.36	-2.59**±0.20	-7.59**±0.77	duplicate
C3	8.16**±0.32	3.26**±0.24	-0.09^{NS}±0.62	-5.76**±0.32	25.34**±0.14	0.86**±0.15	10.88**±0.66	11.52**±0.64	2.45**±0.19	-22.95**±0.89	duplicate
C4	3.04**±0.21	1.90**±0.33	2.14**±0.32	-1.40**±0.14	25.65**±0.02	-0.07^{NS}±0.13	3.54**±0.32	2.80**±0.28	0.57**±0.18	-7.74**±0.64	duplicate
Incidence of Yellow vein mosaic (%).											
C1	13.14**±2.67	-5.51**±1.26	-6.75**±1.93	-7.19**±1.29	25.69**±0.16	14.58**±1.25	7.10**±2.74	14.38**±2.58	9.33**±1.40	-22.00**±5.36	duplicate
C2	-13.97**±1.46	3.38*±1.51	-3.41^{NS}±2.24	3.59**±0.78	28.26**±0.26	-2.85**±0.58	-9.84**±1.85	-7.18**±1.56	-8.67**±0.97	17.77**±3.23	duplicate
C3	50.01**±1.51	-7.05**±1.23	2.36^{NS}±1.53	0.89**±0.94	27.52**±0.22	28.67**±0.83	47.29**±1.99	43.59**±1.89	28.53**±0.90	-86.62**±3.68	duplicate
C4	35.51**±1.95	-9.77**±0.88	-18.09**±1.85	-21.91**±1.21	21.41**±0.36	19.81**±0.97	37.93**±2.49	43.83**±2.42	22.64**±1.00	-69.58**±4.31	duplicate

*and**significant at 5% and 1% respectively.

C1= (Parbhani Kranti × VROR-159) C2 = (Parbhani Kranti × Kashi Pragati) C3 = (Kashi Satadhari × VROR-159) and C4= (Kashi Satadhari × BO-2)

Dominant gene action is predominant for plant height, Internodal length, number of nodes on main stem, number of branches per plant, first fruiting nodes, fruit length, fruit diameter, fruit weight, fruit diameter, fruit yield per plant, fruit yield per plot, fruit yield per hectare, Incidence of fruit and shoot borer (%) and Incidence of yellow vein mosaic (%) in all the four crosses, days to flowering, days to 50% flowering, in cross Parbhani Kranti × Kashi Pragati and Kashi Satadhari × VROR-159, days to 50% flowering and number of fruit per plant in cross Parbhani Kranti × VROR-159 and fruit length, number of fruits per plant in cross Kashi Satadhari × BO-2. Hence heterosis breeding and recurrent selection schemes need to be followed in these respective cross for further improvement of these traits.

The importance of non-additive gene in control of this trait was reported by Mehta *et al.,* (2007), Pal *et al.,* (2009), Akhtar *et al.,* (2010), Mistry and Vashi (2011), Medagam *et al.,* (2012a), Mistry (2013), Adiger *et al.,* (2013) and Verma *and* Sood. (2015).

Additive gene action is predominant for days to flowering in cross Parbhani Kranti × VROR-159 and number of fruit plant in Parbhani Kranti × Kashi Pragati and fruit yield per plant, fruit yield per plot, fruit yield per hectare in Kashi Satadhari × BO-2 and hence, simple selection or simple recurrent selection method needs to be followed for further improvement of these traits using the specific crosses. All the type of gene actions, *viz*., additive, dominance and epistasis are playing important role in controlling all the characters under studied except days to 50%flowering in Kashi Satadhari × BO-2 and hence reciprocal recurrent selection scheme can be followed for further improvement of these traits. Duplicate epistasis played an important role in controlling the all the characters in one or more crosses except in number of nodes on main stem showing complementary epistasis and hence it is further emphasised that heterosis breeding and reciprocal recurrent selection schemes are feasible options for further improvement of these traits. Complementary epistasis played important role in controlling plant height, number of nodes on main stem,, days to flowering, first fruiting nodes, fruit length, number of fruits per plant, marketable fruit yield per plant, marketable fruit yield per plot and marketable fruit yield per hectare in Parbhani Kranti × VROR-159, number of nodes on main stem, marketable fruit yield per plant, marketable fruit yield per plot and marketable fruit yield per hectare in Parbhani Kranti × Kashi Pragati, Plant height, number of nodes on main stem,, days to flowering, first fruiting nodes in cross Kashi Satadhari × VROR-159, Plant height, number of nodes on main stem,, days to flowering, days to 50% flowering, first fruiting nodes, marketable fruit yield per plant, marketable fruit yield per plot and marketable fruit yield per hectare in cross Kashi Satadhari × BO-2 and hence, simple selection or simple recurrent selection needs to be followed for improvement of these traits. These results are in conformity with earlier report by Akhtar *et al.,* (2010), Arora *et al.,* (2010), Patel *et al.,* (2010), Mistry and Vashi (2011) and Mistry (2013).

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