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COMBINING ABILITY AND GENE ACTION IN INDIGENOUS BITTER GOURD (*Momordica charantia* L.)

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ABSTRACT

The investigation was carried out to get information regarding magnitude of combining ability and nature of gene action for fruit yield and several other yield attributing traits following line × tester mating design involving 12 lines and 3 testers and their 36 hybrids tested in two environments viz., summer and rainy season 2010 at Research Farm of Department of Vegetable Science, N. D. University of Agriculture & Technology, Kumarganj, Faizabad, UP, India. From the estimate of gca effects, among the parental lines NDBT-13, NDBT-15 and NDBT-19 were identified as superior donor for both seasons and NDBT-10 for summer season and among the testers Kalyanpur Sona for summer season and Pusa Do Mausami for rainy season for fruit yield per plant and its yield contributing traits like number of fruits per plant and average fruit weight. Eight crosses displayed desirable significant sca effects in both seasons for fruit yield per plant. Among these eight crosses the best cross combinations based on desirable sca effects for fruit yield per plant were NDBT-19 × Pusa Do Mousami in summer season while NDBT-8 × Pusa Do Mousami, NDBT-15 × NDBT-12 and NDBT-10 × Pusa Do Mousami in rainy season. These crosses have more number of fruits per plant, average fruit weight, fruit diameter and other component traits in both seasons.

Key words: Gene action, General combining ability (gca), Hybrids, Line × Tester mating design, *Momordica charantia* L., RBD, Specific combining ability (sca)

INTRODUCTION

Bitter gourd (*Momordica charantia* L.) is one of the most nutritive and commercially important vegetable grown throughout the country. The importance of bitter gourd has been recognized due to its high nutritive value and medicinal

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properties. Bitter gourd still remains an unexploited crop from genetic and breeding point of view. In bitter gourd, Indian variability is quite distinct than that of African/S.E. Asian region (Seshadri and Chatterjee, 1996). Wide range of variability in respect of vegetative and fruit character is available. Many varieties and F_1 hybrids have been developed utilizing those variability. It is a monoecious and highly cross pollinated crop and has been known to offer good potentialities for increased yield. Considering these facts, it is essential and desirable to carry out a successful breeding programme utilizing the land races available in Indian subcontinent. Therefore, this study was conducted to generate information about general and specific combining ability effects for different economic characters.

MATERIALS AND METHODS

The present investigation involving 36 F_1's (derived through line × tester mating design) and their patents i.e., 12 lines (NDBT-1, NDBT-2, NDBT-3, NDBT-4, NDBT-5, NDBT-6, NDBT-7, NDBT-8, NDBT-10, NDBT-13, NDBT-15 and NDBT-19) and 3 testers (Kalyanpur Sona, NDBT-12 and Pusa Do Mausami) was under taken for estimating the gca (general combining ability) and sca (specific combining ability) for the 14 characters. Accordingly the experiment was set up in a complete randomized block design (RBD) with three replications in two seasons, namely summer (S) season and rainy (R) season 2010 at the Research Farm of Department of Vegetable Science, ND University of Agriculture & Technology, Kumarganj, Faizabad, UP, India. Sowing was done with a 3.0 m for row to row and, 0.5 m plant to plant spacing was maintained. All the recommended agronomic package and practices, plant protection measures were followed to raise a good and healthy crop. Among the 14 characters the observations were recorded on plot basis for node number to anthesis of first staminate flower, node number to anthesis of first pistillate flower, days to anthesis of first staminate flower, days to anthesis of first pistillate flower and days to first fruit harvest, where as for fruit length (cm), fruit diameter (cm), average fruit weight (g), number of fruits per plant, fruit yield per plant (kg), number of primary branches per plant, number of nodes per plant, inter-nodal length (cm) and vine length (m) data were recorded on 10 randomly selected plants. The estimation of combining ability and gene action were carried out as per the procedure of Kempthorne (1957).

RESULT AND DISCUSSION

The estimates of sca variances were found to be greater than corresponding gca variances for all the characters in both summer and rainy seasons indicating preponderance of non-additive gene action (Table 1). The ratio of gca to sca variances (average degree of dominance) was observed to be more than unity for all the characters (revealing over dominance) except for node number to anthesis of first pistillate flower in summer and for fruit yield per plant in rainy season (nearly equal to unity, suggests existence of complete dominance) indicating that predominance of

non-additive gene effects representing non-fixable dominance and epistatic components of genetic variance. This indicated that maintenance of heterozygocity would be highly fruitful for improving the characters. These results are in accordance with Singh et al. (2006) who reported non additive type of gene action for yield and yield related traits in their material. However Mishra et al. (1994) found that both additive and non additive gene actions were involved in the expression of yield and yield related characters. Similar gene actions were also observed by Devadas and Ramadas, 1997, Ram et al., 1999 and Jadhav et al., 2010. The differences in the results might have been due to the differences in the genetic material studied.

General combining ability

As per table 2, the general combining ability of parents indicated that four lines i.e. NDBT-10, NDBT-13, NDBT-15 and NDBT-19 had significant and positive gca effects for fruit yield per plant during both seasons and among the testers, Kalyanpur Sona and PDM had significant and positive gca effects during summer and rainy seasons, respectively for this trait. Furthermore, these four lines were found to be good general combiners for number of fruits per plant during both seasons except NDBT-15, which showed negative effect in summer. Among the 12 lines, two lines NDBT-13 and NDBT-19 were found to have significantly positive gca effect for majority of the characters in both seasons like days to anthesis of first pistillate flower, days to first fruit harvest, number of fruits per plant, fruit yield per plant number of nodes per plant, inter-nodal length and vine length. The line NDBT-13 was also good combiner for node number of first staminate flower (significantly negative), fruit length, fruit diameter and average fruit weight (significantly positive) during both seasons. The line NDBT-15 was also found to be a good combiner for days to anthesis of first staminate flower, average fruit weight and inter-nodal length during both the seasons and also found to be a good combiner for days to anthesis of first pistillate flower, number of fruits per plant during rainy season along with node number to anthesis of first pistillate flower in summar season. The line NDBT-2 was found good combiner for earliness and other desirable traits like; node number to anthesis of first staminate flower, node number to anthesis of pistillate flower, days to anthesis of first staminate flower, days to anthesis of first pistillate flower, days to first fruit harvest. Among the testers, Kalyanpur Sona was found to be a good combiner for node number to anthesis of first staminate flower, node number to anthesis of first pistillate flower in both seasons and for days to anthesis of first pistillate flower, days to fruit harvest indicating earliness, and also more number of fruit and fruit yield per plant in summer season. Pusa Do Mousami (PDM) was also found to be a good combiner for fruit length, fruit diameter and vine length in both the seasons and for fruit yield per plant and number of fruits per plant in rainy season. The parents mentioned above may be used in a future breeding programme for bringing improvement in bitter gourd. Similar results were observed in bitter gourd by Ram et al., 1999; Kumar et al., 2005; Sundharaiya and Venkatesan, 2006 and Sundaram, 2008.

Specific combining ability effects

Estimation of specific combining ability effects are given in table 3. Among thirty-six crosses, eight in summer and eight in rainy season exhibited significant positive sca effect for increased fruit yield and among these four are common in both seasons. It was also observed that the majority of the crosses which showed significant sca effects for increased yield also involved at least one parent having high and significant gca estimates. The high significant positive sca effects in respect of fruit yield per plant were observed in a cross NDBT-3 × Pusa Do Mousami followed by NDBT-1 × Kalyanpur Sona, NDBT-4 × NDBT-12, NDBT-19 × Pusa Do Mousami and NDBT-7 × Kalyanpur Sona in summer season, and NDBT-15 × NDBT-12 followed by NDBT-10 × Pusa Do Mousami, NDBT-1 × Kalyanpur Sona, NDBT-8 × Pusa Do Mousami, NDBT-7 × Kalyanpur Sona in rainy season where as NDBT-1 × Kalyanpur Sona and NDBT-7 × Kalyanpur Sona NDBT-4 × NDBT-12 and NDBT-8 × PDM were found desirable in both seasons. These crosses also showed consistently favourable sca effects for other yield component characters. However, the best crosses varied with the characters. Based on sca effects NDBT-19 × Pusa Do Mousami in summer season, NDBT-8 × Pusa Do Mousami, NDBT-15 × NDBT-12 and NDBT-10 × Pusa Do Mousami in rainy season were found to be the best specific combiners for fruit yield per plant. The cross NDBT-19 × Pusa Do Mousami exhibited significantly the highest sca effects for other characters like average fruit weight and number of fruits per plant in summer season. The cross NDBT-3 × Pusa Do Mousami was also found to be having the highest significant sca effects for fruit diameter and number of fruits per plant in both seasons. The cross NDBT-1 × Kalyanpur Sona was also found along with the significant sca effect for number of primary branches per plant and number of nodes per plant in summer season. The cross NDBT-4 × NDBT-12 was also found to be having significant negative sca effects for node number to anthesis of first pistillate flower and vine length in both seasons where as it was positively significant for days to first fruit harvest and fruit length in summer season. The cross NDBT-7 × Kalyanpur Sona was also found to have significant and negative sca effects for days to anthesis of first pistillate flower, days to anthesis of first staminate flower, days to first fruit harvest indicating earliness for these characters, whereas number of fruits per plant, number of nodes per plant and vine length had significant positive sca effect in both seasons. The cross NDBT-6 × Pusa Do Mousami had negative sca effects significant for days to anthesis of first pistillate flower and days to first fruit harvest in rainy season. The highest sca effect for days to first harvest was observed in cross combination NDBT-13 × Kalyanpur Sona in rainy season. For fruit diameter, the highest positive and significant sca effects were observed in the cross combination NDBT-5 × Kalyan Sona followed by NDBT-3 × Pusa Do Mousami, NDBT-7 × NDBT-12, NDBT-13 × Kalyan Sona, NDBT-8 × PDM and NDBT-2 × NDBT-12 in both seasons. For fruit length the highest significant sca effect was observed in a cross combination of NDBT-5 × Kalyanpur Sona followed by NDBT-7 × NDBT-12 in summer, while as

NDBT-3 × Pusa Do Mousami followed by NDBT-4 × Kalyanpur Sona in rainy season were the desirable crosses. Similar results were observed in bitter gourd by Ram et al., 1999, Sundharaiya and Venkatesan, 2006, Sundaram, 2008.

From these studies, it was indicated that sca effects of certain crosses were related with gca of their parents as the best cross combination for most of the characters involved at least one parent with high or average gca effects for particular traits in both or any one season (summer or rainy). Hence, these parents may be utilized for development of new hybrids. The crosses NDBT-1 × Kalyanpur Sona and NDBT-7 × Kalyanpur Sona exhibited high sca effects for fruit yield per plant, days to anthesis of first staminate flower, days to anthesis of first pistillate flower, days to first fruit harvest, average fruit weight, number of fruits per plant, number of primary branches per plant, number of nodes per plant and vine length and these crosses can be exploited for development of desirable hybrids for either both (summer and rainy) or summer/rainy season.

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Table 1: Estimates of genetic components (variances) and heritability narrow sense for 14 traits of bitter gourd during summer and rainy seasons

S. No.	Characters	gca variance (σ^2 g)		sca variance (σ^2 s)		Av. Degree of dominance (σ^2 s/2 σ^2 g)		σ^2 A		σ^2 D	
		Summer	Rainy	Summer	Rainy	Summer	Rainy	Summer	Rainy	Summer	Rainy
1.	Node no. to anthesis of first staminate flower	0.02	0.51	1.90	2.75	5.89	1.64	0.05	1.02	1.90	2.76
2.	Node no. to anthesis of first pistillate flower	0.52	0.03	0.67	1.71	0.80	4.88	1.04	0.07	0.67	1.71
3.	Days to anthesis of first staminate flower	0.44	0.91	3.40	4.51	1.95	1.57	0.89	1.81	3.40	4.51
4.	Days to anthesis of first pistillate flower	2.00	1.36	3.45	6.21	0.92	1.51	4.00	2.73	3.45	6.21
5.	Days to first fruit harvest	1.56	1.37	4.36	7.31	1.18	1.63	3.14	2.74	4.36	7.31
6.	Fruit length (cm)	-0.04	0.05	1.46	0.87	4.22	2.79	-0.09	0.11	1.46	0.87
7.	Fruit diameter (cm)	-0.02	-0.01	0.25	0.25	2.99	3.75	-0.02	-0.01	0.25	0.25
8.	Average fruit weight (g)	4.19	5.48	19.71	21.51	1.54	1.41	8.38	10.97	19.71	21.51
9.	Number of fruits per plant	1.48	2.51	5.89	5.23	1.42	1.02	2.95	5.04	5.89	5.23
10.	Fruit yield per plant (kg)	0.01	0.03	0.03	0.03	1.25	0.87	0.02	0.02	0.03	0.03
11.	No. of primary branches per plant	0.36	1.04	5.85	2.82	2.86	1.16	0.72	2.08	5.85	2.82
12.	No. of nodes per plant	3.98	4.18	33.56	21.52	2.05	1.61	7.96	8.37	33.56	21.42
13.	Internodal length(cm)	0.07	0.06	0.43	0.38	1.70	1.74	0.15	0.12	0.43	0.38
14.	Vine length (m)	0.04	0.03	0.11	0.12	1.18	1.37	0.07	0.06	0.11	0.12

Table 2: Estimate of gca effects of parents for 14 characters during summer and rainy seasons in bitter gourd

Characters	Node no. to anthesis of first staminate flower		Node no. to anthesis of first pistillate flower		Days to anthesis of first staminate flower		Days to anthesis of first pistillate flower		Days to first fruit harvest		Fruit length		Fruit diameter	
Lines	**Summer**	**Rainy**	**Summer**	**Rainy**	**Summer**	**Rainy**	**Summer**	**Rainy**	**Summer**	**Rainy**	**Summer**	**Rainy**	**Summer**	**Rainy**
NDBT-1	-0.56	-1.92**	-2.16**	-1.21**	-0.20	-2.81**	0.83	-3.53**	0.14	-3.68**	-0.04	-0.69**	0.23**	-0.06
NDBT-2	-1.00 **	-1.81**	-3.49**	-1.88**	-1.20**	-2.48**	-4.06**	-4.53**	-4.64**	-5.01**	-0.78**	0.25	-0.39**	-0.34**
NDBT-3	-1.11 **	-0.69	-0.49	-0.10	-1.54**	-1.26**	-0.61	-2.08**	0.03	-2.68**	0.41*	0.39	0.38**	0.30**
NDBT-4	0.11	0.86*	0.84*	1.12**	-0.43	-0.48	-1.28*	-3.08**	-1.86**	-2.68**	0.42*	-0.59*	0.16**	0.10
NDBT-5	-0.11	0.08	0.06	-0.99*	-1.76**	-1.93**	-1.28*	-0.86	-1.34*	0.21	0.16	-0.59*	-0.09	-0.03
NDBT-6	1.00**	1.75**	0.40	-0.10	0.02	-0.93**	-1.63**	-0.08	-0.86	0.32	-0.27	-0.54*	-0.25**	0.08
NDBT-7	0.08	0.86*	-0.16	-0.10	-1.31**	-1.26**	-0.17	0.81	-0.64	1.10	-0.61**	0.12	0.04	-0.13
NDBT-8	0.67	2.31**	-0.16	1.12*	-0.87*	2.74**	-0.50	-0.97*	-0.42	-0.45	-0.41*	-0.05	-0.56**	-0.41**
NDBT-10	1.00**	0.75	0.95**	1.90**	3.69**	2.41**	2.17**	4.58**	2.81**	4.55**	-0.12	0.70**	0.01	-0.05
NDBT-13	-0.78*	-1.81**	0.51	0.12	-0.76	-1.48**	1.83**	2.69**	2.36**	2.77**	0.86**	1.25**	0.57**	0.63**
NDBT-15	-0.11	-1.25**	1.40**	-0.99*	1.69**	2.30**	1.06	3.03**	1.03	2.21	0.31	-0.69**	-0.05	0.06
NDBT-19	0.89*	0.86*	2.40**	1.12*	2.69**	5.19**	3.61**	4.03**	3.36**	3.32**	0.07	0.44	-0.03	-0.18*
E(gi) Lines	0.35	0.40	0.42	0.45	0.42	0.43	0.61	0.48	0.65	0.56	0.20	0.24	0.05	0.08
SE(gi-gj) Lines	0.50	0.57	0.59	0.63	0.60	0.61	0.86	0.68	0.93	0.79	0.28	0.34	0.08	0.12
Testers														
K. Sona	-0.47 **	-0.58**	-0.57**	-0.21	-0.34	-0.59**	-1.42**	0.75**	-1.22**	0.96**	-0.42**	-0.44**	-0.02	-0.08*
NDBT-12	0.56**	0.92**	0.29	0.37	-0.43*	-0.06	-0.14	-0.69**	-0.14	-0.87**	0.05	0.18	-0.02	-0.07
PDM	-0.08	-0.33	0.29	-0.16	0.77**	0.66**	1.56**	-0.06	1.36**	-0.09	0.37*	0.26*	0.04	0.15**
SE(gi) Testers	0.17	0.20	0.21	0.22	0.21	0.21	0.30	0.24	0.32	0.28	0.10	0.12	0.02	0.04
SE(gi-gj) Testers	0.25	0.28	0.29	0.31	0.30	0.30	0.43	0.34	0.46	0.39	0.14	0.17	0.04	0.06
NDBT-1	-10.07**	-12.21**	-1.98**	-2.98**	-0.30**	-0.39**	1.67**	0.77*	-1.39	-1.94*	-1.03**	-0.89**	-0.53**	-0.62**
NDBT-2	2.59**	2.79**	-1.53**	-0.93*	-0.09**	-0.04	-0.68*	2.33**	5.28**	3.72**	-1.18**	-0.83**	-0.40**	-0.23**

Characters	Node no. to anthesis of first staminate flower		Node no. to anthesis of first pistillate flower		Days to anthesis of first staminate flower		Days to anthesis of first pistillate flower		Days to first fruit harvest		Fruit length		Fruit diameter	
Lines	**Summer**	**Rainy**	**Summer**	**Rainy**	**Summer**	**Rainy**	**Summer**	**Rainy**	**Summer**	**Rainy**	**Summer**	**Rainy**	**Summer**	**Rainy**
NDBT-3	2.70**	3.79**	-4.05**	-2.17**	-0.32**	-0.14**	-3.67**	-3.20**	2.50**	2.83**	-0.57**	-0.49**	-0.19**	-0.03**
NDBT-4	-2.52**	-3.99**	0.22	0.32	-0.01	-0.04	1.34**	0.88*	2.94**	0.39	-0.53**	-0.50**	-0.20**	-0.18**
NDBT-5	0.70	-0.88	-0.87*	-2.30**	-0.03	-0.16**	1.50**	1.88**	2.06*	1.28	-0.46**	-0.66**	-0.21**	-0.26**
NDBT-6	-3.74**	-3.66**	1.50**	-2.25**	0.02	-0.24**	0.13	0.22	-2.28*	-2.39**	-0.56**	-0.64**	-0.42**	-0.52**
NDBT-7	-2.07**	-1.88	-0.16	-0.88*	-0.05*	-0.11**	0.28	-2.10**	-6.83**	-5.72**	0.38**	0.36**	-0.03	-0.13**
NDBT-8	-3.96**	-3.44**	0.23	1.16**	-0.04	0.02	0.04	-1.54**	-9.17**	-9.06**	0.59**	0.68**	-0.04	-0.05
NDBT-10	0.70	1.68	2.03**	0.86*	0.19**	0.08**	-1.25**	-1.29**	3.72**	3.06**	1.20**	1.11**	0.65**	0.63**
NDBT-13	10.93**	12.79**	1.69**	1.97**	0.36**	0.38**	0.21	-0.49	8.17**	9.94**	0.59**	0.28**	0.74**	0.67**
NDBT-15	9.26**	8.90**	-1.06**	1.77**	0.07**	0.30**	-0.38	-0.22	-11.72**	-8.61**	0.49**	0.47**	-0.28**	-0.23**
NDBT-19	-4.52**	-3.88**	3.97**	5.49**	0.22**	0.34**	0.82*	2.82**	6.72**	6.50**	1.08**	1.12**	0.90**	0.94**
SE(gi)Lines	0.85	0.93	0.39	0.43	0.02	0.03	0.34	0.38	0.89	0.87	0.07	0.05	0.04	0.03
SE(gi-gj) Lines	1.21	1.32	0.55	0.61	0.03	0.04	0.48	0.54	1.27	1.23	0.10	0.07	0.06	0.05
Testers														
K.Sona	-0.07	-0.05	1.52**	-1.25**	0.11**	-0.11**	-1.10**	0.08	-0.69	-0.56	-0.02	-0.05*	-0.03	-0.05**
NDBT-12	0.48	-0.16	-0.59**	-0.59**	-0.03**	-0.04**	0.75**	0.96**	-0.31	-0.42	-0.01	0.01	-0.07**	-0.01
PD M	-0.41	0.20	-0.94**	1.84**	-0.08**	0.16**	0.35*	-1.04**	1.00*	0.97*	0.03	0.04	0.08**	0.06**
SE(gi) Testers	0.42	0.46	0.19	0.21	0.01	0.01	0.17	0.19	0.44	0.43	0.03	0.02	0.02	0.01
SE(gi-gj) Testers	0.60	0.66	0.27	0.30	0.01	0.02	0.24	0.27	0.63	0.61	0.05	0.03	0.03	0.02

*- Significant at 5 per cent probability level; ** - Significant at 1 per cent probability level

Table 3: Estimate of sca effects of 36 F_1 hybrids for 14 characters during summer and rainy seasons in bitter gourd

Character	Node no. to anthesis of first staminate flower		Node no. to anthesis of first pistillate flower		Days to anthesis of first staminate flower		Days to anthesis of first pistillate flower		Days to first fruit harvest		Fruit length		Fruit diameter	
Hybrids	**Summer**	**Rainy**	**Summer**	**Rainy**	**Summer**	**Rainy**	**Summer**	**Rainy**	**Summer**	**Rainy**	**Summer**	**Rainy**	**Summer**	**Rainy**
NDBT-1 x K.Sona	-0.63	-0.86	-0.53	-0.56	-0.99	-3.51**	0.63	-1.19	0.55	-0.51	0.61	-0.12	0.24*	-0.00
NDBT-1 x NDBT-12	-0.66	-0.02	1.60**	-0.14	-0.57	0.62	-0.63	-0.08	-0.52	-1.35	0.02	0.29	0.20*	0.23
NDBT-1 x PDM	1.30*	0.88	-1.46*	0.71	1.56*	2.89**	0.00	1.27	-0.02	1.87	-0.69*	-0.16	-0.44**	-0.22
NDBT-2 x K.Sona	0.13	0.02	0.12	1.10	1.00	1.51*	-0.13	1.13	-1.00	-0.55	1.35**	0.11	0.13	0.05
NDBT-2 x NDBT-12	-0.55	-0.80	0.93	-0.48	0.42	-0.04	1.91	0.58	3.25**	1.31	-0.94**	0.70	0.27**	0.39**
NDBT-2 x PDM	0.41	0.77	-1.06	-0.62	-1.49*	-1.43	-1.77	-1.72*	-2.28*	-0.79	-0.45	-0.84*	-0.40**	-0.44**
NDBT-3 x K.Sona	-0.08	-0.41	0.46	0.99	-1.65*	-1.07	-0.58	1.02	-0.66	1.48	-0.02	-0.42	-0.24*	-0.24
NDBT-3 x NDBT-12	-0.77	-0.25	-1.49*	-0.25	0.75	1.39	-1.52	-0.19	-2.08	-0.68	-0.70*	-1.54**	-0.31**	-0.20
NDBT-3 x PDM	0.86	0.67	0.93	-0.73	0.89	-0.32	2.11**	-0.83	2.75*	-0.79	0.72*	1.96**	0.55**	0.44**
NDBT-4 x K.Sona	1.69**	3.02**	2.24**	2.10**	-0.76	0.14	2.08	-0.63	1.55	-0.51	-1.64**	1.48**	0.13	0.10
NDBT-4 x NDBT-12	0.02	0.19	-1.62*	-2.48**	0.98	0.28	-1.86	0.80	-2.29*	0.64	1.31**	-0.89*	-0.21*	0.11
NDBT-4 x PDM	-1.69**	-3.22**	-0.62	0.37	-0.21	-0.43	-0.22	-0.16	0.63	-0.12	0.33	-0.58	0.08	-0.21
NDBT-5 x K.Sona	0.91	0.80	0.24	0.21	-0.10	-0.74	1.08	-0.19	1.33	-0.40	2.24**	-0.04	0.80**	0.98**
NDBT-5 x NDBT-12	-0.11	-1.02	-0.28	-1.37	-1.50*	-0.93	-0.52	0.25	-0.08	0.42	-1.82**	-0.60	-0.74**	-0.76**
NDBT-5 x PDM	-0.80	0.22	0.04	1.15	1.45	1.67*	-0.55	-0.05	-1.25	-0.01	-0.41	0.64	-0.06	-0.21
NDBT-6 x K.Sona	-1.29*	0.80	0.57	2.32**	0.45	1.25	-1.91	2.02*	-1.77	2.58**	-0.51	-0.52	-0.38**	-0.39
NDBT-6 x NDBT-12	0.77	-1.69*	-0.28	-1.59	0.20	-0.26	1.80	0.80	1.80	0.31	1.06**	-0.14	0.43**	0.27
NDBT-6 x PDM	0.41	0.88*	-0.27	-0.73	-0.65	-0.99	0.11	-2.83**	-0.02	-2.79**	-0.55	0.66	-0.04	0.12
NDBT-7 x K.Sona	-0.19	-0.63	-0.53	-0.67	-1.54*	-2.07**	-5.36**	-3.19**	-6.00**	-4.29**	-0.07	-0.10	0.34**	0.22
NDBT-7 x NDBT-12	-0.22	-0.13	0.26	1.07	1.87*	1.06	3.69**	-1.41	3.25**	-1.12	1.73**	0.59	0.51**	0.57**
NDBT-7 x PDM	0.41	0.77	0.26	-0.39	-0.32	1.00	1.66	4.61**	2.75*	5.42**	-1.65**	-0.49	-0.86**	-0.79**
NDBT-8 x K.Sona	-1.86**	-0.08	-0.87	-1.89*	-1.99**	0.92	1.63	-0.75	1.77	0.59	-0.20	1.14**	-0.11	-0.30
NDBT-8 x NDBT-12	2.77**	1.75*	-0.39	0.85	0.75	-1.93*	-2.82**	-0.97	-0.97	0.42	-0.94**	0.26	-0.24*	-0.62**
NDBT-8 x PDM	-0.91	-1.66*	1.26	1.04	1.23	1.00	0.66	1.72*	-0.80	-1.01	1.08**	-1.40**	0.36**	0.92**
NDBT-10 x K.Sona	-0.52	-0.19	0.68	0.99	6.12**	5.92**	1.63	0.69	1.55	0.59	-0.11	-0.37	-0.33**	-0.33
NDBT-10 x NDBT-12	1.77**	1.63*	-0.84	-0.25	-3.12**	-2.60**	0.69	-1.19	-0.19	-1.57	0.54	0.20	-0.03	0.03
NDBT-10 x PDM	-1.25*	-1.44*	0.15	-0.73	-2.99**	-3.32**	-2.83**	0.50	-1.36	0.98	-0.43	0.17	0.37**	0.29
NDBT-13 x K.Sona	1.68**	1.36*	-1.53*	-0.89	0.23	0.48	1.30	6.25**	1.00	6.37**	0.49	0.78	0.48**	0.51**
NDBT-13 x NDBT-12	-1.64**	-0.47	0.93	1.51	0.31	0.95	0.02	-0.97	0.91	-1.12	-1.05**	-0.73	-0.09	-0.10

Character	Node no. to anthesis of first staminate flower		Node no. to anthesis of first pistillate flower		Days to anthesis of first staminate flower		Days to anthesis of first pistillate flower		Days to first fruit harvest		Fruit length		Fruit diameter	
Hybrids	**Summer**	**Rainy**	**Summer**	**Rainy**	**Summer**	**Rainy**	**Summer**	**Rainy**	**Summer**	**Rainy**	**Summer**	**Rainy**	**Summer**	**Rainy**
NDBT-13 x PDM	-0.13	-0.88	0.60	-0.62	-0.54	-1.43	-1.33	-5.27**	-1.91	-5.24**	0.55	-0.05	-0.38**	-0.40**
NDBT-15 x K.Sona	0.25	-0.86	-0.42	-1.78*	-0.21	-1.96*	-0.25	-3.08**	0.33	-4.40**	-0.62	-0.38	-0.54**	-0.12
NDBT-15 x NDBT-12	0.88	1.63*	0.37	1.62*	-0.12	1.50*	-1.19	1.36	-1.75	2.75**	0.69*	1.18**	-0.07	-0.15
NDBT-15 x PDM	-1.13	-0.77	0.04	0.15	0.34	0.45	1.44	1.72*	1.41	1.64	-0.03	-0.70	0.61**	0.28
NDBT-19 x K.Sona	-0.08	-2.97**	-0.42	-1.89*	-0.54	-0.85	-0.13	-2.08*	1.33	-0.85	-1.49**	-1.52**	-0.52**	-0.48**
NDBT-19 x NDBT-12	-2.44**	-0.80	0.71	1.51	-0.12	-0.04	-0.08	1.02	-1.41	-0.01	0.01	0.77	0.31**	0.23
NDBT-19 x PDM	2.52**	3.77**	-0.28	0.37	0.67	0.89	0.22	1.05	0.08	0.87	1.48**	0.76	0.20*	0.25
SE(Sij-Skl)	0.86	0.99	1.03	1.10	1.05	1.06	1.49	1.19	1.61	1.37	0.49	0.59	0.14	0.21
SE(Sij-Sik)	1.80	2.06	2.16	2.29	2.18	2.22	3.12	2.48	3.36	2.86	1.02	1.24	0.30	0.43
NDBT-1 x K.Sona	3.95**	3.60*	3.48**	3.63**	0.27**	0.22**	2.89**	-2.40**	6.13**	0.11	-0.15	0.05	0.17*	0.18**
NDBT-1 x NDBT-12	-2.37	-1.62	-2.10**	-1.95*	-0.15**	-0.16**	-4.42**	-0.69	0.75	1.97	0.04	0.00	0.11	0.06
NDBT-1 x PDM	-1.48	-1.98	-1.38*	-1.68*	-0.11**	-0.06	1.56**	3.10**	-6.88**	-2.08	0.10	-0.06	-0.27**	-0.24**
NDBT-2 x K.Sona	-0.81	-0.73	-1.39*	-0.94	-0.13**	-0.07	-1.46	0.39	-0.52	-4.88**	-0.07	-0.00	-0.00	-0.31**
NDBT-2 x NDBT-12	-2.03	-2.28	1.42*	-0.19	0.08*	-0.06	2.51**	-1.89**	-1.25	-1.36	-0.01	0.05	-0.17*	0.06
NDBT-2 x PDM	2.98*	3.01	-0.02	1.13	0.05	0.16**	-1.04	1.50*	1.77	6.25**	0.08	-0.05	0.18*	0.25**
NDBT-3 x K.Sona	2.07	1.60	-2.03**	-3.20**	-0.15**	-0.21**	-3.20**	-0.47	-6.41**	-3.00	-0.11	-0.18	-0.27**	-0.18**
NDBT-3 x NDBT-12	-0.14	0.37	-3.26**	1.36	-0.25**	0.07	0.67	-0.16	3.52*	2.86	-0.05	-0.09	0.08	0.10
NDBT-3 x PDM	-1.92	-1.98	5.28**	1.83*	0.41**	0.13	2.53**	0.63	2.88	0.13	0.17	0.27**	0.18*	0.08
NDBT-4 x K.Sona	2.96*	3.37*	-0.97	-1.72	-0.00	-0.07	-0.68	1.55*	-3.52*	-3.22	-0.08	-0.19*	-0.18*	-0.15
NDBT-4 x NDBT-12	1.07	1.49	2.56**	1.17	0.17**	0.16**	0.05	-1.34*	3.75*	4.63**	0.17	0.18*	0.33**	0.29**
NDBT-4 x PDM	-4.03**	-4.87**	-1.58*	0.55	-0.16**	-0.09	0.62	-0.23	-0.22	-1.41	-0.09	-0.01	-0.14	-0.14*
NDBT-5 x K.Sona	3.40**	4.30**	-0.65	-0.50	-0.01	0.10	-2.44**	0.65	0.02	-0.11	-0.02	0.15	-0.02	0.03
NDBT-5 x NDBT-12	-0.14	0.04	-0.17	1.66*	0.05	0.16**	0.49	0.17	-0.02	-1.58	-0.16	-0.19*	-0.07	-0.11
NDBT-5 x PDM	-3.25*	-4.31**	0.83	-1.16	-0.03	-0.20**	1.95**	-0.83	0.00	1.69	0.19	0.03	0.09	0.08
NDBT-6 x K.Sona	-5.45**	-3.28*	0.94	0.80	-0.03	0.03	-2.54**	1.58*	2.36	2.88	0.00	0.04	0.11	0.15*
NDBT-6 x NDBT-12	8.29**	5.49**	-2.24**	-1.78*	0.00	-0.06	1.73**	0.37	3.97*	4.41**	0.06	-0.06	0.15	0.12*

Character	Node no. to anthesis of first staminate flower		Node no. to anthesis of first pistillate flower		Days to anthesis of first staminate flower		Days to anthesis of first pistillate flower		Days to first fruit harvest		Fruit length		Fruit diameter	
Hybrids	**Summer**	**Rainy**	**Summer**	**Rainy**	**Summer**	**Rainy**	**Summer**	**Rainy**	**Summer**	**Rainy**	**Summer**	**Rainy**	**Summer**	**Rainy**
NDBT-6 x PDM	-2.81	-2.20	1.30	0.98	0.03	0.02	0.80	-1.96**	-6.33**	-7.30**	-0.07	0.02	-0.27**	-0.27**
NDBT-7 x K.Sona	-2.14	-3.39*	2.26**	2.97**	0.15**	0.19**	2.01**	-0.55	8.23**	7.55**	0.20	0.20*	0.39**	0.41**
NDBT-7 x NDBT-12	4.62**	4.71**	0.109	-1.51*	0.06	-0.03	-0.30	0.61	-2.13	-1.91	0.33**	0.36**	0.17*	0.09
NDBT-7 x PDM	-2.48	-1.31	-2.37**	-1.48	-0.22**	-0.16**	-1.70**	-0.06	-6.11**	-5.63**	-0.53**	-0.57**	-0.57**	-0.51**
NDBT-8 x K.Sona	-0.92	0.15	0.60	0.85	0.03	0.06	0.92	-2.06**	-0.41	1.22	-0.97**	-0.98**	-0.49**	-0.48**
NDBT-8 x NDBT-12	-7.81**	-9.39**	0.05	-1.23	-0.14**	-0.26**	-1.66**	2.13**	1.19	-0.25	-0.74**	-0.65**	-0.29**	-0.31**
NDBT-8 x PDM	8.74**	9.24**	-0.66	0.37	0.11**	0.20**	0.73	-0.07	-0.77	-0.97	1.71**	1.63**	0.78**	0.80**
NDBT-10 x K.Sona	-6.25**	-8.62**	2.10**	1.15	0.06	-0.07	1.48	-1.02	-11.97**	-6.88**	1.51**	1.28**	0.23**	0.27**
NDBT-10 x NDBT-12	5.51**	5.49**	-0.94	-3.76**	0.03	-0.19**	-2.34**	2.21**	5.30**	1.63	-0.58**	-0.29**	-0.14	-0.07
NDBT-10 x PDM	0.74	3.12	-1.16	2.60**	-0.10*	0.27**	0.85	-1.18	6.66**	5.25**	-0.92**	-0.99**	-0.06	-0.20**
NDBT-13 x K.Sona	2.18	2.60	-2.57**	-1.99**	-0.17**	-0.13	-1.34	2.69**	0.58	0.55	0.12	0.01	0.00	-0.03
NDBT-13 x NDBT-12	-4.70**	-5.28**	4.29**	1.66*	0.27**	0.03	2.76**	-1.77**	-2.80	-2.25	0.24*	-0.05	-0.15	-0.14*
NDBT-13 x PDM	2.51	2.68	-1.71*	0.23	-0.09*	0.09	-1.41	-0.93	2.22	1.69	-0.35**	0.03	0.15	0.17**
NDBT-15 x K.Sona	1.85	1.15	-0.43	-1.04	0.07	-0.06	1.15	0.48	4.13**	2.11	-0.60**	-0.60**	-0.03	-0.17**
NDBT-15 x NDBT-12	-1.37	-0.39	1.14	4.40**	-0.01	0.33**	1.45	-1.59*	-11.58**	-8.02**	0.45**	0.41**	-0.19*	-0.25**
NDBT-15 x PDM	-0.48	-0.75	-0.707	-3.36**	-0.06	-0.26**	-2.61**	1.10	7.44**	5.91**	0.15	0.18*	0.23**	0.43**
NDBT-19 x K.Sona	-0.70	-0.73	-1.35*	-0.09	-0.09*	-0.00	3.23**	-0.84	1.36	3.66	0.17	0.17	0.13	0.29**
NDBT-19 x NDBT-12	-0.92	1.37	-0.84	0.14	-0.07	0.07	-0.95	1.92**	-0.69	-0.13	0.26*	0.33**	0.17*	0.18**
NDBT-19 x PDM	1.62	-0.64	2.20**	-0.04	0.16**	-0.07	-2.28**	-1.07	-0.66	-3.52	-0.43**	-0.50**	-0.31**	-0.45**
SE(Sij-Skl)	2.10	2.29	0.95	1.06	0.06	0.08	0.833	0.95	2.20	2.13	0.17	0.12	0.11	0.09
SE(Sij-Sik)	4.37	4.77	1.99	2.21	0.13	0.16	1.73	1.98	4.58	4.45	0.36	0.26	0.24	0.19

* - Significant at 5 per cent probability level; ** - Significant at 1 per cent probability level