

Heterosis, Combining Ability and Genetics for Brix%, Days to First Fruit Ripening and Yield in Tomato (*Lycopersicon esculentum* Mill.)

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Abstract: A study was conducted on a 10×10 diallel set of tomato excluding reciprocals to find out the extent of heterosis, combining ability and nature of gene action for yield with two important quality traits: brix% and days to first fruit ripening (DFFR). Significant differences among genotypes were obtained for all three traits. Positive high significant heterosis was found for yield (211.00, 232.00 and 298.00), for brix% (61.04, 106.70 and 37.76) and for DFFR (8.92, 9.33 and 6.07) over the mid, the better and standard parent respectively. The magnitudes of variance due to general as well as specific combining ability were highly significant indicating the importance of both additive and non-additive gene action. However degree of dominance ($\sigma^2_{g/\sigma^2_{s}}$) revealed the prevalence of a non-additive gene effect. Cross combinations $P_9 \times P_7$ (0.66), $P_5 \times P_2$ (7.85) and $P_9 \times P_6$ (1.22) were best specific combiners for brix%, DFFR and yield/plant. Predominance of non-additive gene action plays a greater role in the inheritance of brix% and DFFR in tomato.

Key words:

INTRODUCTION

Now-a-days tomato is grown in most of the countries around the globe except the colder region. As a cash crop, in addition to our country it has a great demand in the international market. Bangladesh could earn foreign exchange by this crop if it could be exported. Unfortunately, the production of this crop in Bangladesh is not enough to meet the internal demand of the country and a large quantity of this crop is to be imported every year. The scope of this new dimension in tomato marketing offers some interesting challenges for breeders, post harvest physiologist and molecular biologist. In the recent past, exploitation of hybrid vigour and selection of parents on the basis of combining ability and gene action have been important breeding approaches in crop improvement. In tomato attention should be given to the breeding and inheritance of traits. The present investigation was undertaken to study and generate information about hybrid vigour, combining ability and nature of gene action, which would help to assess the prepotency of parents in hybrid combinations. A judicious choice of parents promotes an improvement process leading to a well planned hybridization programme in tomato crops.

MATERIALS AND METHODS

A set of 10×10 diallel cross of tomato without reciprocals along with their parents viz. Bari-4 (P_1), Japany (P_2), Dynasagor (P_3), Pusharubi (P_4), Namdhary (P_5), Epoch (P_6), Dynamo (P_7), Ratan (P_8), Deshy (P_9) and Legend (P_{10}) were evaluated in a randomized block design with three replications. The study was conducted during 2004-2005 at Research Field of the Department of Botany, University of Rajshahi, Rajshahi-6205, Bangladesh. Mean values of ten plants in each entry, selected at random were obtained for yield/plant. For brix% determination red ripened fruits were selected randomly. Heterosis was calculated as per Allard [1], combining ability by method 2, model 1 of Griffing [2] and genetic parameters by Hayman [3].

RESULTS AND DISCUSSION

The analysis of variance for combining ability (Table 1) showed the existence of significant variation for all three characters, indicating a wide range of variability among the genotypes. Highly significant variation due to general combining ability (gca) as well as specific combining ability (sca) indicated the importance

Table 1: Analysis of variance of combining ability in 10×10 diallel in tomato

Source	DF	Yield/		Days to first fruit
		plant (kg)	Brix (%)	ripening (DFFR)
Gca	9	10.20**	1.46**	989.20***
Sca	45	73.51**	116.39**	3605.58***
Component of variance				
io ² gca		0.094	0.005	96.73
ijo ⁻² sca		14.86	23.680	7054.17
Component ratio				
o ⁻² g/o ⁻² s		0.006	0.002	0.014

** P = 0.01

Table 2: General combining ability of parents

Parents	Yield/		Days to First Fruit
	plant (kg)	Brix (%)	Ripening (DFFR)
1. Bari-4	0.37	-0.06	-2.20
2. Japany	-0.30	0.29	18.60
3. Dynasagor	0.19	-0.12	-4.24
4. Pusharubi	-0.30	-0.15	-9.13
5. Namdhary	-0.29	0.03	-6.46
6. Epoch	-0.31	0.076	-2.60
7. Dynamo	-0.18	-0.02	-2.26
8. Ratan	0.40	-0.01	-2.77
9. Deshy	0.43	-0.05	17.80
10. Legend	-0.10	0.02	-6.60
SE	0.14	0.14	0.44
CD (0.05)	0.316	0.316	0.99

of additive as well as non-additive types of gene action in inheritance of these characters. These findings are in close agreement with Dod *et al.* [4], Srivastava *et al.* [5], Patil and Bojappa [6] and Gelera *et al.* [7]. Significant highest gca effect for yield/plant was recorded in deshy (0.43), for brix% in Japany (0.29) and for DFFR in Japany (18.6) Table 2. These observations revealed that the two quality traits with yield could be improved by using these parents in hybrid breeding programmes for the accumulation of favourable genes. However none of the parents was best general combiner for all the traits indicating differences in genetic variability for different characters among the parents.

The five top cross combinations selected on the basis of per se performance showed higher sca effects in desirable directions mainly involving high×low and low×low gca parents with a few high×high combinations (Table 3). High sca effects manifested by crosses where both the parents were good general combiners might be attributed to sizeable additive×

Table 3: Top five crosses selected on the basis of specific combining ability effects

S. No.	Character	Crosses	Per se	Sca	Gca
			performance	effects	effects
1.	Yield/plant (kg)	P ₉ ×P ₆	3.42	1.22	H×L
		P ₉ ×P ₈	5.37	1.18	H×H
		P ₇ ×P ₁₀	1.63	1.09	L×L
		P ₁ ×P ₂	3.76	0.89	H×L
		P ₁ ×P ₄	4.33	0.83	H×L
2.	Brix%	P ₉ ×P ₇	4.13	0.66	L×L
		P ₈ ×P ₆	3.16	0.54	L×H
		P ₈ ×P ₁₀	3.43	0.38	L×H
		P ₁₀ ×P ₂	4.50	0.36	H×H
		P ₈ ×P ₂	3.43	0.33	L×H
3.	Day of first fruit ripening	P ₅ ×P ₂	94.6	7.85	L×H
		P ₅ ×P ₄	94.4	6.20	L×L
		P ₇ ×P ₁	91.33	5.78	L×L
		P ₈ ×P ₄	89.32	4.68	L×L
		P ₇ ×P ₆	93.15	4.45	L×L

H = high, L = low general combiner

additive gene action. The high×low combinations, besides expressing the favorable additive effect of the high parent, manifested some complementary gene interaction effects with a higher sca. However a major part of the heterosis displayed by such crosses may be due to additive×dominance type of gene action and be non-fixable. An appreciable amount of the heterosis expressed by low×low crosses might be ascribed to dominance×dominance types of non-allelic gene action producing over dominance and are non-fixable. Thus it appears that the superior performance of most hybrids may be largely due to epistatic interaction. The highest sca effect was observed in the cross P₉×P₇ (0.66) for brix%, P₅×P₂ (7.85) for DFFR and P₉×P₆ (1.22) for yield plant (Table 3).

A significant and high degree of heterosis for brix% content was observed in comparison to better parent, mid parent and standard parents. Parents varied widely in brix% ranging from 1.06 (legend) to 4.50 (deshy), while a wider range was observed in the F₁s from 2.00 (P₄×P₇, P₆×P₁, P₈×P₅ and P₁₀×P₄) to a maximum of 6.60 (P₅×P₆) (Table 4). The highest significant heterosis over the better parent was expressed by the cross P₉×P₇ (61.04%). However the cross P₅×P₆ had the maximum content (6.60) of brix % and had the highest heterosis (4.31%) over the mid parent and also the standard cultivar. Similar variation found in this trait by some researchers [8-10]. A range of 0.59-60.40 and 0.88-13.30% significant heterosis

Table 4: Range, mean values of parents, F₁ hybrids and heterosis in 10×10 diallel in tomato

Particulars	Yield/ plant (kg)	Brix%	Days to first fruit ripening (DFFR)
Range			
Parent	0.96-2.93	1.06-4.50	71.00-96.00
F _{1s}	0.87-6.06	2.00-6.60	82.20-100.10
Range of heterosis over			
BP	-65.20-211.00	-44.9-61.04	-8.88-8.92
MP	-53.40-232.00	-35.2-106.7	-6.99-9.33
SP	-41.00-298.00	-33.7-37.76	-8.87-6.07
Top parents with their mean values	p4 (1.75)	p9 (4.20)	p1 (89.83)
Top F _{1s} with their mean values	P ₉ ×P ₈ (5.37)	P ₆ ×P ₇ (6.70)	P ₁₀ ×P ₉ (99.4)
Top F _{1s} with heterosis% over			
BP	P ₉ ×P ₈ (211.00)	P ₉ ×P ₇ (61.04)	P ₅ ×P ₇ (8.92)
MP	P ₉ ×P ₈ (232.00)	P ₉ ×P ₇ (106.70)	P ₁₀ ×P ₉ (9.33)
SP	P ₉ ×P ₈ (298.00)	P ₁₀ ×P ₂ (37.76)	P ₅ ×P ₇ (6.07)

over the better and the top parent in a 12×12 diallel under hill conditions was found [11].

It was observed that most crosses derived from parents having high amounts of brix% (high×high) showed non-significant or negative heterosis, however F_{1s} involving parents of low×low, mid×mid and mid×high expressed a higher percentage of significant positive heterosis, which confirms our previous study [11]. Positive heterosis was generally absent in tomato for all characters where parents with a high level of expression were involved and was frequent in hybrids of poorer genotypes [12]. The range of DFFR among parents and crosses was not very high (Table 4). Among the parents Dynasagor (96.00) showed the highest DFFR. In 45 crosses only 25 crosses showed significant positive heterosis over the better parent. The ranges of heterosis over the better, the mid and the standard parents were observed as -8.88-8.92, -6.99-9.13 and -10.20-6.07% respectively. A lower range of heterosis for this trait was found, probably associated with the lower parental variation in the content of DFFR. Mandal *et al.* [13] and Dod and Kale [8] also found lower heterosis among tomato crosses for this trait although Zhou and Xu [14] observed phenotypic variation in processing varieties for this trait. The range of heterosis for yield per plant over the better parent was -65.20 - 172.00. The cross P₅×P₁₀ (172.00) showed the maximum heterosis over the better parent. The range of heterosis over the mid parent and standard parent were recorded as -53.40-189.00 and

Table 5: Components of variation and genetic parameters for brix% and days of first fruit ripening

Components/proportions	Characters	
	Brix%	Days to first fruit ripening
D	0.49±0.08	307.96**±2.91
F	0.835±0.10	-68.3±6.71
H ₁	0.91**±0.19	55.28**±6.19
H ₂	0.53**±0.14	44.30**±5.26
(H ₁ /D)	1.35	0.4235
H ₂ /4H ₁	0.145	0.20
(4DH ₁)+F/(4DH ₁)-F=KD/KR	4.25	0.585
Heritability	0.69	0.99

31.00-181.00% respectively. Cross P₅×P₆ and P₁×P₂ showed maximum heterosis (189.00, 181.00%) over the mid parent and standard parent. These results support the findings of Singh *et al.* [15], Valicek and Obeidat [16], Sonone *et al.* [17] and Bhatt *et al.* [12]. At present emphasis is given to improve total yield rather than quality traits in breeding programmes. Exploitation of hybrid vigour for brix% and DFFR in diallel crosses provides an additional opportunity to improve and develop hybrids for quality along with adaptability for specific production environments.

The results presented in Table 5 indicate that the genetic components D, H₁ and H₂ were significant for both brix% and DFFR and demonstrate the importance of both additive and dominant gene effects in regulating these traits. Higher values of H₁ and H₂ compared to D show that non-additive gene effects have a greater role than additive gene effects in the genetic control of these traits. The positive estimates of H₂ for both traits suggested that the dominant genes were in the favorable direction and the significant positive H₁ value confirmed the positive direction of dominance.

The average degree of dominance over all loci H/D was more than unity for both traits suggesting the prevalence of over dominance. The value of the F was non-significant for both the characters indicating symmetrical distribution of dominant and recessive genes among parents. The H₂/4H₁ index estimates the frequency of positive and negative alleles showing dominance in the parents. The value of this index was less than unity for both traits indicating unequal combinations of genes with positive and negative effects at loci exhibiting dominance among the parents. The ambidirectional dominance effect and the uncorrelated distribution of genes among the parents may be one of the causes for low estimates of this ratio for the traits [19]. The KD/KR ratio which

represents the proportion of dominant and recessive genes in parents was found to be greater than unity for both traits suggesting an excess of dominant than recessive genes among the parents. In conclusion the present investigation suggests that hybrid breeding can be used efficiently to improve yield together with quality in tomato.

REFERENCES

1. Allard, R.W., 1960. Principles of Plant Breeding. New York: John Wiley and Sons.
2. Griffing, B., 1956. Concept of general and specific combining ability in relation to diallel crossing system. Genetics, 39: 789-809.
3. Hyman, B.I., 1954. The theory and analysis of diallel crosses. Genetics, 39: 789-809.
4. Dod, V.N., B.P. Kale and V.R. Wankhade, 1992. Combining ability study in tomato. Haryana J. Hort. Sci., 21: 296-302.
5. Srivastava, J.P., H. Singh, P.B. Srivastava and H.P.S. Verma, 1998. Heterosis in relation to combining ability in tomato. Vegetable Sci., 25: 43-47.
6. Patil, A.A. and K.M. Bojappa, 1986. Combining ability for certain quality traits in tomato (*Lycopersicon esculentum* Mill.). Progressive Horticulture, 18: 73-76.
7. Geleta, F. Legesse, Labuschagne and T. Maryke, 2006. Combining ability and heritability for vitamin C and total soluble solids in pepper (*Capsicum annum* L.). J. Sci. Food and Agric., 86 (9): 1317-1320(4).
8. Dod, V.N. and B.P. Kale, 1992. Heterosis for certain quality traits in tomato (*Lycopersicon esculentum* Mill.) Crop Research (Hisar), 5: 302-308.
9. Patil, A.A. and S.S. Patil, 1988. Heterosis for certain quality attributes in tomato. J. Maharashtra Agric. Univ., 13: 241.
10. Singh, B., S.P. Rawat and C.P. Pant, 1979. Heterosis for ascorbic acid in tomato. Ind. J. Agric. Sci., 49: 177-178.
11. Bhatt, R.P., R.V. Biswas, K.H. Pandey, S.G. Verma and N. Kumar, 1998. Heterosis for vitamin 'C' in tomato (*Lycopersicon esculentum*). Ind. J. Agric. Sci., 68: 176-178.
12. Williams, W. and M. Gilbert, 1960. Heterosis and inheritance of yield in tomato. Heredity, 14: 113-149.
13. Mandal, A.R., P. Hazara and G.M. Som, 1989. Studies on heterobeltiosis for fruit byield and quality in tomato (*Lycopersicon esculentum* Mill.). Haryana J. Hort. Sci., 18: 272-279.
14. Zhou, Y.J. and J.H. Xu, 1984. An inheritance of soluble solids contents in tomato fruits. J. Acta Hort. Sinca, 11: 29-34.
15. Singh, B., S. Joshi and N. Kumar, 1976. Heterosis and combining ability in tomato. Veget. Sci., 3: 91-96.
16. Valicek, P. and A.G. Obeidat, 1987. Using the heterosis effect in tomato. Agriculture Tropica et Subtropical, 20: 115-126.
17. Sonone, H.N., P.B. Deore and K.S. Patil, 1981. A preliminary estimation of hybrid vigour in tomato (*Lycopersicon esculentum* Mill.). J. Maharashtra Agric. Univ., 6: 250-252.
18. Bhatt, P.R., V.R. Biswas and N. Kumar, 2001. Heterosis, combining ability and genetics for vitamin C, total soluble solids and yield in tomato (*Lycopersicon esculentum*) at 1700 m altitude. J. Agric. Sci., Cambridge, 137: 71-75.
19. Mather, K. and L.J. Jinks, 1971. Biometrical Genetics, (Second edition). London: Chapman and Hall.