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C Karak
Department of Vegetable Science, Faculty of Horticulture, Bidhan Chandra Krishi Viswavidyalaya, West Bengal, India

P Hazra
Department of Vegetable Science, Faculty of Horticulture, Bidhan Chandra Krishi Viswavidyalaya, West Bengal, India

Corresponding Author:
C Karak
Department of Vegetable Science, Faculty of Horticulture, Bidhan Chandra Krishi Viswavidyalaya, West Bengal, India

Manifestation of heterosis for different fruit characters in F_1 hybrids of tomato

C Karak and P Hazra

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Abstract
The study was conducted employing 14 parental lines showing divergences in different characters were crossed to produce 23 F_1 hybrids. Manifestation of heterosis for fruit characters namely, fruit weight, equatorial diameter, polar diameter, pericarp thickness, and locule no. /fruit are also correlated with the qualitative characters. Fruit weight of the 23 hybrids only 9 hybrids manifested significantly positive heterosis ranging between 8.82 – 48.30 % over the mid parent (H1) and of them; only 6 hybrids surpassed their respective better parent for fruit weight. In 13 hybrids out of 23 manifested significant heterosis over the mid parent ranging between 3.08-24.46% and out of them 9 hybrids had fruits with higher equatorial diameter than the respective better parent. Only 4 hybrids registered significantly higher polar diameter ranging between 0.63 to 4.66% over the mid parental value. From the study of fruit shape in the hybrids high propensity of round or flattish-round fruit in hybrid was also recorded. Pericarp thickness in 15 hybrids manifested significant positive heterosis over mid parental value and 12 of them even surpassed their respective better parent for pericarp thickness. This result suggested that high fruit weight in the hybrid was basically realized through high pericarp thickness in the hybrids. Locule no. fruit^{-1} as expected, 13 out of 23 F_1 hybrids registered significant heterosis over the mid parental values which ranged between 4.68-35.45%. Extent of manifestation of heterosis in the hybrids for different fruit characters was analysed with reference to of genetic divergence and *per se* performances of the parents. The situation has been examined with reference to 4 top ranking hybrids in this investigation viz., BCT-109xBCT-115, BCT-82xBCT-110, BCT-90 x BCT-110, BCT-90 x BCT-109 which manifested high heterosis for most of the fruit characters. *Per se* performance of the parents the high performing hybrids in terms of manifestation of heterosis for all the five characters have been emanated either from Medium x Low or Medium x High cross combination with respect to *per se* performance of the parents.

Keywords: Heterosis, hybrids, fruit characters, tomato

Introduction
Tomato is one of the most important vegetable crops grown throughout the world occupying the 3rd position amongst the vegetable crops after potato and sweet potato with respect to total area and total production. It is the top ranking vegetable crops for use in the processing industries. Among the different methods of breeding, hybrid technology has been proved to the most efficient throughout the world for developing different qualitative and quantitative characters including fruit yield. In India also about 60 percent of the tomato growing areas in the country is occupied by different hybrids. The fruits contain appreciable number of seeds which is an additional advantage for hybrid seed production by labour intensive manual emasculation and hand pollination method. The expression of different monogenic or oligogenic characters in the F1 hybrids determines the cosmetic quality of the hybrids. These characters also provide ample opportunity for framing “distinct, uniform and stable” (DUS) characters for the hybrids. Keeping this information in view, the present investigation was basically framed to investigate the expression of different qualitative characters in hybrids and manifestation of heterosis in them for some important quantitative characters. At the same time, extent of heterosis in the hybrids was also investigated in relation to the genetic divergence of the parental lines involved.

Materials and Methods
The fourteen parental genotypes were selectively crossed during autumn-winter season at Central Research Farm of Bidhan Chandra Krishi Viswavidyalaya, West Bengal in field condition with the intension to develop reciprocal crosses in the entire cross combinations. However, only 23 cross combinations could be developed which were utilized in the present study.

The 23 F_1 hybrids and their 14 parental lines were grown under autumn-winter season following randomized block design with three replications keeping 16 plants per replication spaced 75 cm in both line and row. Five plants per replication (plot) were selected at random for recording observations on different characters. Ten matured fruits per plant per replication have been sampled to record data on different characters viz. Fruit weight, Equatorial diameter, Polar diameter, Pericarp thickness, Locule number per fruit.

Manifestation of heterosis: Heterosis was determined and their significance was tested as per method suggested by Wynne *et al.* (1970) [9] and Bitzer *et al.* (1967) [1].

Multivariate analysis: The D^2 statistic as suggested by Mahalanobis (1936) [4] was used for assessing the genetic divergence between the lines/varieties. The grouping of the inbreds was done by using Tocher's method as described by Rao (1952) [7]. The criterion used in clustering by this method is any two lines/varieties belonging to the same cluster should at least, on an average show a smaller D^2 value than those belonging to different clusters.

Results and Discussion

Manifestation of heterosis for fruit characters

The hybrid cultivar is the first generation (F1) progeny of a cross between two selected and genetically diverse parents and the superiority of the performance of hybrids over its parent is known as heterosis. The development of hybrid and their commercial cultivation is one of the major achievements in breeding of tomato and other vegetable crops. Manifestation of heterosis for different characters in tomato was recorded in several studies (Tiwari and Lal 2000; Harer *et al*., 2006; Makesh *et al*., 2002; Premalakshmi *et al*., 2002; Kurian *et al*., 2001 etc.) [2, 5, 6, 3]

In the present investigation manifestation of heterosis for five fruit characters namely fruit weight, equatorial diameter of fruit, polar diameter of fruit, pericarp thickness and locule number was studied through field evaluation of the hybrids and their parental lines in Randomized Block Design (RBD) with three replications.

Analysis of variance revealed (Table 1) highly significant differences among the parents and the hybrids for all the 5 fruit characters indicating wide variability among the parents and the resultant hybrids as well.

Manifestation of heterosis for different characters has been presented in Table 2. The results are presented and discussed character wise.

Fruit weight

Of the 23 hybrids only 9 hybrids manifested significantly positive heterosis ranging between 8.82 – 48.30 % over the mid parent (H1) and of them; only 6 hybrids surpassed their respective better parent for fruit weight. The hybrid showing the highest heterosis both over mid parent and better parent was BCT-90 x BCT-110. Heterotic depression in most of the hybrids indicated the partial dominance of light weight fruit over the high fruit weight.

Equatorial diameter of fruit

It is an important character which depicts fruit shape. As many as 13 hybrids out 23 hybrids manifested significant heterosis over the mid parent ranging between 3.08-24.46% and out of them 9 hybrids had fruits with higher equatorial diameter than the respective better parent. The manifestation of heterosis for equatorial diameter points towards sidewise increase in fruit which might have resulted higher fruit weight in them.

Polar diameter

Polar diameter which is actually the length between stem ends to blossom end of the fruit. Interestingly, only 4 hybrids registered significantly higher polar diameter ranging between 0.63 to 4.66% over the mid parental value. These findings pointed towards the propensity of somewhat more Flattish or Round or Flattish-round fruit shape in the hybrids compared to those of parents. From the study of fruit shape in the hybrids high propensity of round or flattish-round fruit in hybrid was also recorded.

Pericarp thickness

It is one of the most important characters both for table and processing purpose tomato variety. It has been established from different studies that pericarp thickness is positively correlated with total soluble solid content and the recovery percentage of tomato product used in processing. In the present investigation, as high as 15 hybrids manifested significant positive heterosis over mid parental value and 12 of them even surpassed their respective better parent for pericarp thickness. This result suggested that high fruit weight in the hybrid was basically realized through high pericarp thickness in the hybrids. This character in the hybrids proves to be one of the most important characters for both commercialization and industrialization of tomato hybrids through out of world. It has been estimated that nearly 50% tomato produced in the world are processed for which high pericarp thickness is one of the important character in fruits.

Locule no Fruit^{-1}

Locule number has also emerged as an important processing quality of tomato because of its direct relationship with pericarp thickness and total soluble solid content of juice. As expected, 13 out of 23 F1 hybrids registered significant heterosis over the mid parental values which ranged between 4.68-35.45%. Significant positive heterosis over respective better parents in comparatively lesser number of hybrids (8) indicated partial dominance of high locule number over low locule number.

Analysis of heterosis

Extent of manifestation of heterosis in the hybrids for different fruit characters was analysed with reference to of genetic divergence and *per se* performances of the parents.

Genetic divergence of the parents

It was expressed through different studies that mid parent heterosis would be expressed as HMP= Y2D, Where, D= Level of dominance, Y=Difference in allele frequency in the parents. Therefore, the level of heterosis expressed in a hybrid depends largely on allelic frequency differences between to parents and presents of certain level of dominance. If two inbred line or lines of self pollinated crops instead of population are crossed Y can be 0 or 1. Therefore, heterosis in a cross of two inbred or two lines of a self pollinated crops which is a function of level of dominance at loci with different alleles only. For this reason the heterotic performance in the hybrids have been consider with a view of genetic divergence of parents. The D^2 value among the 14 parental lines has been presented in the Table 3. The situation has been examined with reference to 4 top ranking hybrids in this investigation viz., BCT-109xBCT-115, BCT-82xBCT-110, BCT-90 x BCT-110, BCT-90 x BCT-109 which manifested high heterosis for most of the fruit characters.

In case of hybrids BCT-109 x BCT-115, BCT-82 x BCT-110 both the parents belonged to the same cluster. On the other hand, the respective parents of the other two conspicuous hybrids BCT-90 x BCT-110, BCT-90 x BCT-109 belonged to different cluster. These findings did not justify fully the influence of the genetic divergence of the parents as determined by the multivariate analysis for the prediction of heterosis in the hybrids all the time. It is to be mentioned that apart from the widely used dominance factor hypothesis for genetical concept of heterosis, epistatic effect of quantitative trait loci or polygenes emerged as one of the most important theory for describing heterosis in self pollinated crops. Allele divergence in the parents may not depict the epistatic effect of the polygenes in the hybrids.

Per se performance of the parents

The mid parental heterosis averaged over different relevant hybrids was considered in relation to the *per se* performance of the respective parents. The high performing hybrids in terms of manifestation of heterosis for all the five characters have been emanated either from Medium x Low or Medium x High cross combination with respect to *per se* performance of the parents. If genetic diversity would be the sole influencing factor for the manifestation of heterosis the highest heterotic hybrid would have been emanated from Low x High cross combinations. From the study of heterosis with reference to genetic divergence and *per se* performance of the parents, genetic diversity of the parents and complementary epistatic action emerged as the most important determining factor for manifestation of heterosis in the hybrids.

Table 1: Analysis of Variance

Characters	Mean sum of squares			CV (%)	SE_d (±)
	Replication	Treatment	Error		
Fruit weight(g)	17.818	2861.962**	34.657	4.806	5.689
Equatorial diameter (cm)	0.152	1.520**	0.034	0.151	3.226
Polar diameter(cm)	1.152	1.152**	0.035	0.152	3.551
Pericarp thickness(cm)	0.03	0.027**	0.001	0.030	6.060
Locule no.	0.108	1.979**	0.035	0.153	4.851
d.f.	2	36	72		

**= Significant at 0.01 probability level.

Table 2: Percentage heterosis over mid parent (H_1) and over better parent (H_2) for fruit characters in 23 hybrids of Tomato

Hybrids	Fruit weight(g)		Equatorial diameter(cm)		Polar diameter(cm)		Pericarp thickness(cm)		Locule no.	
	H_1	H_2	H_1	H_2	H_1	H_2	H_1	H_2	H_1	H_2
BCT-115XBCT-53	-0.42	-2.49	-4.93**	-5.48**	-10.73**	-12.01**	19.01**	18.03**	26.46**	20.8**
BCT-53XBCT-115	11.28**	8.96**	6.93**	6.31**	-2.32**	-3.72**	20.66**	19.67**	4.68**	0.00
BCT-115xBCT-109	8.82**	6.94	10.15**	9.06**	-8.73**	-8.88**	24.56**	18.33**	13.43**	5.81**
BCT-109xBCT-115	44.56**	42.07**	24.46**	23.22**	-1.92**	-2.09**	15.79**	10.00**	45.56**	35.79**
BCT-115x119(HXH)	-18.45**	-33.26**	-6.29**	-13.82**	-2.23**	-8.53**	-3.13**	-8.82**	-23.26**	-28.41**
BCT-119X115(HXH)	-18.00**	-32.89**	-5.98**	-13.54**	4.66**	-2.09**	9.38**	2.94**	-5.76**	-12.08**
BCT-79P4X115(MXH)	-7.46**	-20.98**	9.93**	0.5**	-14.48**	-15.35**	0.92**	-8.33**	-10.00**	-13.42**
BCT-79P7X115(LXH)	-11.16**	-25.18**	-5.60**	-7.89**	-15.39**	-21.77**	-11.50**	-16.66**	4.68**	0.00
BCT-53X82(MXM)	16.42**	1.18	-1.04**	-7.89**	11.50**	8.29**	24.59**	24.59**	-5.45**	-14.74**
BCT53X111nor(MXH)	-23.48**	-34.64**	0.26**	-3.65**	-6.22**	-9.47**	-12.90**	-14.28**	-12.67**	-20.28**
BCT-79P7X53(LXM)	-0.07	-23.37**	3.08**	0	-22.69**	-27.91**	-19.30**	-24.59**	19.66**	19.65**
BCT-82X53(MXM)	-22.43**	-32.58**	-7.77**	-11.29**	-11.67**	-14.21**	9.84**	9.83**	10.90**	0..00
BCT-82X110(MXL)	33.66**	15.66**	7.11**	1.61**	0.10	-8.79**	-41.82**	1.63**	-0.86**	-6.97**
BCT-82X116(MXM)	-14.61**	-24.10**	-9.04**	-13.47**	-17.04**	-19.56**	-19.33**	-21.31**	-3.82**	-13.26**
BCT82X111nor(MXH)	-21.84**	-40.49**	8.73**	8.63**	-5.33**	-5.92**	-22.58**	-23.8**	4.15**	-13.38**
BCT-90X82(LXM)	-1.79	-11.86**	-4.64**	-9.53**	-4.21**	-6.10**	7.94**	4.61**	31.00**	20.18**
BCT-90X110(LXL)	48.30**	42.96**	14.43**	14.42**	1.51**	5.60**	10.53**	-3.07**	34.06**	16.08**
BCT-90X109(LXM)	48.78**	21.58**	16.64**	6.26**	-1.36**	-4.54**	-2.52**	-10.76**	35.45**	15.5**
BCT-109X110(MXL)	-2.37	-22.72**	-4.70**	-13.17**	-8.16**	-17.3**	4.85**	0.00	-5.26**	-6.00**
BCT-77X110(LXL)	10.39**	-19.06**	5.82**	-5.21**	-4.84**	-18.34**	20.83**	18.36**	5.15**	-6.97**
BCT-119X132(HXL)	0.97	-27.62**	9.96**	-10.43**	0.63**	-8.91**	28.07**	7.35**	-2.19**	-19.12**
BCT-132X119(LXH)	-8.95**	-34.74**	11.52**	-9.16**	-0.99**	-10.37**	31.58**	10.29**	-10.31**	-25.83**
BCT-50X132(MXL)	15.11**	11.47**	34.34**	28.8**	-15.67**	-19.28**	45.13**	22.38**	18.70**	7.9.00**

**= Significant at 0.01 probability level

Table 3: Total D^2 values among 14 genotypes

Genotypes	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	0	257.7	260.5	141.47	203.41	79.25	20.25	227.56	166.34	309.09	255.73	667.31	759.33	36.99
2		0	514.37	79.21	62.98	64.71	186.29	9.68	151.03	5.85	2.87	154.29	213.48	277.44
3			0	292.61	258.83	274.39	196.09	425.6	118.8	519.7	496.76	907.42	995.18	268
4				0	39.25	32.61	75.72	63.79	58.27	84.03	72.63	358.2	517.77	110.29
5					0	35.95	108.66	34.33	28.27	58.9	49.4	329.25	388.37	207.22
6						0	34.25	44.41	58.02	85.45	57.95	372.7	436.95	102.28
7							0	155.5	82.94	217.48	179.49	576.24	673.01	52.56
8								0	103.28	18.08	4.66	208.78	240.95	236

9									0	149.88	137.05	449.35	529.62	161.95
10										0	8.54	137.61	213.95	325.51
11											0	188.86	234.64	268.92
12												0	105.43	697.65
13													0	844.85
14														0

1=BCT-50, 2=BCT-53, 3=BCT-77, 4=BCT-79P-4, 5=BCT-79P-7, 6=BCT-82, 7=BCT-90, 8=BCT-109, 9=BCT-110, 10=BCT-115, 11=BCT-116, 12=BCT-111nor, 13=BCT-119, 14=BCT-132

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