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Heterosis for Some Physiological Traits in Tomato (*Solanum lycopersicum* L.) Hybrids in East Hararghe, Ethiopia

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Abstract: Seven tomato inbred lines and 21 F_1 hybrids produced by crossing of the lines in 7 x 7 half diallel fashion were evaluated at Haramaya University during July 2015 to June 2016 to estimate the magnitude of heterosis effects for physiological traits. A randomized complete block design with three replications was used to conduct the experiment. More than 76% of the crosses showed negative mid-parent and higher parent heterosis for days to flowering and days to maturity. Thus, the hybrids were exhibiting in desired direction for earliness. The crosses Bishola x CLN2037E, ARP Tomato d2 x Marglobe, Eshete x CLN2037E, Bishola x ARP Tomato d2, Roma VF x Marglobe and ARP Tomato d2 x CLN2037E recorded highly significant negative mid-parent and higher parent heterosis for days to flowering and days to maturity, this revealed the feasibility of heterotic breeding to develop early maturing hybrids. The crosses Roma VF x Marglobe, Roma VF x ARP Tomato d2 and Bishola x CLN2037E recorded the highest magnitudes of positive highly significant mid-parent and higher parent heterosis for fruits per cluster and clusters per plant. Therefore, heterotic breeding for tomato yield improvement through utilizing the potentiality of these parents is feasible.

Key words: Tomato · Ethiopia · Heterosis · Flowering · Clusters Per Plant · Physiological Traits

INTRODUCTION

Tomato (*Solanum lycopersicum* L.) is the most popular produced vegetable crop. It is produced for both processing and fresh market purposes [1]. It is an excellent source of vitaminA, vitamin C, minerals and carotenoids [2]. In Ethiopia, tomato is produced by small farmers and commercial growers for both fresh fruit and processing as well as it is an important cash generating crop [3, 4].

Even though tomato is an important crop in Ethiopia, its productivity is very low due to different abiotic and biotic stresses such as diseases, insect pests, salinity, heat complexes [5, 6, 7, 1] that require systematic breeding efforts. In order to design an appropriate breeding strategy to overcome such problems, it is important to have the information on the genetic properties for morpho-physiological traits of the crop that could affect the cumulative yield of the economical important traits such as yield and different quality attributes.

Although tomato is the one the most studied crop [8], little attention was given regarding magnitude of potential exploitable heterosis and genetic variability present among the population for morpho-physiological traits of this crop.

But to design a successful breeding strategy, it requires a breeder to have a proper knowledge on different morpho-physiological traits of the crop of interest regarding the magnitude of potential exploitable heterosis and genetic variability present among the population, a type and magnitude of gene action controlling their inheritance and the magnitude of heritability of the traits. Thus, it is necessary to identify parental lines having desirable traits and make crossing in

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all possible combinations to generate information regarding the attainable magnitude of exploitable heterosis and extent of variations among parental lines required to produce heterotic hybrids for a given trait of interest.

A full knowledge on such traits helps the breeders to understand the potential exploitable heterosis and genetic variability available among the genotypes [9, 10]. Such knowledge enables them to apply an appropriate breeding method for farther utilization of the potential variability and manipulation of the genes to develop lines (Hybrids) with higher yield potential, earlier maturing, better quality and more adaptable in wider geographical-ecology in respect to biotic and abiotic stresses resistance/tolerance. This research is therefore, conducted with the objective to estimate the magnitude of heterosis for some physiological traits and to generate the information on the extent variations in parental lines that helps to produce potential heterotic hybrids

MATERIALS AND METHODS

Plant Materials: The experimental materials included seven tomato lines (Metadel, Bishola, Roma VF, ARP Tomato d2, Eshete, CLN2037E and Marglobe) and 21 F_1 hybrids produced from crossing of the seven parental lines in 7 x 7 half diallel fashion [11]. The varieties were collected from different part of the world and maintained at Melkasa Agricultural Research Center, Ethiopia and by Asian Vegetable Research Development Center [12].

Testing Location and Season: The study was conducted under irrigation conditions during off season. It was conducted at Haramaya University research field (Rare Research Station) from July 2015 to June 2016. The experimental site is located between at 42° 30' E longitude, 9°26' N latitude and at an altitude of 2006 meters above sea level in Eastern part of Ethiopia. The area receives annual rain fall of 790 mm and mean annual minimum and maximum temperature of 10.1°C and 23.6°C, respectively. The soil of the study area is alluvial type [13].

Experimental Design: The experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications and plot s ize of 7 x 1.5 m, each plot having 7 rows. Inter-row spacing of 1.0 m and intra-row spacing of 0.3 m was maintained to accommodate 35 plants per gross plot (9859 plants per hectare). The spacing of 1 m and 1.5 m was maintained between plots and blocks, respectively.

Field Management: Seedlings were grown in a ventilated glasshouse on a bed comprised of sand and compost (1:3 v: v) and transplanted after six weeks of their emergence. A recommended fertilizer rate of 200 Kg/ha DAP (92 kg P_2O_5 and 36 kg N/ha) was drilled at transplanting and 100 Kg/ha Urea was side dressed at early flowering stage. All agronomic managements were applied as per recommendation made for the crop [14].

Data Collection: In this study, nine traits (Days to flowering, flowers per cluster, stem diameter, primary branches, fruits per cluster, fruit set, days to maturity, clusters per plant and plant height) were measured on sample plants in each plot and the results were expressed as mean values.

Data Analysis: The data collected for each trait were subjected to analysis of variance for Randomized Complete Block Design as per [15]. SAS statistical software package [16] was employed for analysis of variance. The statistical significance was determined by using F-test

Estimation of Heterosis: Mid-parent and higher parent heterosis were calculated for each character using the following formula suggested by Falconer [17] as follows:

Mid-parent heterosis was calculated as: $MPH = \frac{(F_1 - MPV)}{MPV})x100$, where, F_1 is the mean performance of the cross and MPV is mean value of the two parents involved in producing the F_1 hybrid.

High parent heterosis was calculated as: $HPH = \frac{(F_1 - HPV)}{HPV})x100$, where HPV is the mean value of the high performing parent involved in producing the hybrid.

Testing whether heterosis is significant or not was done following the procedure given by [18, 19] and significance of the heterosis effects was determined by the least significant difference and t-test, using standard errors of the respective heterosis. Least significant difference (LSD) for heterosis over MPH, $LSD = \left(\sqrt{\frac{3ErMs}{2r}}\right)t$ and Least significant difference (LSD) for heterosis over HPH, $LSD = \left(\sqrt{\frac{2ErMs}{r}}\right)t$ and standard error (SE), $SE = LSD / t$

where,
r = Number of replications

ErMS = Error mean square from ANOVA
t = Tabulated t - value at error degrees of freedom corresponding to 5 or 1% level of significance
And the respective heterosis 't' value (Calculated 't' value) was computed as:

$$MPH\ (t) = (F_1 - MPV) / SE$$
$$HPH(t) = (F_1 - HPV) / SE$$

If the calculated t-value is greater than tabulated value at error degree of freedom (For t-test) and if the difference of the mean performance of the crosses (F_1) and respective mean values of heterosis (Mean value of the two parents, the mean value of the high performing parent and the mean value of the check) is greater than the (LSD) value, then only the results was declared as significant i.e. $F_1 - MPV$ *and* F_1 - *HPV*, is greater than respective *LSD* values (For the test by the statistic *LSD*).

RESULTS AND DISCUSSION

Analysis of variance showed highly significant differences ($P < 0.01$) among the tested genotypes (Parents + hybrids) for all studied (Table 1).

Mid-Parent Heterosis: Sixteen out of 21 cross combinations showed negative mid-parent heterosis for days to flowering and days maturity of which twelve out of 21 were significant for days to flowering and thirteen out of 21 were significant for days to Maturity (Table 4 and 5). Negative heterosis over mid-parent also reported for days to flowering by [20-25].

The cross Bishola x CLN2037E recorded the highest magnitude of negative significant mid-parent heterosis for days to flowering (-34.48%) and days maturity (-15.34%) followed by the crosses ARP Tomato d2 x Marglobe, Eshete x CLN2037E, Bishola x ARP Tomato d2, Roma VF x Marglobe and ARP Tomato d2 x CLN2037E (Table 2 and 3).

All crosses showed nonsignificant mid-parent heterosis for fruit set except the crosses Bishola x Eshete and CLN2037E x Marglobe which recorded negative and positive significant mid-parent heterosis respectively. All crosses showed positive mid-parent heterosis for flowers per cluster, fruits per cluster, clusters per plant and plant height, of which more than 50% are highly significant (Table 2 and 3). Increase in plant height positively affects total fruit yield [26-28]. Thus, this could be utilized for yield improvement.

Higher Parent Heterosis: Seventeen out of 21 crosses showed negative higher parent heterosis for days to flowering and days maturity of which thirteen out of 21 were significant for days to flowering and fourteen out of 21 were significant for days to Maturity (Table 4 and 5).

The cross Bishola x CLN2037E recorded the highest magnitudes of negative significant higher parent heterosis for days to flowering (-40.63%) and days maturity (-21.01%) followed by the crosses ARP Tomato d2 x Marglobe, Eshete x CLN2037E, Bishola x ARP Tomato d2, Roma VF x Marglobe and ARP Tomato d2 x CLN2037E (Table 6 and 7). Many workers also reported negative heterosis for days to flowering over the better [29-31].

All crosses showed nonsignificant higher-parent heterosis for fruit set except the crosses Bishola x Eshete and CLN2037E x Marglobe which recorded negative and positive significant higher-parent heterosis respectively. All crosses showed positive higher parent heterosis for the characters, flowers per cluster, fruits per cluster, of which more than 50% are significant (Table 4 and 5).

Table 1: Analysis of variances for the studied tomato characters

	Mean square			Statistics		
Character	Block (2)	Parents + Hybrids (27)	Error (54)	Mean	CV (%)	LSD (5%)
Days to flowering	25.58	49.62**	3.52	34.99	5.36	3.07
Flower per cluster	6.18	0.74**	0.18	4.37	9.73	0.70
Stem diameter (cm)	0.013	0.05**	0.006	1.36	5.43	0.121
Primary branches	0.09	2.32**	0.26	7.28	7.04	0.84
Fruits per cluster	0.56	0.75**	0.2	3.98	11.08	0.72
Fruit set	0.01	0.01*	0.003	0.87	6.03	0.086
Days to maturity	36.33	66.56**	4.65	80.85	2.67	3.53
Clusters per plant	0.62	5.98**	0.28	6.43	8.24	0.87
Plant height (cm)	51.38	2331.38**	43.74	85.30	7.75	10.83

** and * indicate significance at 1 and 5% probability levels by F-test, ns = not significant by F-test, number in parenthesis indicates degrees of freedom.

Table 2: Mid-parent heterosis of the crosses for days to flowering, flowers per cluster, stem diameter, number primary branches and fruits per cluster

	Heterosis Estimates									
	Days to 50% flowering (DF1)		Flowers per cluster (FlPC)		Stem diameter (SD)		Number of primary branches (PB)		Fruits per cluster (FrPC)	
Cross	Mean	MPH	Mean	MPH	Mean	MPH	Mean	MPH	Mean	MPH
P1xP2	39.67	0.85ns	4.20	9.33ns	1.49	17.28**	6.96	16.13**	3.78	9.20ns
P1xP3	36.33	-3.54ns	4.47	15.26ns	1.38	0.49ns	7.68	15.48**	4.04	16.61ns
P1xP4	33.33	-12.28**	4.12	8.99ns	1.33	2.44ns	7.01	1.11ns	3.70	10.00ns
P1xP5	37.67	6.60ns	3.85	0.04 ns	1.66	29.26**	7.94	25.83**	3.65	4.04ns
P1xP6	32.67	-7.55*	4.40	10.92ns	1.30	-3.35ns	8.16	25.08**	4.06	17.08ns
P1xP7	38.00	5.07ns	4.27	13.45ns	1.38	10.43*	6.89	-7.12ns	4.03	19.13*
P2xP3	35.33	-13.82**	4.48	15.68*	1.39	10.34*	7.57	11.98ns	4.00	14.18ns
P2xP4	32.33	-21.77**	4.08	7.99ns	1.34	13.12**	6.66	-5.40 ns	3.88	13.74ns
P2xP5	34.33	-11.21**	4.40	14.58ns	1.45	24.18**	5.75	-10.39ns	3.60	1.41ns
P2xP6	25.33	-34.48**	5.18	30.78**	1.36	10.99*	7.56	14.02*	4.82	37.55**
P2xP7	38.33	-2.95ns	4.61	22.66**	1.47	30.09**	6.67	-11.36*	4.38	28.11**
P3xP4	37.00	-6.72*	4.71	23.57**	1.35	5.07ns	7.57	-1.69ns	4.38	28.29**
P3xP5	36.33	-1.80ns	5.05	30.27**	1.57	24.37**	8.75	23.60 **	4.72	32.74**
P3xP6	34.67	-6.31ns	5.27	32.00**	1.54	15.68**	9.08	24.45**	4.83	37.70**
P3xP7	30.33	-19.82**	4.69	23.67**	1.32	7.59ns	7.12	-13.01**	4.31	25.84**
P4xP5	33.33	-10.71**	4.52	19.61*	1.29	8.12ns	6.02	-18.18 **	3.93	13.54ns
P4xP6	31.67	-15.18**	4.93	26.50**	1.23	-1.86ns	7.16	-5.37ns	4.19	22.79*
P4xP7	28.33	-25.76**	3.77	1.80ns	1.25	7.94ns	6.64	-21.53**	3.53	6.11ns
P5xP6	26.00	-25.00**	4.94	24.67**	1.36	9.70*	6.51	-6.28ns	4.45	25.12**
P5xP7	38.33	7.98*	4.30	14.21ns	1.45	27.38**	7.71	-1.64ns	3.81	9.65ns
P6xP7	36.67	3.29ns	5.30	36.57**	1.55	28.99**	8.13	0.89ns	5.19	51.39**
P1	36.00	-	3.85	-	1.39	-	5.89	-	3.42	-
P2	42.67	-	3.83	-	1.16	-	6.10	-	3.50	-
P3	39.33	-	3.91	-	1.36	-	7.42	-	3.51	-
P4	40.00	-	3.72	-	1.21	-	7.97	-	3.32	-
P5	34.67	-	3.85	-	1.17	-	6.73	-	3.60	-
P6	34.67	-	4.08	-	1.30	-	7.17	-	3.51	-
P7	36.33	-	3.68	-	1.10	-	8.95	-	3.34	-
LSD (5%)	2.67		0.6		0.14		0.72		0.63	
LSD (1%)	3.54		0.8		0.19		0.96		0.84	
SE±	1.33		0.3		0.07		0.36		0.32	

** *: Significant at 1 and 5% probability levels by t- test at error degree freedom and ns = nonsignificant. P1 = Metadel, P2 = Bishola, P3 = Roma VF, P4 = ARP Tomato d2, P5 = Eshete, P6 = CLN2037E, P7 = Marglobe.

Table 3: Mid-parent heterosis of the crosses for fruit set, days to maturity, clusters per plant and plant height

	Heterosis estimate							
	Fruit set (FS) = (FlPC) / (FrPC)		Days to maturity (DM)		Clusters per plant (CPP)		Plant height (PH)	
Cross	Mean	MPH	Mean	MPH	Mean	MPH	Mean	MPH
p1xP2	0.83	-3.66ns	87.00	1.16ns	4.92	6.12ns	73.71	24.09**
p1xP3	0.89	3.89ns	81.33	-1.21ns	6.41	27.07**	52.34	3.27ns
p1xP4	0.86	1.17ns	78.00	-8.59**	5.4	13.21ns	58.45	2.59ns
p1xP5	0.89	-0.19ns	83.33	4.38*	5.12	14.77ns	103.4	46.85**
p1xP6	0.85	-1.36ns	77.67	-2.71ns	5.5	11.86ns	122.51	43.37**
p1xP7	0.92	6.18ns	83.67	2.66ns	7.81	22.46**	85.28	40.06**
P2xP3	0.84	-1.37ns	80.67	-8.68**	7.42	41.05**	66.93	34.91**
P2xP4	0.90	5.70ns	77.33	-15.33**	6.2	24.4**	55.5	-0.72ns
P2xP5	0.75	-15.09**	78.67	-8.35**	5.26	12.51ns	115.5	66.55**
P2xP6	0.89	4.69ns	72.67	-15.34**	5.8	12.99ns	89.87	6.49ns
P2xP7	0.90	4.85ns	83.67	-4.38*	7.78	17.98**	66.16	10.59ns
P3xP4	0.91	7.94ns	83.67	-4.56*	7.1	31.54**	67.28	42.59**
P3xP5	0.89	1.71ns	81.33	-1.01ns	6.26	23.15**	119.85	97.69**

Table 3: Continued

P3xP6	0.89	5.33ns	78.67	-4.26*	7.93	43.04**	114.11	50.8**
P3xP7	0.88	3.53ns	75.67	-9.74**	8.3	18.62**	64.7	26.61**
P4xP5	0.81	-6.69ns	78.00	-8.41**	5.76	19.78*	106.8	59.6**
P4xP6	0.80	-5.35ns	75.00	-11.94**	6.48	23.02**	125.07	52.6**
P4xP7	0.89	5.12ns	74.00	-14.78**	8.91	32.47**	75.95	32.27**
P5xP6	0.88	0.38ns	75.00	-5.86**	5.94	19.8*	130.95	37.27**
P5xP7	0.84	-4.73ns	86.00	5.74**	9.15	42.6**	97.6	37.78**
P6xP7	0.94	10.76*	82.67	1.64ns	8.36	21.55**	131.16	52.72**
P1	0.87	-	80.00	-	4.42	-	60.47	-
P2	0.86	-	92.00	-	4.85	-	58.33	-
P3	0.84	-	84.67	-	5.67	-	40.89	-
P4	0.84	-	90.67	-	5.12	-	53.47	-
P5	0.91	-	79.67	-	4.5	-	80.36	-
P6	0.85	-	79.67	-	5.42	-	110.44	-
P7	0.86	-	83.00	-	8.33	-	61.32	-
LSD (5%)	0.08		3.06		0.75		9.38	
LSD (1%)	0.1		4.07		0.99		12.49	
SE±	0.04		1.52		0.37		4.68	

** *: Significant at 1 and 5% probability levels by t- test at error degree freedom and ns = nonsignificant. P1 = Metadel, P2 = Bishola, P3 = Roma VF, P4 = ARP Tomato d2, P5 = Eshete, P6 = CLN2037E, P7 = Marglobe.

Table 4: Higher parent heterosis of the crosses for days to flowering, flowers per cluster, stem diameter, number primary branches and fruits per cluster

	Heterosis estimate									
	Days to 50% flowering (DF1)		Flowers per cluster (FlPC)		Stem diameter (SD)		Number of primary branches (PB)		Fruits per cluster (FrPC)	
Cross	Mean	HPH	Mean	HPH	Mean	HPH	Mean	HPH	Mean	HPH
p1xP2	39.67	-7.03ns	4.20	9.09ns	1.49	7.43ns	6.96	14.10*	3.78	7.90ns
p1xP3	36.33	-7.63ns	4.47	14.42ns	1.38	-0.72ns	7.68	3.55ns	4.04	15.11ns
p1xP4	33.33	-16.67**	4.12	7.10ns	1.33	-4.32ns	7.01	-12.12*	3.70	8.39ns
p1xP5	37.67	4.63ns	3.85	0.00ns	1.66	19.18**	7.94	17.92**	3.65	1.39ns
p1xP6	32.67	-9.26*	4.40	7.76ns	1.30	-6.47ns	8.16	13.91*	4.06	15.46ns
p1xP7	38.00	4.59ns	4.27	11.00ns	1.38	-0.96ns	6.89	-23.02**	4.03	17.85ns
P2xP3	35.33	-17.19**	4.48	14.59ns	1.39	2.21ns	7.57	2.02ns	4.00	14.07ns
P2xP4	32.33	-24.22**	4.08	6.35ns	1.34	10.77*	6.66	-16.51**	3.88	10.76ns
P2xP5	34.33	-19.53**	4.40	14.38ns	1.45	23.30**	5.75	-14.60*	3.60	0.00ns
P2xP6	25.33	-40.63**	5.18	26.78**	1.36	4.87ns	7.56	5.53ns	4.82	37.29**
P2xP7	38.33	-10.16**	4.61	20.26*	1.47	27.09**	6.67	-25.47**	4.38	25.24*
P3xP4	37.00	-7.50ns	4.71	20.56*	1.35	-0.74ns	7.57	-5.10ns	4.38	24.81*
P3xP5	36.33	-7.63ns	5.05	29.27**	1.57	15.97**	8.75	17.88**	4.72	31.02**
P3xP6	34.67	-11.86**	5.27	29.14**	1.54	13.27**	9.08	22.33**	4.83	37.57**
P3xP7	30.33	-22.88**	4.69	20.14*	1.32	-2.46ns	7.12	-20.45**	4.31	22.91*
P4xP5	33.33	-16.67**	4.52	17.59ns	1.29	6.63ns	6.02	-24.54**	3.93	9.07ns
P4xP6	31.67	-20.83**	4.93	20.82*	1.23	-5.38ns	7.16	-10.16ns	4.19	19.35ns
P4xP7	28.33	-29.17**	3.77	1.35ns	1.25	3.31ns	6.64	-25.81**	3.53	5.68ns
P5xP6	26.00	-25.00**	4.94	21.06*	1.36	4.36ns	6.51	-9.12ns	4.45	23.61*
P5xP7	38.33	5.50ns	4.30	11.79ns	1.45	23.58**	7.71	-13.82**	3.81	5.74ns
P6xP7	36.67	0.92ns	5.30	29.88**	1.55	19.23**	8.13	-9.16ns	5.19	47.72**
P1	36.00	-	3.85	-	1.39	-	5.89	-	3.42	-
P2	42.67	-	3.83	-	1.16	-	6.10	-	3.50	-
P3	39.33	-	3.91	-	1.36	-	7.42	-	3.51	-
P4	40.00	-	3.72	-	1.21	-	7.97	-	3.32	-
P5	34.67	-	3.85	-	1.17	-	6.73	-	3.60	-
P6	34.67	-	4.08	-	1.30	-	7.17	-	3.51	-
P7	36.33	-	3.68	-	1.10	-	8.95	-	3.34	-
LSD (5%)	3.07		0.69		0.16		0.83		0.73	
LSD (1%)	4.09		0.92		0.22		1.11		0.97	
SE±	1.53		0.35		0.08		0.42		0.37	

** *: Significant at 1 and 5% probability levels by t- test at error degree freedom and ns = nonsignificant. P1 = Metadel, P2 = Bishola, P3 = Roma VF, P4 = ARP Tomato d2, P5 = Eshete, P6 = CLN2037E, P7 = Marglobe.

Table 5: Higher parent heterosis of the crosses for fruit set, days to maturity, clusters per plant and plant height

	Heterosis estimate							
	Fruit set (FS) = (FlPC) / (FrPC)		Days to maturity (DM)		Clusters per plant (CPP)		Plant height (PH)	
Cross	Mean	HPH	Mean	HPH	Mean	HPH	Mean	HPH
p1xP2	0.83	-4.21ns	87.00	-5.43**	4.92	1.37ns	73.71	21.9*
p1xP3	0.89	2.30ns	81.33	-3.94ns	6.41	13.06ns	52.34	-13.45ns
p1xP4	0.86	-0.77ns	78.00	-13.97**	5.4	5.4ns	58.45	-3.34ns
p1xP5	0.89	-2.21ns	83.33	4.17ns	5.12	13.7ns	103.4	28.67**
p1xP6	0.85	-2.68ns	77.67	-2.92ns	5.5	1.54ns	122.51	10.93*
p1xP7	0.92	5.36ns	83.67	0.80ns	7.81	-6.32ns	85.28	39.09**
P2xP3	0.84	-2.33ns	80.67	-12.32**	7.42	30.88**	66.93	14.74ns
P2xP4	0.90	4.26ns	77.33	-15.94**	6.2	21.08*	55.5	-4.86ns
P2xP5	0.75	-17.28**	78.67	-14.49**	5.26	8.45ns	115.5	43.73**
P2xP6	0.89	3.88ns	72.67	-21.01**	5.8	7.08ns	89.87	-18.63**
P2xP7	0.90	4.65ns	83.67	-9.06**	7.78	-6.68ns	66.16	7.90ns
P3xP4	0.91	7.51ns	83.67	-7.72**	7.1	25.24**	67.28	25.81*
P3xP5	0.89	-1.84ns	81.33	-3.94ns	6.26	10.47ns	119.85	49.14**
P3xP6	0.89	5.12ns	78.67	-7.09**	7.93	39.88**	114.11	3.32ns
P3xP7	0.88	2.72ns	75.67	-10.63**	8.3	-0.36ns	64.7	5.52ns
P4xP5	0.81	-10.29 *	78.00	-13.97**	5.76	12.49ns	106.8	32.90**
P4xP6	0.80	-5.91ns	75.00	-17.28**	6.48	19.69*	125.07	13.24**
P4xP7	0.89	3.89ns	74.00	-18.38**	8.91	6.96ns	75.95	23.81**
P5xP6	0.88	-2.94ns	75.00	-5.86**	5.94	9.66ns	130.95	18.57**
P5xP7	0.84	-7.35ns	86.00	3.61ns	9.15	9.8ns	97.6	21.46**
P6xP7	0.94	10.12*	82.67	-0.40ns	8.36	0.28ns	131.16	18.75**
P1	0.87	-	80.00	-	4.42	-	60.47	-
P2	0.86	-	92.00	-	4.85	-	58.33	-
P3	0.84	-	84.67	-	5.67	-	40.89	-
P4	0.84	-	90.67	-	5.12	-	53.47	-
P5	0.91	-	79.67	-	4.5	-	80.36	-
P6	0.85	-	79.67	-	5.42	-	110.44	-
P7	0.86	-	83.00	-	8.33	-	61.32	-
LSD (5%)	0.09		3.53		0.87		10.83	
LSD (1%)	0.12		4.7		1.15		14.42	
SE±	0.04		1.76		0.43		5.4	

** *: Significant at 1 and 5% probability levels by t- test at error degree freedom and ns = nonsignificant. P1 = Metadel, P2 = Bishola, P3 = Roma VF, P4 = ARP Tomato d2, P5 = Eshete, P6 = CLN2037E, P7 = Marglobe.

CONCLUSION

Analysis of variance showed significance differences among the tested genotypes (Parents + hybrids) for all studded characters indicating the presence of sufficient genetic variability among the parental lines and the evolved hybrids.

More than 76% of the crosses showed negative mid-parent and higher parent heterosis for the characters days to flowering and days to maturity. Therefore, the hybrids were exhibiting in desired direction for early maturating varieties development since negative heterosis is desired for early maturity of the fruits.

The crosses Bishola x CLN2037E, ARP Tomato d2 x Marglobe, Eshete x CLN2037E, Bishola x ARP Tomato d2, Roma VF x Marglobe and ARP Tomato d2 x CLN2037E recorded the higher and highly significant negative mid-parent and better/higher parent heterosis for the characters days to flowering and days to maturity, this revealed that the feasibility of heterotic breeding to develop early maturing tomato varieties, through utilizing the potentiality of parents.

Positive significant mid-parent and higher parent heterosis are recorded by more than 85% of the crosses for the characters flowers per cluster, fruits per cluster and clusters per plant indicating the crosses were exhibiting in positive desired direction. The crosses Roma VF x Marglobe, Roma VF x ARP Tomato d2, Bishola x CLN2037E, Roma VF x CLN2037E, Eshete x CLN2037E and CLN2037E x Marglobe recorded the highest magnitudes of positive and highly significant mid-parent and higher parent heterosis for fruits per cluster and clusters per plant. Thus, heterotic breeding for tomato yield improvement through utilizing the potentiality of these parents is feasible.

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REFERENCES

1. Jiregna Tasisa, 2014a. Field, Greenhouse and Detached-Leaf Evaluation of Tomato (*Lycopersicon esculentum* Mill.) Genotypes for Late Blight Resistance. World Applied Sciences Journal, 32(11): 2259-2263.
2. FAO, 1979. Recommended practices for the prevention of mycotoxins in food, feed and their products. Food Agriculture Organization UN Rome., Italy, 51: 35-45.
3. Gemechis, A.O., P.C. Struik and B. Emana, 2012. Tomato production in Ethiopia: Constraints and opportunities. Paper presented at the International Research on Food Security, Natural Resource Management and Rural Development Conference, Gottingen, Germany.
4. Jiregana Tasisa, 2013. Evaluation of Agronomic Performance and Lycopene Variation in Tomato (*Lycopersicon esculantum* Mill.) Genotypes in Mizan, Southwestern Ethiopia. World Applied Sciences Journal, 27(11): 1450-1454.
5. Girefe Sahile, Girma Abebe and Abdel-Rahman M. Al-Tawaha, 2005. Effect of Soil Solarization on *Orobanche* Soil Seed Bank and Tomato Yield in Central Rift Valley of Ethiopia. World Journal of Agricultural Sciences, 1(2): 143-147.
6. Girma Abebe, Girefe Sahile and Abdel-Rahman M. Al-Tawaha, 2005. Evaluation of Potential Trap Crops on *Orobanche* Soil Seed Bank and Tomato Yield in the Central Rift Valley of Ethiopia. World Journal of Agricultural Sciences, 1(2): 148-151.
7. Jiregna Tasisa, Derbew Belew, Kassahun Bantte, Wossesn Gebresilasie, 2011. Variability, Heritability and Genetic Adivance in Tomato (*Lycopersicon esculentum* Mill.) Genotypes in West Shoa, Ethiopia. Americal-Eurasian Journal of Agriculture and Environmental Science, 11(1): 87-94.
8. Foolad, M.R., 2007. Genome mapping and molecular breeding of tomato. International journal of plant Genomics, 2007: 643-658.
9. Jiregana Tasisa, 2014b. Multivariate Analysis and Selection of Parents for Hybridization inTomato (*Lycopersicon esculentum* Mill.) Genotypes. World Journal of Agricultural Sciences, 10(3): 103-107.
10. Goswami, P.K., P.P. Baruah and R.K. Behl, 2006. Genetic Divergence in Relation to Combining ability and Transgression in Indian Mustard (*Brassica juncea L.*). World Journal of Agriculture Science, 2(4): 390-393.
11. Griffing, B., 1956. Concepts of .general and specific combining ability in relation to diallel crossing systems. Australian Journal of Biological Science, 9: 464-493.
12. AVRDC, 2007. AVRDC Report 2004. AVRDC Publication Number 07-691. Shanhua, Taiwan: AVRDC-The WorldVegetable Center.
13. Tamire, H., 1973. Characterization of alemaya soils. Soil science paper, Series No.1, pp: 45.
14. Lemma, D., 2002. Tomatoes Research Experience and Production Prospects. Research Report No. 43. Ethiopian Agricultural Research Organization, Addis Ababa, pp: 1, 33, 46.
15. Montgomery, D.C., 2005. Design and Analysis of Experimentals, 6th ed. John Wiley and Sons Inc., USA., pp: 97, 203.
16. SAS, 2002. Statistical Analysis System Software. Ver. 9.0. SAS Institute InC., Carry. NC.
17. Falconer, D.S., 1994. Introduction to quantitative genetics. 4th ed., John Whiley and sons, Inc., New York., pp: 438.
18. Panse, V.G. and P.V. Sukhatme, 1961. Statistical Methods for Agricultural Workers, ICAR Publication, New Delhi, pp: 145.
19. Wynne, J.C., D.A. Em+ary and P.H. Rice, 1970. Combining ability estimation in F_1 Arachic hypogeal hybrid. Crop Science, 10: 713-715.
20. Asati, B.S., G. Singh, N. Rai and A.K. Chaturvedi, 2007. Hetrosis and combining ability studies for yield and quality traits in tomato. Vegetable Science, 34(1): 92-94.
21. Singh, C.B., N. Rai, R.K. Singh, M.C. Singh, A.K. Singh and A.K. Chaturvedi, 2008. Heterosis, combining ability and gene action studies in tomato (*Solanum lycopersicum* L.). Vegetable Sciences, 35(2): 132-135.
22. Singh, J. and E.V.D. Sastry, 2011. Heterosis and stress susceptibility index for fruit yield and contributing traits in tomato (Lycopersicon esculentum). Indian journal of agricultural science, 81(10): 957-966.
23. Kumari, S. and M.K. Sharma, 2011. Exploitation of hetero-sis for yield and its contributing traits in tomato (*Solanum lycopersicum* L.). International Journal of Farm Science, 1(2): 45-55.

24. Shankar, A., R.V.S.K. Reddy, M. Sujatha and M. Pratap, 2014. Development of superior F1 hybrids for com-mercial exploitation in tomato (*Solanum lycopersicum* L.). International journal of farm science, 4(2): 58-69.
25. Kumar, C. and S.P. Singh, 2016. Heterosis and inbreeding depression to identify superior F1 hybrids in tomato (*Solanum lycopersicum* L.) for the yield and its contributing traits. Applied and Natural Science, 8(1): 290-296.
26. Joshi, A. and M.C. Thakur, 2003. Exploitation of heterosis for yield and yield contributing traits in tomato (*Lycopersicon esculentum* Mill.). Progress of Horticulture, 35(1): 64-68.
27. Thakur, A.K., U.K. Kholi and A. Joshi, 2004. Evaluation of diallel progeny and heterosisfor yield and yield components in tomato (*Lycopersicon esculentum* Mill.). Haryana Journal of Horticultural Science, 33(1&2): 106-108.
28. Gul, R., H. Rahman, M. Tahir, M. Naeem and A. Ghafoor, 2013. Estimates of Heterosis for Morphological and Flavor Attributes in Tomato. International Journal of Vegetable Sci., 19: 256-262.
29. Ahmed, S.U., H.K. Shaha and A.F.M. Sharfuddin, 1988. Study of heterosis and correlation in tomato. Thai Journal of Agricultural Science, 21(2): 117-123.
30. Singh, R.K. and V.K. Singh, 1993. Heterosis breeding in tomato (*Lycopersicon esculentum* Mill.). Annals of Agricultural Science Research, 14(4): 416-420.
31. Ahmad, L.S., A.K.M. Quamruzzaman and M.R. Islam, 2011. Estimate of heterosis in tomato (*Solanum lycopersicum* L.). Bangladesh Journal of Agricultural Research, 36(3): 521-527.