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SELECTION FOR HEAT TOLERANCE IN TOMATO *Ex situ* GERMPLASM

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ABSTRACT

In Egypt, the impact of high temperatures on tomato production during summer season has become an urgent issue. Where the day/night temperature rising above the optimal for flowering and fruit set, consequently, the fresh market tomato prices increase about 400 to 500% during this period with inferior quality of fruits. The objective of this work was to assay new genetic resources of a set of *ex situ* lines and cultivars for heat-tolerant. Furthermore, selection for promising parents that would be used in developing more adaptive cultivars to heat stress. All experiments were carried out during 2013 to 2015. Fifty tomato genotypes (*Lycopersicon esculentum*, Mill.) were evaluated in a randomized complete blocks design under the natural heat stress conditions. The following traits; plant height, number of branches, leave area, fruit set %, total chlorophyll, chl a/b ratio, chl T/carotenoid, in addition to yield and some fruit quality traits were estimated. Based on the phenotypic performance and the genetic divergence of these genotypes, 10 parental varieties were selected for a factorial mating design using 6 as males and 4 as females. High genetic variability was observed among the genotypes for all studied traits. Mean of fruit set % ranged from 12.7 % to 66.5%. Twelve genotypes gave more than 50kg/plot where the genotypes LA0535 and BGH-0226 recorded the highest mean values of 63.15 and 61.88 kg/plot, respectively. The mean squares of GCA as well as SCA were significant for the majority of studied traits indicting the importance of both additive and non-additive types of variation for all studied traits. Among the female lines, BGH-2004 exhibited maximum positive gi effect, while among the male lines, BGH-0226 displayed highest gi effect for plant height. The cross resulted from BGH-3474 x BGH-0226 gave the highest Sij effect for fruit set % indicating that the female line BGH3474 and tester BGH-0226 produced promising progenies for vegetative traits and fruit set improvement. While the female line BGH-3474 and male line BGH-7466 gave the highest gi effects for total yield per plot. According to the variation and diversity analysis, the genotype LA0535 from group I showed stable high yield across the two summer seasons 2014 and 2015 and was a good donor for fruit set, TSS and firmness however its poor fruit in lycopene. The hybrid 2x5 showed high adaptation against heat stress under field condition in 2015 with high total yield, leave area number of branches per plant, average fruit weight and fruit firmness but low lycopene. Therefore, for hybridization program, crosses among LA0535, BGH-0025, BGH-7466 for heat tolerance and yield could be effective and promising.

Keywords: *Lycopersicon esculentum*, factorial mating design, high temperature, GCA and SCA effects.

INTRODUCTION

Heat stress is considered an agricultural problem in many areas worldwide including Egypt as a consequence of global warming that threaten global food and nutrition security. The optimal daily temperature for tomato development is between 25 ˚C and 30 ˚C during day light and 20˚C during the night (Camejo *et al*., 2005). Under higher temperatures, negative effects on plant growth and development have been reported in tomato (Camejo *et al*., 2006; Zhang *et al*., 2014) and consequently decrease its productivity (Peet *et al*., 1998; Sato *et al*., 2006). In this context, the impact of high temperatures on tomato production during the summer season in Egypt has become an urgent issue. Where in this period of year, June to August, the day/night temperature rising above the optimal temperature for tomato development especially for flowering and fruit set. Consequently, the fresh market tomato prices increase about 400% to 500% during October every year with inferior fruit quality too.

However, genetic improvement for high temperature tolerance was initiated about 30 years ago using relatively new approach where most plant breeding programs have interested on development of high yielding under stress conditions. Most abiotic stress tolerances are polygenic traits controlled by more than one gene which direct selection under uncontrollable environmental factors (Wahid *et al*., 2007).Both genetic improvement and cultural practices such as planting time, plant density, and soil and irrigation managements must be employed simultaneously to reduce the negative impacts of abiotic stresses in general. The objective of present study was to evaluate a set of *ex-situ* lines and cultivars for heat-tolerant under high temperatures of the summer season which teach about 35˚C as more and selection for promising progenies which would be used in the development of heat tolerant tomato cultivars possessing adequate fruit quality.

MATERIALS AND METHODS

Screening trial

In this study, a total of fifty genotypes (*Lycopersicon esculentum*, Mill.) were used including the strain B as standard heat tolerant variety. Forty one genotypes belonging to BGH group were supplied through Horticulture Germplasm Bank, UFV- Brazil. While three lines; LA3320, LA0535 and LA0345 were provided by Tomato Genetic Resources Center, University of California, USA. Finally, the genotypes EC-41824, EC-41824, Red Rock, Avalanche and Saladette were supplied by personal communication with Indian Agricultural Research Institute. In the summer season of 2013, all these genotypes were grown in a randomized complete blocks design with three replicates. Each replication consisted of 50 plots. Each plot was 4.5 m long with two ridges contained 22 plants. Different vegetative, yield and fruit traits were evaluated under the natural heat stress at the summer season in the field in order to identify the promising genotypes for direct usage or as primary material for tomato genetic improvement programs. Based on the phenotypic performance of these genotypes,10 parental varieties were selected for a factorial mating design using 4 lines as a female and 6 lines as males to produce 24 hybrids.

Factorial mating design

In December 2013,seeds of 10 genotypes were sown in seedling trays at Horticultural Research Station, Mansoura city. After 35 days, the seedlings were transplanted to 6 letter pots to apply a factorial mating design involving two groups G I included 4 female and G II includes 6 males, respectively. The crosses were accomplished by the end of March and the fruits of twenty four crosses were collected during April and May 2014 and saved for the next evaluation experiment.

Evaluation trial

In the summer season of 2015, 10 parental lines and their 24 F1 hybrids were sown and transplanted in the end of May and grown in a randomized complete blocks design with three replicates. Each replication consisted of 24 plots. Each plot was 4 m long with two ridges contained 20 plants. The experiment of evaluation was carried out at private farm in Aga district, Dakahlia governorate. Weed control and other cultural practices were performed according to the requirements of tomato plants. Data were recorded on five randomly selected plants from each plot from the three replicates for the following traits:

Plant height (PH cm), number of braches per plant (NBP)**,** the percentage of fruit set (F set%)which was determined as follows:

$$\textbf{F set \%} = \frac{\text{n. of fruit set in the first four flower clusters}}{\text{total n. of flowers anthesis in these clusters}} \times \mathbf{100}$$

Leaf area / plant (LA in cm^2): was determined using the fresh weight method. The leaves were cleaned from dust and then weighed. Certain known disks were taken from the leaves with a cork puncher and weighed. The leaf area was calculated according to the following formula:

$$\textbf{LA in cm}^2 = \frac{\text{fresh weight of leaves}}{\text{fresh weight of disk}} \times \textbf{leaf area of disks in cm}^2$$

Chlorophyll concentration and carotenoid (mg per g tissue); weight 0.5g of finely cut and grind the tissue to a fine pulp with the addition of 10 ml of 80% methanol and kept overnight in the dark. Read the absorbance at 650 and 665 nm against the solvent (80% methanol) blank. Calculate the amount of chlorophyll a, b and total present in the extract according to Markinney (1941). The carotenoid was calculated according the formula 103 x A470 - 2.05 x Chl a - 114.8 x Chl chlorophyll a / b ratio (Chla/Chlb) and Total chlorophyll/ carotenoid (ChlT/ Caro) ratio were estimated as a heat tolerant parameters which the highest values of Chla/Chlb ratio and the low in Chl T/Car ratio were observed in the heat tolerant genotypes under stress (Camejo et al., 2005).

Lycopene(Lyco mg/100g)was estimated according to Sadasivam and Manickam (1996) using the following materials; acetone (AR grade), petroleum ether (AR),anhydrous sodium sulphate, and 5% sodium sulphate.

$$\textbf{Lyco} = \frac{31.206 \text{ x Absorbance}}{\text{weight of sample (g)}}$$

Average fruit weight (FW); was measured as the average weight in grams of 10 fruits for each plot as follows:

$$Fw = \frac{\text{Total weight of 10 fruits}}{10}$$

Total yield (TYP kg/plot) was determined by adding the total weight of all picked fruits per plot. Firmness (Firm inch/cm^2) was estimated by the average of ten fruits using fruit pressure tester of the fruit using stainless steel borne of 10 mm in diameter. Total soluble solids (TSS) were measured using a hand refractometer.

Statistical analysis:

Statistical analyses were applied to obtain the analyses of variance of all traits. The statistical model was applied according to steel and Torrie 1960 using random model as follows:

$$Yij = \mu + G_i + R_j + E_{ij}$$

Where:

Y_{ij}:the *ith* genotype value in the *jth* replication; μ: population means; G_i: the *ith* genotype effect; R_j: the *jth* replicate effect;E_{ij}:the experimental error effect

Genetic analysis

The dissimilarity matrix of 50 genotypes was established by the method of means linkage between groups (UPGMA) using Mahalanobis distance obtained from 13 quantitative traits. A factorial model was applied using 4 lines as female and 6 lines as male for generating 24 F1 crosses according the method proposed by Miranda Filho and Geraldi (1984). Including parental lines, provide unbiased estimates of effects with lower standard error by providing additional estimates for combining ability effects (Sij and Sji) and enable an assessment of parental potential *per se*. The ANOVA, the general and specific combining ability effects were estimated using statistical software program GENES (Cruz, 2013). The amount of heterosis was estimated as the deviation of F1 mean performance from the mid parent (MP) and better parent (BP) as follows:

$$H\%(BP) = \frac{F_1 - BP}{BP} x\,100 \;\; ; \;\; H\%(MP) = \frac{F_1 - MP}{MP} x\,100$$

RESULTS AND DISCUSSION

I.Screening trial for heat tolerant sources based on morphophysiological and yield traits

In this experiment, forty nine genotypes in addition to strain B as a check variety were used in order to assay their performance under the heat tolerance stress. The analysis of variance showed that the mean squares of the genotypes were highly significant for all studied traits indicating the different response of these genotypes under exposure to target stress (Tables 1 and 2). Besides, the same Tables show the coefficient of variance values (CV%) where their values were in the logical ranges except for some biochemical traits such as Chl a/b, Chl T/Caro and lycopene were relatively high. Furthermore, genetic coefficient and coefficient of heritability in broad sense for the majority of studied traits (Tables 3 and 4) revealed magnitude of the genetic variance relative to the total phenotypic variance. This coefficient of heritability (h^2%) was greater than 90% for most studied traits except Chl a/b, Chl T/Car ratio, TSS and Lycopene. The ratio CVg/CVe was more than 1.00 concluding the same finding.

Table 1. Analysis of variance and mean squares for vegetative and some biochemical traits in tomato evaluated in randomized complete blocks during summer season 2013.

SV	Df	PH	NBP	LA	Fset%	Chl T	Chl a/b	Caro	ChlT/Caro
Blocks	2	10.01	1.147	1443.5	41.42	0.015	0.075	0.002	0.019
Genotypes	49	619.1**	12.65**	30466**	674.1**	0.137**	0.460**	0.708**	1.103**
Error	98	19.44	0.875	777.43	20.87	0.009	0.106	0.006	0.126
Mean		82.37	19.27	365.2	41.11	1.44	1.910	0.710	2.340
CV(%)		5.350	4.850	7.634	11.11	6.47	16.97	11.06	15.18

**and * significant at 1% and 5% probability levels respectively by F test

Table 2. Analysis of variance and mean squares for yield and some fruit characters in tomato during summer season 2013.

SV	df	AFW	TYP	TSS	Firm	Lyco
Blocks	2	11.128	34.05	0.057	0.003	1.265
Genotypes	49	2496.7**	763.1**	0.705**	3.137**	5.262**
Error	98	61.35	17.41	0.092	0.078	0.828
Mean		70.94	35.18	5.530	2.280	2.870
CV(%)		11.04	11.86	5.480	12.20	31.74

** and * significant at 1 and 5% probability levels respectively by F test

Table 3. Estimates of genetic and phenotypic parameters for vegetative and some biochemical traits evaluated in tomato

Description	PH	NPB	LA	Fset%	ChlT	Chla/Chlb	Caro	ChlT/Car
Range	52.46	13.00	190.1	9.430	0.910	1.150	0.350	0.430
	108.6	24.00	727.0	73.54	1.940	4.100	3.290	4.450
CVg (%)	17.16	10.28	27.24	35.90	14.41	17.95	67.95	24.42
CVg/Cve	3.21	2.120	3.570	3.230	2.230	1.060	6.140	1.610
S² G	199.9	3.925	9896	217.8	0.043	0.118	0.234	0.326
S² E	19.44	0.875	777.4	20.87	0.009	0.106	0.006	0.126
H (%)	96.86	93.09	97.45	96.90	93.70	77.06	99.12	88.59

Table 4. Estimates of genetic and phenotypic parameters for fruit characters evaluated in tomato

Description	AFW	TSS	Firm	Lyco	TYP
Range	22.30	4.000	0.300	0.160	6.700
	159.3	6.700	4.400	7.430	69.53
CVg (%)	40.16	8.170	44.23	42.41	44.81
CVg/Cve	3.640	1.490	3.620	1.340	3.780
S^2 G	811.8	0.204	1.020	1.478	248.6
S^2 E	61.35	0.092	0.078	0.828	17.41
H (%)	97.54	86.96	97.53	84.27	97.72

II. Mean performance

Four vegetative traits; plant height (PH) in cm, number of branches per plant (NBP), leave area (LA) in cm^2, percentage of fruit set (F set %), in addition to three biochemical traits; total chlorophyll (Chl T) mg per gram tissue, the chl a/b ratio and Chl T/Carotenoid (Chl T/Car) were estimated for the fifty genotypes under the field condition of heat stress as shown in Table 5. The average temperature of day/night was 32˚C and 23.7 ˚C, respectively during the flowering stage with mean relative humidity of 85.4% Max. and 52.6%Min. The general mean of plant height was 82 cm which ranged from 57 to 102 cm recorded by BGH-0160 and BGH-0243, respectively with highly significant differences among the genotypes. Also, a highly significant ($p<0.01$) variation was observed among the 50 genotypes for number of branches per plant which ranged from 14 to 23 recorded by BGH-2004 and BGH-0468, respectively. Although, the impact of high temperatures is not limited to fruit set, it represents an important factor which was sensitive to heat and strongly correlated with yield (Berry and Uddin, 1988; Metwally *et al*., 2004). In this context, the percentage of fruit set ranged from 12.7 % to 66.5% for BGH-1706 and BGH-0226, respectively while the overall mean of this trait was 41.11% that would be considered as moderate under the heat stress. The estimation of chlorophyll content as indirect indicator of photosynthesis rate showed high variability over the 50 genotypes and ranged from 1.028 to 1.859 mg per gram recorded by Red Rock and BGH-0226, respectively.

The importance of estimations the chl a/b and chl T/ carotenoid ratios were observed by Camejo *et al*., 2005 who found relationship between the genotypes for heat tolerant which showed increasing in the chl a/b ratio and decreasing in the chlorophyll/carotenoid ratio. Rong et al., 2015 also reported similar finding related to higher leaf pigment content and higher total phenolic content in the heat-tolerant tomato genotypes than the heat-sensitive under heat stress. It worth to note that significant positive correlation of 0.323 (data not shown) was detected between the percentage of fruit set and chl a/b ratio while this correlation was not significant for chlorophyll/carotenoid ratio. In general, among the highest genotypes for high chl a/b ratio were BGH-0468, BGH-2048, BGH-0185, BGH-2215 and LA0345. On the other hand the genotypes BGH-2057, BGH-1214, BGH-3338, BGH-1987 and Avalanche were among the genotypes with low chlorophyll/carotenoid ratio.

The average fruit weight in gms (AFW), yield per plot (TYP kg), fruit firmness (Firm inch/cm^2), total soluble solids (TSS) and lycopene concentration (Lyco mg/100gm) were estimated and presented in Table 6. High genetic variability was observed for AFW which ranged from 27 to 151.7gms recorded by BGH-1254 and BGH-0025, respectively with general mean of 70.94 gms. The small fruit is most common due to adverse effects of high temperature on the production of auxins in the fruit. Regarding the yield per plot, the genotypes differed in their yield as it was expected from fruit set % and also the variation in growth vigor over the genotypes. The genotypes BHG-2026, BGH-1706, BGH-0993 and BGH-2000 gave less than 10kg/plot with less than 0.5kg/plant which considered very low yield and uneconomical. While 12 genotypes gave more than 50kg/plot where the genotypes LA0535 and BGH-0226 recorded the highest mean values of 63.15 and 61.88 kg/plot, respectively and considered the highest yield under heat stress. It worth to mention that a highly significant positive correlation has been reported between fruit set and yield under heat stress in tomato. Therefore, identifying heat-tolerance sources in tomato has been depended upon screening for fruit set under high temperature (Berry and Rafique-Uddin, 1988).

Regarding fruit firmness which represents a critical aspect of tomato quality, due to the high temperatures during the fruit development stage, the majority of genotypes suffered from this stress except late genotypes that less affected by high temperatures comparing to the others. Among these genotypes, BGH-1214, BGH-2057, BGH-0984 and BGH-3474 recorded 4.26, 3.73, 3.63 and 3.63 inch/cm^2, respectively. For TSS, a narrow range was recorded among the evaluated genotypes where TSS ranged from 4.36 to 6.5% for BGH-2004 and strain B, respectively and it appeared that this trait was not affect by high temperature stress. A wide range of lycopene concentration was observed among the evaluated genotypes in the field. The high temperature inhibits fruit ripening and the formation of lycopene the principal pigment in tomato fruits. Statistically, this trait ranged from 0.280 to 6.47 mg/100mg recorded by LA0535 and BGH-7466, respectively while the standard variety has 3.77 mg/100mg lycopene.

III. Cluster analysis and genetic distance

The estimation of genetic divergence is the first step in any breeding program for parent selection. The assessment of genetic diversity aid the breeder in choosing promising parents for breeding program where this process would be more effective when depend upon the divergence analysis (Latif *et al*., 2011). Hence, the data of five traits; fruit set %, chl a/b ratio, carotenoid, average fruit weight and total yield per plot were standardized before to calculate the Mahalanobis distances among the 50 tomato genotypes and an UPGMA dendrogram was constructed (Figure 1).

Table 5.The mean performance of forty nine genotypes in addition strain B check variety for vegetative and some biochemical traits in tomato.

No.	Genotype	PH	LA	NPB	F set %	Chl T	Chl a/b	ChlT/Car
1	BGH-0160	57.13	314.4	15.67	31.84	1.737	1.782	3.026
2	BGH-0243	102.1	239.1	22.00	41.54	1.644	1.891	2.624
3	BGH-0773	70.46	695.4	15.33	48.91	1.411	1.953	2.106
4	BGH-1214	59.79	634.4	19.67	42.88	1.601	1.790	0.494
5	BGH-0025	87.46	340.4	20.67	54.54	1.659	1.829	2.914
6	BGH-0468	92.13	211.5	23.33	61.91	1.670	3.320	2.687
7	BGH-0984	94.46	409.8	20.67	47.41	1.781	1.603	2.393
8	BGH-0987	100.5	317.9	21.33	58.39	1.529	2.015	2.488
9	BGH-1987	90.79	353.8	20.67	29.81	1.628	1.744	1.590
10	BGH-7466	66.46	536.3	16.67	65.51	1.701	1.509	3.131
11	BGH-7299	93.13	323.5	19.33	40.43	1.212	1.633	2.082
12	BGH-7474	76.46	543.9	19.00	55.54	1.618	1.905	2.387
13	BGH-7269	69.13	397.9	20.00	39.73	1.410	1.799	2.800
14	BGH-3474	89.13	353.4	21.00	41.17	1.745	2.015	2.127
15	BGH-3495	90.46	376.6	20.00	19.80	1.629	1.623	2.380
16	BGH-6854	98.13	359.6	17.67	46.92	1.612	2.184	2.370
17	BGH-2049	100.8	362.5	19.67	26.73	1.491	1.320	2.159
18	BGH-0226	87.13	410.2	21.00	66.51	1.860	2.243	2.580
19	BGH-0351	75.13	313.4	20.67	33.73	1.256	1.530	1.845
20	BGH-0813	88.46	415.1	21.00	43.07	1.256	1.420	2.480
21	BGH-0993	77.13	414.9	20.33	13.36	1.514	1.650	1.901
22	BGH-1254	99.13	379.3	22.00	35.83	1.132	1.483	1.693
23	BGH-0975	70.13	394.9	17.33	27.03	1.232	1.744	1.959
24	BGH-1706	66.79	424.0	19.33	12.73	1.596	1.774	2.074
25	BGH-2000	59.79	300.1	16.33	15.43	1.317	1.648	2.832
26	BGH-2004	60.23	221.5	14.00	33.81	1.524	1.889	3.136
27	BGH-2026	99.23	260.3	18.67	13.63	1.489	2.012	2.714
28	BGH-2048	64.23	533.3	15.00	50.18	1.363	3.237	2.353
29	BGH-2057	59.90	479.5	20.00	59.13	1.288	1.830	0.478
30	BGH-2016	92.23	261.9	21.00	47.58	1.581	1.847	3.601
31	BGH-7192	97.90	208.2	21.00	56.87	1.564	2.020	3.405
32	BGH-0322	92.23	379.3	20.67	51.78	1.581	2.478	2.388
33	BGH-0185	95.57	264.6	20.00	62.21	1.453	2.567	2.811
34	BGH-3383	95.57	266.4	20.67	31.84	1.377	1.668	1.556
35	BGH-6897	65.23	420.4	15.67	51.43	1.342	1.536	3.006
36	BGH-7000	100.6	260.3	19.00	49.44	1.185	1.915	2.239
37	BGH-2215	84.90	481.6	17.67	59.47	1.323	2.487	2.353
38	BGH-2276	70.90	378.0	19.67	40.10	1.394	1.803	3.241
39	BGH-2289	87.90	301.2	20.67	51.54	1.599	2.099	2.157
40	BGH-2305	90.23	347.6	19.67	19.17	1.497	2.052	2.541
41	BGH-2332	98.57	342.1	19.67	44.80	1.266	1.824	2.080
42	LA3320	98.23	293.4	19.67	32.09	1.463	2.049	2.408
43	LA0535	84.90	346.5	19.00	58.50	1.584	2.086	2.555
44	LA0345	74.23	290.8	21.00	23.09	1.055	2.281	1.843
45	EC-41824	83.23	403.6	20.33	59.47	1.110	1.507	2.641
46	EC-162935	72.90	415.4	19.67	44.51	1.158	1.701	1.683
47	Red Rock	95.90	333.4	20.00	38.80	1.028	1.602	1.879
48	Saladette	66.23	322.6	16.33	28.36	1.110	1.852	2.136
49	Avalanche	65.23	345.5	18.00	23.76	1.251	2.177	1.885
50	Strain B	59.90	282.2	16.00	23.17	1.032	1.811	2.639
LSD	5%	5.969	37.75	1.266	6.184	0.128	0.441	0.481
	1%	8.489	53.68	1.801	8.795	0.183	0.627	0.683

Table 6. The mean performances of forty nine genotypes in addition strain B check variety for yield and fruit characters in tomato.

No.	Genotype	AFW	TYP	Firm	TSS	Lyco
1	BGH-0160	85.39	22.83	3.433	4.467	3.910
2	BGH-0243	89.99	33.67	0.333	6.033	4.295
3	BGH-0773	43.18	41.70	3.300	5.167	2.703
4	BGH-1214	109.14	38.26	4.267	5.367	1.870
5	BGH-0025	151.71	44.67	3.233	5.700	3.770
6	BGH-0468	67.10	46.24	2.500	5.467	1.092
7	BGH-0984	88.42	35.74	3.633	4.567	2.594
8	BGH-0987	76.67	50.83	2.767	5.333	1.652
9	BGH-1987	92.73	20.25	0.833	6.067	1.790
10	BGH-7466	84.80	57.20	1.967	5.367	6.470
11	BGH-7299	39.47	29.68	1.000	5.633	2.337
12	BGH-7474	105.93	56.79	2.500	5.200	1.841
13	BGH-7269	44.70	30.08	2.400	5.667	1.770
14	BGH-3474	102.95	36.77	3.633	5.633	3.013
15	BGH-3495	122.25	10.95	0.767	5.533	2.151
16	BGH-6854	90.79	41.74	3.167	4.800	1.990
17	BGH-2049	34.52	18.39	0.900	5.700	2.097
18	BGH-0226	85.33	61.89	3.467	5.267	5.220
19	BGH-0351	66.53	22.17	2.200	5.533	5.470
20	BGH-0813	72.00	34.59	0.900	5.500	3.227
21	BGH-0993	35.13	8.857	2.033	5.800	3.923
22	BGH-1254	27.02	23.95	0.833	5.867	2.997
23	BGH-0975	69.48	20.82	2.667	5.800	3.286
24	BGH-1706	63.08	7.790	2.767	5.967	1.693
25	BGH-2000	124.3	9.960	2.767	6.333	3.395
26	BGH-2004	128.1	27.09	3.200	4.367	3.084
27	BGH-2026	89.48	7.767	0.833	5.967	2.682
28	BGH-2048	76.50	46.08	3.333	5.233	2.350
29	BGH-2057	78.82	53.57	3.733	5.767	2.893
30	BGH-2016	116.4	39.17	3.067	5.700	1.547
31	BGH-7192	65.33	54.23	2.367	5.100	1.784
32	BGH-0322	52.33	43.27	3.267	4.533	2.297
33	BGH-0185	58.07	55.98	2.533	5.867	1.278
34	BGH-3383	86.21	27.12	1.000	6.200	1.817
35	BGH-6897	80.97	55.23	1.900	5.200	1.623
36	BGH-7000	87.47	41.60	1.200	5.667	1.663
37	BGH-2215	59.25	58.03	2.633	4.767	5.030
38	BGH-2276	53.79	34.32	2.233	5.733	3.097
39	BGH-2289	47.16	51.10	3.433	5.733	2.663
40	BGH-2305	53.13	17.30	1.100	5.833	4.650
41	BGH-2332	56.78	43.15	3.067	5.400	3.256
42	LA3320	48.58	26.43	0.933	5.467	3.331
43	LA0535	43.20	63.15	3.467	5.233	0.280
44	LA0345	34.39	18.74	1.533	5.267	3.703
45	EC-41824	47.98	54.84	1.033	5.267	0.837
46	EC-162935	44.97	40.76	1.900	5.533	3.037
47	Red Rock	48.65	39.57	1.033	6.133	6.053
48	Saladette	36.57	27.15	2.433	5.967	2.255
49	Avalanche	39.57	13.31	2.367	6.367	3.806
50	Strain B	40.85	14.39	2.300	6.500	3.771
LSD	5%	10.60	5.649	0.411	0.105	1.232
	1%	15.08	8.033	0.584	0.149	1.752

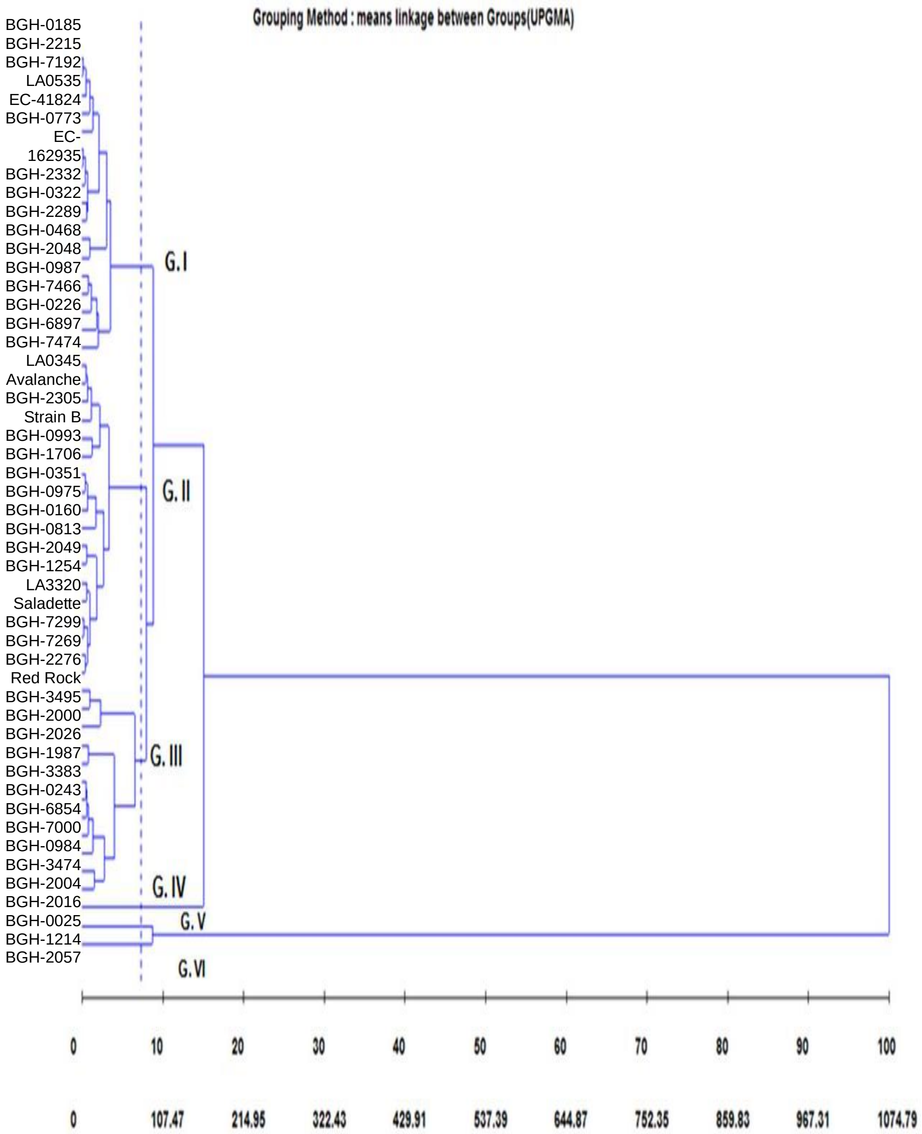

Figure1. Dendrogram of genetic dissimilarity of 50 genotypes of tomato established by the method of means linkage between groups (UPGMA) using Mahalanobis distance obtained from different quantitative traits.

The dendrogram of the 50 tomato genotypes were grouped into 6 major groups at 7.29% dissimilarity coefficients. Group II recorded the highest number of individuals with 18 genotypes followed by group III with 17 genotypes and V with 12 genotypes. Groups IV, V and VI had 1 genotype each. The individuals of Group V and VI gave the highest carotenoid value while the individual of group VI recorded the highest average fruit weight. While the majority of Group I individuals gave the highest fruit set % and yield.

V. factorial analysis

The analysis of variance of the factorial analysis for vegetative traits, yield and some fruit characters in tomato are presented in Table 7. Highly significant differences were found among genotypes for all studied traits. The mean squares of general combining ability (GCA) as well as specific combining ability (SCA) were highly significant for the majority of studied traits except number of branches per plant, early yield per plot and AFW for GCA (male) and EYP, AFW, Firm and lyco their mean squares for GCA (female) were insignificant. Thus, the significance of GCA and SCA revealed that the importance of both additive and non-additive types of variation for all studied traits, even additive genes were more important than the dominant genes. Similar findings were reported by Shankar *et al.*, 2013; Metwally *et al*., 2004; Shende *et al*. 2012 and Alex 2015.

The mean performance of parental varieties and their 24 F1 hybrids for vegetative traits, yield and some fruit characters in tomato is presented in Table 8. The means showed that no specific parent and/or cross were superior or inferior for all studied traits. However, of the parental varieties, the greatest mean were observed in BGH-0468for PH, NBP and LA with means 96.93, 25.33 and 724.00, respectively. While, the greatest overall value for TSS and Firm were recorded in BGH-2057. Among the F1 hybrids per se, the maximum PH was formed by the crosses 1x7 and 4x9 (130 cm). While the highest values of NBP, LA, F set% and firmness were found in the cross 2x9. For early yield, the cross 3x10 recorded maximum EYP value (8.05 kg/plot) for the first two harvests. While the lycopene content reached its highest value in the crosses 1x10 and 1x9, respectively.

Table 7. Analysis of combining ability variance and mean squares for vegetative traits, yield and some fruit characters in tomato.

S.O.V	DF	PH	NBP	LA	F set %	EYP	Y Pot	AFW	TSS	Firm	Lyco
Reps.	2	145.05	27.30	7808.2	343.4	0.427	15.44**	199.8	0.644	0.091	0.379
Genotypes	33	1246.02**	51.44**	126352.8**	666.63**	7.597**	720.6**	2030.5**	1.638**	3.528**	8.694**
Parents	9	603.53**	26.03**	58959.9**	888.87**	7.954**	967.02**	3561.92**	0.240^{ns}	1.907**	9.933**
P vs hybrids	1	4689.35**	66.34**	114885.7**	622.2**	0.748^{ns}	640.28**	0.2226**	1.378*	3.630**	0.8493*
GCA Male	3	3339.18**	79.77^{ns}	463927.4**	566.5**	5.399^{ns}	708.81**	4634.9^{ns}	4.156**	11.66**	27.32**
GCA Female	5	1922.89**	152.66**	274327.4**	2848.2**	8.824^{ns}	2746.72**	1049.3^{ns}	5.381**	2.928^{ns}	3.459^{ns}
SCA MxF	15	568.86*	36.02**	25433.31**	133.3**	8.327**	176.79**	575.21**	0.9049**	1.901**	3.309**
Error	66	47.65	7.14	3669.2	17.19	0.457	27.11	52.77	0.273	0.212	0.212

**** and* significant at 1% and 5% probability levels respectively by F test**

Table 8. The mean performance of selected parental varieties and their 24 F1 hybrids for vegetative traits yield and some fruit characters in tomato.

Genotypes		PH	NBP	LA	F set%	EYP	TYP	AFW	TSS	Firm	Lyco
BGH-2004 (1)		61.33	16.62	464.07	26.23	3.992	22.28	134.30	4.637	3.395	3.247
BGH-0025 (2)		86.11	22.14	623.27	53.50	1.917	41.14	148.47	5.193	3.333	3.622
BGH-3474 (3)		94.62	20.99	682.40	35.34	4.329	35.21	112.20	4.768	3.169	3.185
BGH-2000 (4)		61.88	15.96	560.23	12.40	3.091	10.58	123.20	5.101	3.102	3.150
BGH-0468 (5)		96.93	25.33	724.00	55.60	2.917	46.99	63.55	5.249	2.680	1.696
BGH-7466 (6)		69.08	16.84	397.40	61.49	4.690	60.02	91.85	5.176	2.256	6.483
BGH-0226 (7)		88.53	20.91	694.17	62.49	6.492	61.58	86.05	5.367	3.784	5.360
BGH-2057 (8)		61.59	20.91	500.97	60.33	4.498	55.18	82.89	5.642	3.940	2.971
LA0535 (9)		85.88	18.29	314.60	58.16	3.251	64.74	48.69	5.234	3.418	0.506
EC-41824 (10)		86.07	21.36	425.00	53.47	7.241	54.60	52.28	5.162	1.240	1.042
1x5		119.29	19.32	547.62	37.76	3.167	32.73	74.81	5.104	3.413	3.837
1x6		109.26	25.47	963.64	44.10	4.220	60.10	93.36	6.573	3.032	4.000
1x7		130.69	23.76	951.36	45.00	7.563	57.47	86.44	5.067	5.183	3.195
1x8		73.99	20.36	821.06	22.40	4.063	16.37	83.79	6.140	1.940	2.792
1x9		74.39	11.14	392.39	47.47	3.113	37.76	118.70	5.311	2.798	5.254
1x10		86.99	20.66	602.10	64.13	5.643	49.84	145.35	5.397	1.797	6.193
2x5		98.96	20.10	604.73	49.54	1.913	45.54	97.07	4.545	2.473	4.365
2x6		73.70	20.43	498.80	30.43	2.770	25.10	106.66	5.697	2.548	4.691
2x7		102.69	16.43	613.29	45.80	2.463	41.08	114.70	4.446	4.167	4.543
2x8		75.29	21.40	934.09	59.87	3.747	61.13	134.09	4.413	4.270	5.072
2x9		85.36	30.47	1044.10	70.13	3.063	46.21	128.43	4.500	5.120	3.653
2x10		76.36	15.10	953.10	36.73	3.280	36.84	95.73	5.297	3.447	2.104
3x5		67.39	14.47	437.76	31.06	3.308	62.40	74.10	5.637	5.510	2.902
3x6		91.30	21.39	671.73	55.10	4.727	58.10	100.07	6.733	3.330	2.737
3x7		84.03	22.10	555.69	48.17	6.357	43.47	93.06	5.465	4.970	2.020
3x8		62.10	22.10	363.43	13.70	3.733	30.40	110.27	6.897	3.963	1.391
3x9		78.07	26.43	343.73	39.10	2.437	30.17	69.73	4.801	3.537	0.999
3x10		86.36	24.13	392.76	43.07	8.057	54.07	78.05	4.957	4.660	1.298
4x5		107.69	26.42	478.80	50.73	3.013	30.44	100.00	6.180	4.507	0.676
4x6		94.39	22.73	319.13	28.07	4.550	23.06	76.07	7.213	3.543	0.696
4x7		139.80	23.69	434.72	36.13	4.317	23.44	80.74	4.808	1.697	1.002
4x8		100.76	20.70	542.73	38.47	2.583	39.76	76.74	5.245	2.630	1.385
4x9		130.73	29.76	789.00	40.50	3.327	35.32	67.23	3.893	1.533	0.710
4x10		108.40	22.36	438.64	24.42	5.880	12.80	56.70	5.473	2.630	4.708
LSD	5%	11.16	4.32	97.93	6.70	1.09	2.66	11.74	0.85	0.74	0.74
	1%	14.75	5.71	129.43	8.86	1.45	3.52	15.52	1.12	0.98	0.98

VI. The mid-parent heterosis

The F1 hybrids exhibited considerable mid-parent heterosis for vegetative traits, yield and fruit characters under the heat stress condition (Table 9). The magnitude of average heterosis varied from -13.8 to 89.7% for PH. Since the cross 4x7 showed maximum positive and significant heterosis value followed by the cross 1x5. While for other vegetative traits, it ranged from -62 to 52%. For EYP, the heterosis ranged from -48.2 to 117.3% with 20 hybrids have lower early yield than their respective mid-parental values. Regarding TYP, the heterosis varied from -85.6 to 61.1% where the cross 3x5 had the maximum total yield value. For AFW, the heterosis ranged from -24.4 to 182.8% in the cross 4x6. Regarding fruit quality traits, for TSS, the cross 4x6 showed the highest heterosis value relative to mid-parent whereas, the fruits of cross 4x10 had maximum heterosis values of 199.7 and 124.7 for firmness and lycopene content, respectively.

In respect to heterosis relative to the better parent (Table 10), the results showed that most of studied crosses exhibited different heterotic values which would be due to the difference in the performance of the genotypes when subjected to high temperatures of field. However, ten out of twenty four crosses exhibited positive and significant heterosis relative to their better parents for PH. While for NBP, a total of 11 hybrids showed less number of branches per plant comparing with its better parent. While 16 hybrids were less in their leave area although the hybrid 1x6 showed the highest heterosis value of (107.65%) for LA. For fruit set %, the highest heterosis value was 20.58 % for the hybrid 2x9 relative to its better parent. This could be attributed to the relative high values of fruit set in their parents and the heat stress conditions that negatively affected this trait which is strongly correlated with yield. Consequently, the EYP and TYP were affected with this fact where the highest values of heterosis were 16.53 and 32.79, respectively. Regarding AFW, the hybrid 1x10 was the only one that exhibited positive heterosis relative to its better parent of 8.23%. For fruit quality traits, TSS, firmness and lycopene, the maximum heterosis values were found in the hybrids 4x6, 3x5 and 1x10, respectively. Only three hybrids exhibited moderate heterosis for lycopene content under high temperatures of field.

Table 9. Heterosis relative to the mid parent of 24 F1 hybrids for vegetative traits, yield and some fruit characters in tomato.

Hybrids	PH	NBP	LA	F set%	EYP	TYP	AFW	TSS	Firm	Lyco
1x5	50.8**	-7.89	-7.81	-7.70	-39.6**	-5.49	-24.4**	3.27	12.4	55.2**
1x6	19.4**	7.30	43.1**	-19.2**	-0.59	36.4**	-11.9	25.9**	0.84	50.4**
1x7	36.5**	2.59	35.3**	-1.03	108.8**	39.8**	-1.64	1.16	77.2**	30.9*
1x8	-6.82	-1.36	27.9**	-34.11**	-27.7**	-80.8**	144.1**	47.0**	21.4	15.2
1x9	14.09	-33.4**	-8.90	8.22	-26.0*	-8.23	4.97	8.24	-0.96	8.00
1x10	12.11	5.99	18.0**	11.5*	75.9**	-1.47	21.0**	4.09	-35.7**	22.6**
2x5	20.90**	6.27	12.0	2.31	-26.0	-4.36	-4.86	-8.59	-8.82	-9.71
2x6	12.55	24.6*	4.17	-17.6*	-39.5**	-72.6**	120.0**	37.6**	83.9**	-2.60
2x7	37.0	-12.4	5.90	3.24	-54.5**	-2.04	4.10	-11.1	16.1	5.56
2x8	-13.78*	-0.58	41.8**	3.23	-15.1	19.0**	14.3	-16.4*	20.0*	12.95
2x9	-6.79	45.4**	51.7**	43.4**	-19.2	-4.53	29.6**	-11.2	47.3**	-14.50
2x10	1.53	-18.1	52.0**	-1.91	-43.3**	-60.1**	110.0**	25.08**	60.3**	-50.56**
3x5	9.65	-22.9*	-9.28	-28.2**	-31.0**	61.1**	-31.8**	9.69	50.2**	-6.64
3x6	23.6**	-0.63	19.5**	-3.19	24.6	20.6**	-13.5	24.3**	-8.43	-17.0
3x7	7.59	5.47	-6.08	0.70	100.5**	-3.82	-4.60	4.99	39.8**	-34.4
3x8	0.59	19.9	-31.5**	-62.3**	-27.7**	-65.9**	150.6**	57.7**	77.9**	-54.5**
3x9	6.06	51.4**	-11.7	-7.34	-48.2**	-30.7**	-23.8*	-2.73	3.83	-46.7**
3x10	0.42	19.4*	-16.2	-22.9**	117.3**	2.12	-20.8*	-4.93	38.1**	-37.1*
4x5	19.3**	34.5**	-3.95	8.52	-2.30	-39.1**	24.3*	23.6**	36.8**	-63.4**
4x6	27.8**	32.7**	-27.0**	-20.4*	-10.4	-75.5**	182.8**	73.1	80.2**	-61.9**
4x7	89.7**	24.8*	-2.21	-9.33	-22.8**	-39.0**	-13.5	-1.87	-26.8	-53.3**
4x8	17.04**	-4.85	3.55	-28.1**	-43.8**	-16.9*	-23.5**	1.29	15.0	-40.6**
4x9	44.70**	40.5**	42.5**	-8.80	-16.2	-21.3*	-18.3	-21.6**	-30.5*	-66.4**
4x10	46.54**	19.8	-11.0	-25.8**	-1.43	-85.6**	97.6**	32.5**	199.7**	124.7**
LSD 5%	9.67	3.74	84.81	5.81	0.95	7.29	17.62	0.73	0.65	0.65
LSD 1%	12.77	4.95	112.09	7.67	1.25	9.64	23.28	0.97	0.85	0.85

Table 10. Heterosis relative to the better parent of 24 F1 hybrids for vegetative traits, yield and some fruit and characters in tomato.

Hybrids	PH	NBP	LA	F set%	EYP	TYP	AFW	TSS	Firm	Lyco
1x5	23.07**	-23.73**	-24.36**	-32.09**	-20.63	-30.35**	-44.30**	-2.76	0.53	18.43
1x6	58.16**	53.25**	107.65*	-28.28**	-10.02	0.13	-30.50**	26.99**	-10.69	-38.27**
1x7	47.62**	13.63	37.05**	-27.99**	16.53	-6.67**	-35.64**	-5.59	36.97**	-40.39**
1x8	20.13*	-2.63	63.89**	-62.87**	-9.51	-70.33**	-37.61**	8.83	-50.76**	-13.83
1x9	-13.38*	-39.09**	-15.45	-18.38**	-21.98	-41.67**	-11.62*	1.47	-18.14	62.16**
1x10	1.07	-3.41	29.74**	19.94**	-22.06**	-8.72**	8.23	4.55	-47.07**	91.14**
2x5	14.92*	-20.65*	-16.47*	-10.90	-34.26*	-3.09	-34.62**	-13.41	-25.74*	20.58*
2x6	-14.41*	-7.72	-19.97*	-50.51**	-40.94**	-58.18**	-28.16**	9.71	-23.48*	-27.61**
2x7	15.99	-25.79*	-11.65	-26.71**	-62.05**	-33.29**	-22.75**	-17.16	10.24	-15.24*
2x8	-12.57	-3.34	49.87**	-0.76	-16.55	10.78**	-9.69*	-21.78**	8.38	40.11**
2x9	-0.87	37.62**	67.52**	20.58**	-5.75	-28.62**	-13.50**	-14.02	50.15**	0.91
2x10	-11.32	-31.80**	52.92**	-31.31**	-54.70**	-32.53**	-35.52**	2.00	3.51	-41.88**
3x5	-30.48**	-42.87**	-39.54**	-44.14**	-23.43*	32.79**	-33.96**	7.39	74.37**	-8.74
3x6	-3.51	1.91	-1.56	-10.39	0.79	-3.20	-10.81*	30.08**	5.38	-57.76**
3x7	-11.19	5.69	-19.95**	-22.92**	-2.05	-29.41**	-17.06**	1.83	31.48**	-62.31**
3x8	-34.37*	5.69	-46.74**	-77.29**	-16.86	-44.91**	-1.72	22.24**	0.58	-56.26**
3x9	-17.49*	25.92*	-49.63**	-33.28**	-43.59**	-53.40**	-37.85**	-8.27	3.72	-68.58**
3x10	-8.73	12.97	-42.44**	-19.45**	11.28	-0.97	-30.44**	-3.97	47.47**	-59.18**
4x5	11.10	4.30	-33.87**	-8.76	-2.49	-53.16**	-18.83**	17.74*	45.39**	-78.54**
4x6	36.64**	34.98**	-43.04**	-54.35**	-2.99	-61.58**	-38.25**	39.35**	14.29	-89.26**
4x7	57.91**	13.30	-37.38**	-42.18**	-33.48**	-61.94**	-34.46**	-10.42	-55.11**	-81.31**
4x8	62.83**	-1.00	-3.12	-36.23**	-42.47**	-27.94**	-37.71**	-7.04	-33.25**	-56.03**
4x9	52.22**	62.71**	40.84**	-30.36**	2.37	-45.44**	-45.43**	-25.62**	-55.04**	-77.46**
4x10	25.94**	4.68	-21.70*	-54.33**	-18.78*	-76.56**	-53.98**	6.02	-15.16	49.46**
LSD 5%	11.16	4.32	97.93	6.70	1.09	2.66	11.74	0.85	0.74	0.74
LSD 1%	14.75	5.71	129.43	8.86	1.45	3.52	15.52	1.12	0.98	0.98

The effects of general combining ability effects (gi) and specific combining ability effects (Sij) are presented in Tables 11 and 12, respectively. Positive and negative estimates would indicate that a given much better or much poorer than the average of the group involved with it. Among the female lines, BGH-2004 exhibited maximum positive gi effect of 5.097, while among the male lines, BGH-0226 displayed highest gi effect of 22.26 for PH. Regarding, NBP and LA, which sharing the common female and male parents BGH-3474 and BGH-0226 showed the highest gi effects. On other hand, the female line BGH-0025 exhibited the highest gi effect but the cross resulted from BGH-3474 x BGH-0226 gave the highest Sij effect for fruit set % revealing that the female line BGH3474 and male BGH-0226 would produce promising progenies to improve PH, NBP, LA and F set%. In respect to EYP, the female line BGH-0025 and male line LA0535 exhibited the maximum negative values for gi, of -0.517 and -1.715, respectively. While the female line BGH-3474 and male line BGH-7466 gave the highest gi effects for total yield per plot (TYP). Regarding to average fruit weight (AFW), the female line BGH-0025 and male line BGH-0468 were the best parents to improve fruit weight. Finally, for fruit quality traits, TSS and Firmness which shared a common female parent of BGH-2000 did not show any best combination for all fruits quality (Table 11).

Table 11. General combining ability effects (gi) of parental varieties for vegetative traits yield and some fruit characters in tomato.

Parents	PH	NBP	LA	F set%	EYP	TYP	AFW	TSS	Firm	Lyco
BGH-2004	5.097**	0.312	30.81*	-2.413*	0.455*	-1.951	-6.624**	0.050	-0.063	-0.097
BGH-0025	0.134	-0.242	-55.91**	5.508**	-0.517**	0.978	9.148**	-0.032	-0.471**	0.646**
BGH-3474	2.402	0.635	100.6**	3.972**	-0.124	2.494*	2.411	-0.346*	0.235*	0.045
BGH-2000	-7.634**	-0.705	-75.46**	-7.067**	0.186	-1.521	-4.934*	0.328*	0.299*	-0.594**
SE (gi)	1.091	0.422	9.578	0.656	0.107	0.823	1.149	0.083	0.073	0.073
BGH-0468	19.95**	2.086**	74.32**	4.534**	-0.292	4.520**	29.84**	0.731**	0.727**	0.515**
BGH-7466	12.88**	3.409**	140.2**	13.65**	0.937**	14.68**	19.90**	1.040**	0.189	1.895**
BGH-0226	22.26**	5.365**	212.5**	14.81**	1.458**	10.51**	18.04**	0.646**	1.235**	1.018**
BGH-2057	1.417	3.060**	99.23**	-1.638	0.328*	-1.590	-40.06**	1.271**	0.543**	0.139
LA0535	-28.28**	-7.344**	-276.9**	-15.09**	-1.715**	-12.79**	-39.16**	-1.835**	-1.075**	-1.850**
EC-41824	-28.23**	-6.576**	-249.3**	-16.26**	-0.717**	-15.32**	29.84**	-1.853**	-1.619**	-1.716**
SE (gi)	1.286	0.498	11.29	0.773	0.126	0.970	1.354	0.097	0.086	0.086

The genotypes with high genetic distant are able to exhibit high heterosis (Falconer, 1981). According to the variation and diversity analysis, the female genotype LA0535 from group I having stable high yield across the two seasons of 2014 and 2015 and good donor for fruit set, TSS and firmness, however it was poor in lycopene. The hybrid 2x9 showed high adaptation against heat stress under field condition in 2015 with high total yield, leave area number of branches per plant, average fruit weight and fruit firmness but low lycopene. Therefore, for a breeding program, involving LA0535, BGH-0025, BGH-7466 would yield an improving lines for heat tolerance and yield.

Table 12. Specific combining ability effects among and their 24 F1 hybrids for vegetative traits, yield and some fruit characters in tomato.

F	M	PH	NBP	LA	F set%	EYP	TYP	AFW	TSS	Firm	Lyco
1	5	29.75**	1.610	-39.52	1.316	-0.044	-2.877	-7.945*	0.265	0.148	0.770**
1	6	26.79**	6.438**	310.6**	-1.455	-0.220	14.34**	-7.790*	1.425**	0.305	-0.448
1	7	38.84**	2.772	226.1**	15.93**	2.603**	15.88**	-4.776	0.314	1.409**	-0.376
1	8	2.982	1.677	209.0**	-7.873**	0.233	-13.13**	-5.567	0.761**	-1.142**	0.101
1	9	-41.31**	-8.280**	-235.9**	-16.82**	-1.788**	-18.30**	-31.25**	-2.273**	-1.464**	-0.703**
1	10	-41.36**	-9.047**	-263.5**	-15.65**	-2.786**	-15.76**	-32.15**	-2.255**	-0.919**	-0.837**
2	5	-10.19**	-6.016**	-108.0**	3.106	0.875*	-0.776	20.17**	0.555	-0.060	1.444**
2	6	9.486*	2.182	35.77	10.66**	2.176**	1.147	28.43**	0.332	-0.522*	1.003**
2	7	12.07**	-0.334	-33.83	-5.096*	-2.075**	1.017	-9.918*	-0.126	-0.893**	0.052
2	8	7.655*	2.301	-26.53	-7.763**	-0.088	-7.33*	1.531	0.401	-0.126	1.257**
2	9	-36.35**	-7.726**	-149.2**	-24.74**	-0.816*	-21.23**	-47.02**	-2.191**	-1.056**	-1.446**
2	10	-36.40**	-8.493**	-176.8**	-23.57**	-1.813**	-18.69**	-47.92**	-2.173**	-0.512*	-1.580**
3	5	15.84**	-1.603	-43.61	2.972	-0.169	1.028	22.91**	0.004	0.603*	1.333**
3	6	-4.482	2.045	211.3**	7.931**	-0.114	10.92**	23.91**	-0.338	1.245**	0.482*
3	7	-3.799	9.159**	249.1**	17.03**	-1.319**	0.171	28.18**	0.144	1.048**	-0.060
3	8	8.047*	-3.907**	271.3**	0.074	0.028	2.898	-2.662	0.315	0.067	-0.730**
3	9	-38.62**	-8.603**	-305.7**	-23.21**	-1.209**	-22.74**	-40.29**	-1.876**	-1.762**	-0.845**
3	10	-38.66**	-9.370**	-333.3**	-22.03**	-2.207**	-20.21**	-41.18**	-1.858**	-1.218**	-0.979**
4	5	-9.423*	-2.223	-43.11	-0.730	0.366	26.36**	-10.34*	0.521	1.883**	0.331
4	6	21.56**	3.375*	124.9**	14.20**	0.556	11.91**	-2.770	1.308**	0.241	-1.214**
4	7	4.907	2.129	-63.32	6.108*	1.666**	1.446	0.154	0.434	0.835**	-1.054**
4	8	3.823	4.434**	-142.3**	-11.92**	0.172	0.473	19.22**	1.241**	0.520*	-0.804**
4	9	-28.58**	-7.263**	-129.6**	-12.17**	-1.519**	-18.73**	-32.94**	-2.550**	-1.826**	-0.206
4	10	-28.63**	-8.030**	-157.2**	-11.00**	-2.517**	-16.19**	-33.84**	-2.532**	-1.281**	-0.340
SD (Sij)		3.545	1.372	31.11	2.129	0.347	2.674	3.730	0.268	0.236	0.236

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الانتخاب لتحمل الحرارة المرتفعة لبعض السلالات المستوردة من الطماطم

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يعد تـاثير الحـرارة العاليـة علـى انتـاج محصـول الطمـاطم فـى مصـر خـلال فصـل الصـيف مـن المشـاكل الخطيرة , حيث ان درجة الحرارة المرتفعة لها تأثيرسلبى علي العقد في الطماطم. وخاصة فى العروة الصيفية والتى يكون إزهارها يتوافق مع الارتفاع الشديد فى درجات الحرارة اثناء النهار و درجة حرارة الليل ايضا. وبالتالى فان اسعار الطماطم الطازجة ترتفع بنسبة من 400% الى 500%خلال هذه الفترة مع رداءة جودة المعروض. لذا كـان الهدف مـن هذه الدراسـة تقييم بعض المصـادرالوراثية الجديدة لمجموعـة مـن السـلالات المستوردة والاصناف المنزرعة لتحمل الحرارة العالية وانتخاب افضل الاباء منها لاستخدامها فى التحسين لتحمل الضغوط الحرارية. اجريت جميع التجارب خلال الاعوام من 2013 الى 2015 حيث تم تقييم 50 تركيب وراثـى فـى تجربـة مـن قطاعـات كاملـة العشـوائية تحـت ظـروف الحـرارة العاليـة الطبيعيـة وتـم دراسـة الصفات التالية : طول النبات, عدد الافرع للنبات, مساحة الورقة, نسبة العقد, نسبة كلورفيل الكلية a و b , نسبة الكاروتين بلأضـافة الـى صـفة المحصـول و بعـض صـفات جـودة الثمـار. وقد تـم انتخـاب عشـرة تراكيب وراثية تم استخدامهم كأباء فى نظام تزاوج عاملى يشمل 4 اباء اناث و6 اباء ذكور.

وكانت اهم النتائج التى تم التوصل اليها كالاتى:

اشارت معنوية متوسط المربعات إلى وجود فروق بين التراكيب الوراثية لجميع الصفات المدروسة. وأوضحت نتائج المتوسطات أن متوسط صفة نسبة العقد كان يتراوح بين 12.7% الى 66.5%, واعطى 12 تركيب وراثى اعلى من 50 كجم/للقطعة التجريبية لصفة المحصول الكلى وقد سجلت السلالات LA0535 and BGH-0226 اعلى قيم لصفة المحصول63.15 و61.88 كجم/ للقطعة التجريبية. وبتحليل القدرة على التآلف أشارت النتائج إلى أن متوسط المربعات الراجع للقدرة العامة على التآلف و القدرة الخاصة على التآلف كانت عالية المعنوية لمعظم الصفات المدروسة وهذا يشير إلى أن كل من الفعل الجينى الإضافي وغير الإضافي يساهم في التعبير الوراثي لهذه الصفات. أشارت نتائج تأثير القدرة العامة على التآلف لكل سلالة إلى ان السلالة BGH-2004 كانت من افضل السلالات المستخدمة كامهات من حيث القدرة على التالف بينما السلالة BGH-0226 من افضل السلالات المستخدمة كاباء من حيث القدرة على التالف لصف طول النبات. بينما أظهرت الهجن الناتجة من السلالة BGH-3474 كأم و BGH-7466 كأب افضل الهجن قوة خاصة على التآلف لصفة المحصول الكلى. وتبعا للتحليل العنقودى و الاختلاف كان التركيب الوراثى LA0535 من المجموعة الاولى لديه ثبات عالى لصفة المحصول خلال الموسمين 2014 و2015 وافضل معطى لنسبة العقد ونسبة المواد الصلبة الذائبة والصلابة ولكن ثماره كانت فقيرة فى نسبة الليكوبين. واظهر الهجين 5 x 2 اعلى قدرة على التأقلم للحرارة المرتفعة تحت ظروف الحقل خلال الموسم 2015 وكان الافضل فى صفة المحصول الكلى, مساحة الورقة و عدد الافرع للنبات, متوسط وزن الثمرة, ولكنه الاقل فى نسبة الليكوبين. لذا يوصى باتباع برنامج التهجين بين السلالات LA0535, BGH-0025, BGH-7466 لتحمل الحرارة المرتفعة والحصول على انتاج عالى.