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Half Diallel Analysis of Some Quantitative Traits in Tomato under Drought Stress Conditions.

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Abstract

The present experiment was performed to classify best combiner parents and cross combinations for developing hybrids for quality components in tomato under drought stress (DS) compared with irrigated control (I), using half diallel analysis for six parents and their fifteen hybrids. The parental genotypes are *Solanum pimpenillifolium* (LA:411) and five cultivated genotypes *Solanum lycopersicum*, i. e. , Edkawi , Super Marmande , Super Strain B, Castle Rock and Peto 86 for some characters, i. e. , length of fruit (cm), fruit diameter (cm), fruit shape index, locules number, average fruit weight (g), fruit flesh thickness (cm), fruit firmness ($g/_{3mm}$), and total soluble solid (brix). The results indicated that heterosis over mid parent gave significant values in most crosses, i. e. , the hybrid Edkawi ×Super Marmande for length of fruit (cm), fruit shape index, fruit flesh thickness (cm) and fruit firmness ($g/_{3mm}$) and the hybrid Edkawi×Super Strain B for fruit diameter (cm), locules number, fruit flesh thickness (cm) and average fruit weight (g). Also, these hybrids showed high values for specific combining ability (SCA). Based on the general combining ability (GCA) effects, the best combiners were the parental genotypes LA411 for total soluble solid, Edkawi for fruit diameter (cm), locules number and average fruit weight (g) and Super Strain B for length of fruit (cm), fruit shape index and fruit firmness ($g/_{3mm}$) .

Introduction

Tomato, formerly classified as *Lycopersicon esculentum* Wettsd (2n = 2x = 24), and currenty named as *Solanum lycopersicum* Mill based on morphological and molecular studies **(Rick *et al.*, 1980).** Tomato is grown in a diversity of climatic conditions and is susceptible to frost and high extreme temperature.

Tomato crop is one of the most common and extensively grown vegetables next to potato at the international level. Tomato is identified as protective food not only because of its highly nutritional value but also for its high content of antioxidants.

The current mandate of tomato is depending on the industrial and consumer's needs. Consequently, there is an essential need for further development of superior varieties/hybrids of tomato to meet the current necessities.

Drought tolerance of tomato plants has usually been expressed as the decrease in yield at a given level of water stress compared with the yield of non water-stressed plants. The performance of tomato genotypes under drought stress showed significant differences in fruit length, fruit diameter, fruit flesh thickness, locules number, fruit shape index, fruit firmness, total soluble solids and average fruit weight traits, suggesting that they could be taken into account when selecting for drought tolerance. **(Wahb-Allah *et al.*, 2011).**

Hybrid vigour in tomato was first determined by (**Hedrick and Booth, 1907).** Exploitation of heterosis in vegetable crops was done in various aspects with great improvement. The commercial possibilities of F1 hybrid production in tomato have been reported by Wellington (1912). Breeding of F1 hybrid is prominent among the approaches used in the crop enhancement of vegetable crops.

According to **Hallauer, 1999** the exact genetic basis of heterosis may never be known and understood because of allelic interactions of alleles at a locus, interactions of alleles at different loci, interactions of the nucleus and cytoplasm and interactions of the genotype and environment. However, heterosis will continue to have a main role in the future plant improvement even though our knowledge on its genetic basis is limited. Heterosis in tomato was monitored in several crosses **(Fortuny *et al.*, 2021).** Tomato being a self-pollinated vegetable crop has enormous potential for heterosis breeding. That is why, many commercial hybrids have been developed. Hybrids introduce opportunities for improving earliness, productivity, uniformity and quality of yield, (**Riggs, 1988).**

Hybrids and parents could be exploited and selected based on combining ability through breeding approaches in crop improvement **(Shankar *et al.*, 2013).** GCA effects caused by the additive type of gene action and SCA effects are due to non-additive (dominant or epistatic) gene action. Half diallel cross analysis was proposed by **(Griffing, 1956).** It is the quickest and most appropriate approach for obtaining worthwhile information on different cross combinations by assessing the genetic makeup of parental lines.

Through this method, the GCA and SCA effects give very effective genetic information for deciding the next phase of breeding programe

(Eswara Reddy *et al.*, 2017). Valuable information on heritability and heterosis can be easily obtained **(Saleem *et al.*, 2013).** It also helps in the selection of suitable parents for hybridization **(Rakha and Sabry, 2019)**.

Substantial genetic variation in drought tolerance exists within cultivated tomato genotypes, as well as within its related wild species *Lycopersicon pimpinellifolium*, **(Wudiri and Henderson, 1985).**

A primary task in breeding for stress tolerance is the identification and genetic characterization of useful germplasm. The objectives of this study were to evaluate drought tolerance of six tomato parental genotypes and their 15 hybrid combinations in order to identify best combiner parents to develop promising hybrids with drought tolerance and high quality characteristics which can be produced locally at low cost, and to obtain valuable information on the genetic controle of some quantitative characters which will be useful in tomato breeding programs.

Materials and Methods

This study was conducted during the period from 2018 to 2020 in the greenhouse at Kaha vegetable research farm, Qalubia Governorate, Egypt.

Six tomato genotypes were chosen and crossed following half diallel approach to produce 15 F_1 hybrids. The chosen parental genotypes included one wild type, i.e. , *Solanum pimpenillifolium* (LA:411) and five cultivated genotypes *Solanum lycopersicum*, i. e. , Edkawi , Super Marmande , Super Strain B, Castle Rock and Peto 86. Seeds of these parental genotypes were sown in September and transplanted in October 2018.

Crosses between these parental genotype were conducted during the 2018/2019 winter season in greenhouse to produce the F_1s seeds. Parental genotypes and their F_1 hybrids were evaluated in successive winter planting of 2020 under greenhouse conditions. Seeding and transplanting dates were August 27 and September 24 in the season of 2019.

The experimental design used was randomized complete blocks design (RCBD) with three replications.

Drought experiment

In the second season (2020), irrigation treatments were started after 7 days from transplanting. Two irrigation treatments drought stress (DS) and irrigated control (I), DS = 50% and I = 100% where a drip irrigation system was gave 2Liters/2Hours as irrigation control and 1Liter/1Hour as drought stress twice weekly. **(Wahb-Allah *et al*, 2011).**

Data of ten randomly selected plants of each parental genotype and cross in each replication were randomly record assigned to length of fruit (cm), fruit diameter (cm), fruit shape index (L / D), number of fruit locules, average fruit weight (g), fruit flesh thickness (cm) and quality parameters, fruit firmness (g/3mm), total soluble solids (brix). The readings were taken from freshly harvested fruits, and averaged over replications to calculate data means which were used for statistical analysis.

Analysis of variance of complete randomized block design was conducted and LSD test was used for mean comparisons of different genotypes for all traits according to (**Cochran and Cox, 1957).** General and specific combining ability analysis was performance according to the procedure given by (**Griffing, 1956).**

Heterosis

Heterosis based on the mid and parent was estimated according to the following equations **(Sinha and Khanna, 1975):**

Mid-parent heterosis $= \frac{\overline{F1}-\overline{MP}}{\overline{MP}} \times 100$

Where:

$\overline{MP}$=Mean of the mid-parent.

$\overline{F1}$ =Mean of the first generation hybrid.

Better parent heterosis $= \frac{\overline{F1}-\overline{BP}}{\overline{BP}} \times 100$

Where:

$\overline{BP}$=Mean of the better parent.

$\overline{F1}$ =Mean of the first generation hybrid

Heritability

Heritability values in broad sense (h^2_b %) were calculated according to **(Mather and Jinks, 1971).**

A combining ability analysis was carried out according to **(Singh and Chaudhary, 1979)** based on **(Griffing, 1956)**, method II, model 1.

Results and Discussion

Mean Performance of Parents and F1 Hybrids

Analysis of variance (Table 1a&b) show significant differences among genotypes for (fruit length, fruit diameter, fruit flesh thickness, locules number, fruit shape index, fruit firmness, total soluble solids and average fruit weight.) the studied characters under irrigated control (I) and drought stress (DS) conditions.

Table 1a: Mean squares for analysis of variance of tomato genotypes for the characters fruit length, fruit diameter, fruit flesh thickness, locules number and fruit shape index.

Source of Variance	Degrees of Freedom	Fruit length (cm)		Fruit diameter (cm)		Fruit flesh thickness (cm)		Locules number		Fruit shape index	
		I	DS	I	DS	I	DS	I	DS	I	DS
Genotypes	20	6.135 *	6.44*	9.795	10.734	0.171	0.169	14.787	7.452	0.08	0.076
Error	40	0.128	0.149	0.212	0.409	0.004	0.003	0.461	0.745	0.008	0.007

*** significance at 5% level.**

Table 1b: Mean squares for analysis of variance of tomato genotypes for the characters fruit firmness, total soluble solids and average fruit weight.

Source of Variance	Degrees of Freedom	Fruit firmness (g/3mm)		Total Soluble Solids (Brix)		Average fruit weight (g)	
		I	DS	I	DS	I	DS
Genotypes	20.000	167968.611*	65925.278*	3.463*	4.947*	13053.867*	14189.428*
Error	40.000	11188.909	8731.825	0.156	0.191	360.665	1246.874

*** significance at 5% level.**

Significant differences were observed among several genotypes (parents and crosses) under irrigated control (I) and drought stress (DS) conditions (Table 2a).

The parental cultivar Super Strain B showed the highest mean value of fruit length under drought and irrigation conditions comparing to other parents, i.e. 5.783 cm and 5.700 cm , respectively. In addition the F1 hybrid Edkawi × Super Marmand showed the highest fruit length under both drought and irrigation conditions , i.e. 5.600 cm and 5.950 cm, respectively.

The parental cultivar Edkawi showed the highest mean value of fruit diameter under drought and irrigation conditions comparing to other parents, i.e. 9.300 cm and 7.983 cm , respectively. In addition the F1 hybrid Edkawi × Super Strain B showed the highest fruit diameter comparing to other F1 hybrids under both drought and irrigation conditions , i.e. 6.533 cm and 7.533 cm, respectively.

The parental cultivar Peto 86 showed the highest mean value of fruit flesh thickness under drought and irrigation conditions comparing to other parents, i.e. 0.733 cm and 0.733 cm , respectively. In addition the F1 hybrid Edkawi × Castle Rock showed the highest fruit flesh thickness comparing to other F1 hybrids under both drought and irrigation conditions , i.e. 0.783 cm and 0.783 cm, respectively.

The parental cultivar Edkawi showed the highest mean value of locules number under drought and irrigation conditions comparing to other parents, i.e. 8.000 and 8.667 , respectively. In addition the F1hybrid Edkawi × Super Strain B showed the highest locules number comparing to other F1 hybrids under both drought and irrigation conditions , i.e. 7.000 and 9.000 , respectively.

The parental cultivar Peto 86 showed the highest mean value of fruit shape index under drought and irrigation conditions comparing to other parents, i.e. 1.206 and 1.261 , respectively. In addition the F1hybrid Edkawi × Super Marmand showed the highest fruit shape index comparing to other F1 hybrids under both drought and irrigation conditions , i.e. 1.211 and 1.009, respectively.

Significant differences were observed among several genotypes (parents and crosses) under irrigated control (I) and drought sress (DS) conditions (Table 2b).

The parental cultivar Castle Rock showed the highest mean value of fruit firmness under drought conditions comparing to other parental genotypes, i.e. 776.667 g/3mm. In addition the hybrid Edkawi × Super Marmand showed the highest fruit firmness under both drought and irrigation conditions comparing to other F1 hybrids, i.e. 823.333 $g/_{3mm}$. and 1236.667 $g/_{3mm}$., respectively, and the hybrid Castel Rock× Peto 86 showed highfruit firmness under drought conditions , i.e. 933.333 $g/_{3mm.}$, comparing to other F1 hybrids.

The parental line LA411 showed the highest mean value of total soluble solids under drought and irrigation conditions comparing to other parental cultivars, i.e. 9.333 and 8.833, respectively. In addition the F1 hybrid LA411 × Edkawi showed the highest total soluble solids under both drought and irrigation conditions comparing to other F1 hybrids , i.e. 7.667 and 7.333, respectively.

Table 2a: Mean performance of tomato genotypes for the characters fruit length, fruit diameter, fruit flesh thickness, locules number and fruit shape index.

genotypes	Fruit length (cm)		Fruit diameter (cm)		Fruit flesh thickness (cm)		locules number		Fruit shape index	
	I	DS	I	DS	I	DS	I	DS	I	DS
P1	1.100	1.083	1.133	0.973	0.050	0.050	3.000	3.000	1.112	0.970
P2	4.883	5.067	7.983	9.300	0.667	0.767	8.667	8.000	0.544	0.630
P3	4.650	3.933	7.317	5.800	0.733	0.650	9.000	5.667	0.707	0.637
P4	5.700	5.783	5.400	5.533	0.467	0.667	4.667	4.333	1.047	1.062
P5	5.533	5.617	5.667	5.033	0.633	0.633	4.000	3.667	1.150	0.989
P6	5.183	5.583	4.300	4.433	0.733	0.733	2.333	2.000	1.261	1.206
P1×P2	2.617	1.950	2.867	2.100	0.133	0.200	2.000	2.000	0.928	0.912
P1×P3	2.183	2.137	2.317	2.317	0.203	0.233	2.667	2.333	0.922	0.947
P1×P4	2.267	2.000	2.167	2.167	0.183	0.150	2.000	3.000	0.923	1.048
P1×P5	1.733	2.050	1.917	2.227	0.100	0.217	2.000	2.000	0.924	0.905
P1×P6	4.683	4.433	4.983	5.333	0.683	0.633	2.667	3.333	0.832	0.940
P2×P3	5.950	5.600	4.933	5.600	0.667	0.733	3.333	4.667	1.009	1.211
P2×P4	4.900	4.400	7.533	6.533	0.700	0.727	9.000	7.000	0.678	0.650
P2×P5	4.800	5.333	5.300	5.433	0.783	0.783	5.333	4.667	0.983	0.909
P2×P6	4.400	4.850	5.300	5.633	0.733	0.750	4.333	4.000	0.863	0.830
P3×P4	5.367	5.533	5.200	5.667	0.550	0.700	4.333	4.333	0.976	1.032
P3×P5	4.533	4.950	4.700	5.633	0.540	0.750	3.333	4.000	0.880	0.966
P3×P6	4.900	4.633	5.283	5.700	0.617	0.667	4.000	4.333	0.815	0.930
P4×P5	3.717	4.733	4.133	5.367	0.600	0.700	2.333	3.000	0.882	0.901
P4×P6	5.083	4.983	5.183	4.767	0.650	0.667	3.333	3.000	1.045	0.982
P5×P6	5.683	4.270	5.067	4.183	0.667	0.517	3.000	2.667	1.020	1.124
LSD 5%	0.591	0.637	0.759	1.055	0.106	0.093	1.121	1.425	0.145	0.135

I=irrigated control, DS=drought stress, P1= LA411, P2= Edkawi, P3= Super Marmmande, P4= Super Strain B, P5= Castle Rock, P6= Peto 86 .

The parental cultivar Edkawi showed the highest mean value of average fruit weight under drought conditions comparing to other parents, i.e. 259.370 g. In addition the F1 hybrid Edkawi × super Strain B showed the highest average fruit weight under drought conditions comparing to other F1 hybrids , i.e. 225.600g.

Heterosis

Presented data in table (3a) show heterosis in the 15 F1 crosses for the characters, fruit length (cm), fruit diameter (cm), fruit flesh thickness (cm), locules number and fruit shape index. Heterosis (%) was estimated as percent of increase or decrease of F1 values over mid parent (MP).

The F1 hybrid Edkawi × Super Marmand showed the highest positive heterosis of fruit length, and fruit shape index under drought conditions , i.e.(123.256 %)and (50.602 %), respectively.

The hybrid F1 Edkawi×Super Strain B showed highe positive heterosis of fruit diameter , fruit flesh thickness and locules number under drought conditions , i.e. (100.820 %), (102.791%) and (90.909%), respectively.

The F1 hybrid LA411× Super Marmand showed highe positive heterosis of fruit shape index under drought and irrigation conditions , i.e. 49.425 %, respectively. While The hybrid Edkawi × Super Marmand showed the highest positive heterosis of fruit shape index under drought conditions , i.e. 50.602 %.

Table (3b) is showing the heterosis (%) over mid-parent for the 15 F1 hybrids of tomato concerning the characters fruit firmness, total soluble solids and average fruit weight (g).

The F1 hybrid Edkawi × Super Marmand showed the highest positive heterosis of fruit firmness under drought and irrigation conditions comparing to other F1 hybrids , i.e. 50.381 % and 152.381%, respectively.

The F1 hybrid LA411 × Super Strain B showed the highest positive heterosis of total soluble solids under drought conditions , i.e. 41.066 %.

The F1 hybrid Edkawi× Super Strain B showed the highest positive heterosis of average fruit weight under drought and irrigation conditions , i.e. 352.860 % and 190.727%, respectively.

Table 2b : Mean performance of tomato genotypes for the characters fruit firmness, total soluble solids and average fruit weight.

geotypes	Fruit firmness (g/3mm)		Total Soluble Solids (Brix)		Average fruit weight (g)	
	I	DS	I	DS	I	DS
P1	516.667	536.667	8.833	9.333	0.500	0.500
P2	355.000	436.667	4.500	5.300	230.643	259.370
P3	463.333	558.333	4.333	4.233	248.667	133.863
P4	1100.000	686.667	5.833	5.333	107.633	99.133
P5	820.000	776.667	5.667	6.000	78.743	101.737
P6	823.333	703.333	5.667	6.500	63.560	47.033
P1×P2	411.667	526.667	7.333	7.667	6.573	5.760
P1×P3	533.333	523.333	6.833	6.333	7.920	5.583
P1×P4	700.000	665.000	5.000	4.833	7.140	8.300
P1×P5	663.333	840.000	6.333	7.167	7.333	7.187
P1×P6	793.333	493.333	4.833	4.667	7.198	6.833
P2×P3	1236.667	823.333	5.833	6.333	92.757	120.083
P2×P4	623.333	720.000	7.167	7.500	157.187	225.600
P2×P5	966.667	773.333	5.167	5.167	108.530	87.817
P2×P6	753.333	650.000	6.000	6.000	70.670	93.333
P3×P4	935.000	883.333	5.000	5.167	86.827	101.867
P3×P5	803.333	540.000	6.333	5.000	62.490	98.600
P3×P6	933.333	826.667	5.333	4.667	88.013	67.340
P4×P5	830.000	803.333	6.167	5.333	82.917	73.623
P4×P6	1103.333	871.667	5.083	7.000	83.037	78.923
P5×P6	933.333	933.333	5.000	7.500	88.807	61.033
LSD 5%	174.548	154.196	0.652	0.720	31.338	58.268

I=irrigated control, DS=drought stress, P1= LA411, P2= Edkawi, P3= Super Marmmande, P4= Super Strain B, P5= Castle Rock, P6= Peto 86 .

Table 3a : Mid-parent heterosis(%) caculated for the 15 F_1 tomato crosses for the characters fruit length, fruit diameter, fruit flesh thickness, Locules number and fruit shape index.

cross	Fruit length		Fruit diameter		Fruit flesh thickness		locules number		Fruit shape index	
	I	DS	I	DS	I	DS	I	DS	I	DS
P1×P2	-12.535	-36.585*	-37.112*	-59.117*	-62.791*	-51.020*	-65.714*	-63.636*	12.099	14.009
P1×P3	-54.196*	-52.519	-69.717*	-69.316*	-70.952*	-67.059*	-69.811*	-65.854*	47.433	49.425
P1×P4	-57.165*	-63.134*	-67.621*	-70.787*	-67.647	-79.070*	-70.000*	-51.351	16.075*	23.874
P1×P5	36.683*	47.761*	38.235*	87.569	58.049*	119.512*	-4.762*	20.000	-22.176*	-1.345
P1×P6	55.968*	39.000*	94.479*	110.851*	57.447*	70.213*	50.000	73.333	-31.339*	-14.561
P2×P3	106.957*	123.256*	16.765*	65.354*	70.213	109.524	-44.444*	7.692*	10.963*	50.602*
P2×P4	44.118	28.155*	130.612*	100.820	170.968*	102.791	134.783*	90.909	-37.185	-36.005*
P2×P5	-7.840	-0.156	-22.344*	-24.186*	20.513*	11.905	-15.789	-20.000*	16.044*	12.260*
P2×P6	-12.583*	-8.920	-13.704*	-17.961*	4.762	0.000	-21.212*	-20.000	-4.437	-9.563
P3×P4	3.704	13.894*	-18.218*	0.000	-8.333	6.329	-36.585*	-13.333	11.280	21.389
P3×P5	-65.957	-57.068	-70.475*	-58.892	-85.366*	-66.234*	-69.231*	-57.143	-0.427	11.289*
P3×P6	-4.746	-6.830	-14.204	4.235	-6.818*	-8.434	-52.941*	-13.043	-15.455*	1.957*
P4×P5	-33.828*	-16.959*	-25.301*	1.577	9.091	7.692	-46.154	-25.000	-19.662*	-12.162
P4×P6	-6.585	-12.317*	6.873	-4.348	8.333	-4.762	-4.762	-5.263	-9.402	-13.408
P5×P6	6.065	-23.750*	1.672	-11.620	-2.439	-24.390	-5.263	-5.882	-15.343*	2.471

I=irrigated control, DS=drought stress, P1= LA411, P2= Edkawi, P3= Super Marmmande, P4= Super Strain B, P5= Castle Rock, P6= Peto 86

*** significance at 5% level..**

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Table 3b: Heterosis of 15 F_1 tomato crosses for the characters fruit firmness, total soluble solids and average fruit weight.

	Fruit firmness		Total Soluble Solids		Average fruit weight	
cross	**I**	**DS**	**I**	**DS**	**I**	**DS**
P1×P2	-5.545	8.219	10.000*	4.784	-94.312*	-95.567*
P1×P3	30.346	5.193	54.717	32.867	-96.695*	-97.160*
P1×P4	-14.318*	28.190	38.710*	41.066*	-95.779*	-95.370*
P1×P5	3.377	25.843*	26.667*	40.065	-95.520*	-93.899*
P1×P6	23.316	-21.797	-3.333*	-13.043*	-53.892*	-92.445*
P2×P3	152.381*	50.381*	-11.392*	-6.634*	-25.546*	78.744*
P2×P4	-13.402	8.719	-31.818	-34.091	190.727*	352.860*
P2×P5	64.539*	27.473*	1.639	-8.555	-29.842*	-51.362*
P2×P6	27.864	14.035	18.033*	1.695*	-51.958*	-39.078
P3×P4	19.616	41.901*	-1.639	8.014	-51.262*	-12.560
P3×P5	20.200	-17.766	-12.644*	-34.783	57.717*	92.886
P3×P6	39.303*	33.333*	-26.437	-41.053	174.784*	183.338
P4×P5	-13.542	9.795	7.246	-5.882	-11.022	-26.696
P4×P6	14.731	25.420	-11.594*	18.310*	-2.991	7.991
P5×P6	13.590	26.126*	-11.765*	20.000*	24.813	-17.949

I=irrigated control, DS=drought stress, P1= LA411, P2= Edkawi, P3= Super Marmmande, P4= Super Strain B, P5= Castle Rock, P6= Peto 86 .
 * significance at 5% level.

Data presented data in table (4) show the better-parent heterosis in the 15 F1 crosses for the characters fruit length, fruit diameter, fruit flesh thickness, locules number, fruit shape index, fruit firmness, total soluble solids and average fruit weight. Heterosis (%) was estimated as percent of increase or decrease of F1 values over better parent (BP). The F1 hybrid Edkawi × Super Marmand showed the highest positive better-parent heterosis of fruit length, fruit firmness and total soluble solids under drought conditions , i.e.(12%),(47.4%) and (19.4%), respectively.

The F1 hybrid Edkawi×Super Strain B showed the highest positive heterosis of locules number under drought conditions , i.e. (62.8%) .

The F1hybrid Edkawi×Castle Rock showed the highest positive heterosis of average fruit weight under drought conditions , i.e. 66.1%.

The hybrids Super Marmand× Super Strain B, Super Strain B×Peto86, Castel Rock×Peto86, Super Marmand×Peto86 and Super Strain B× Castle Rock showed the highest positive heterosis of fruit firmness under drought conditions , i.e. 28.6%, 26.9% , 20.2%, 17.5% and 17% respectively.

Table 4: Heterosis for better parent of 15 F_1 tomato crosses for the characters fruit length, fruit diameter, fruit flesh thickness, Locules number, fruit shape index, fruit firmness, total soluble solids and average fruit weight.

cross	Fruit length		Fruit diameter		Fruit flesh thickness		locules number		Fruit shape index		Fruit firmness		Total Soluble Solids		Average fruit weight	
	I	**DS**	**I**	**DS**	**I**	**DS**	**I**	**DS**	**I**	**DS**	**I**	**DS**	**I**	**DS**	**I**	**DS**
P1×P2	-46.9*	-60	-63.8*	-77.4*	-85.7	-75*	-77	-75*	-15.5	-6.2	-20.3	-1.9	-16.9*	-16.7*	-97.2*	-97.8*
P1×P3	-55.1*	-58	-71.3*	-75.3*	-72.6*	-74*	-70*	-71.3*	29.6	48.4	15.1	-0.1	-22.6	-32.2	-96.8*	-95.8*
P1×P4	-59.6*	-65.5	-72.5*	-76.3*	-70.2*	-80*	-77*	-62.5*	-12.3	3.8*	-43.3*	4.8	-19.4*	-19.6*	-93.4*	-91.6
P1×P5	-69.1*	-64.3	-83.6*	-62*	-86.3*	-66.2*	-77.8*	-64.9*	-22.5	-8.1	-19.1	8.1	-28.3	-23.7*	-90.7*	-92.9
P1×P6	-9.6	-21.4	-31.5*	-8.2	-7.9	-13.7*	-70*	-42.1*	-30.8*	-14.5	-3.6	-29.9	-44.7	-49.9*	-88.7*	-85.5*
P2×P3	22.5	12	-31.5*	-3.4	0.0	12.5*	-63.3*	-17.5	-9.1	23.7	139.5*	47.4*	29.5*	19.4*	-62.7*	-53.7*

P2×P4	-14*	-24.1	36.8	18.2	40	14.9*	91.5	62.8	-33.3*	-41*	-36.4*	-3.2	-14.2*	-17.2*	-31.8*	13*
P2×P5	-12.7*	-5.4	-33.8*	-32.5*	19.4*	3.9*	-39.1*	-41.3*	-14.8	-8.1*	17.9	-0.4	-8.7	-12.2*	-52.9*	66.1*
P2×P6	-15.4*	-12.5	-33.8*	-30*	0.0	3.8	-50.6*	-50*	-31.7*	-31.4	-8.5	-7.6	-3.9	-7.7	-69.4*	-64*
P3×P4	-5.3	-5.2	-28.8*	-1.8	-24.7*	6	-52.2*	-24.6*	-6.6	8.3	15	28.6*	-14.2*	-1.1	-65.1*	-23.9
P3×P5	-18.2*	-12.5*	-0.2*	12	-14.3	19	-17.5	8.1	-23.5	-2	-2*	-30.5	9.7*	-16.7*	-74.9*	-26.3*
P3×P6	-5.7	-17.8*	-0.2	29.5	-15*	-8.2	33.3	43.3	-34.9	-23.1	13.4	17.5*	-7.6*	-28.2*	-64.6*	-49.7
P4×P5	-35.1*	-19*	-28*	-1.2	-4.8	4.5	-51.1*	-30.2	-26.7*	-18.2*	24.5*	17	7.5	-11.2*	-23	-27.6*
P4×P6	-10.5	-13.8*	-3.7	-12.7	-11	-8.2	29.8*	-30.2	-12.7*	-22.5	0.3	26.9*	-10.2	7.7	-22.9	-20.4
P5×P6	3.6	-23.2*	-10.5	-16	-8.2	-28.7*	25	-27	-20.6*	-12.7	13.8*	20.2*	-13.3*	15.4	12.8	-40

I=irrigated control, DS=drought stress, P1= LA411, P2= Edkawi, P3= Super Marmmande, P4= Super Strain B, P5= Castle Rock, P6= Peto 86.
*** significance at 5% level.**

Heritability

Heritability in broad sense is the ratio of total genetic variance to the total or phenotypic variance. Estimates of broad sense heritability (Table 5a) was relatively intermedidte for number of locules per fruit (36.6%) under drought stress (DS) but it was below intermediate (25.6%) under irrigated control(I). Heritability was intermediate for average fruit weight (32.1%) under drought stress (DS) but low (18.8%) under irrigated control(I)(Table 8).All the other characters gave much lower heritability (table 5a &b). These results indicate the major role of environmental conditions on the inheritance of the studied characters. Similar results had been reported by Kumari *et al.*, 2007; Islam *et al.*, 2012; Manna and Paul, 2012; Mohamed *et al.*, 2012 and Mohamed and Gaafer , 2003.

Table 5a : Broad sense hertability of tomato genotypes for the characters fruit length, fruit diameter, fruit flesh thickness, locules number and fruit shape index.

	Fruit length		**Fruit diameter**		**Fruit flesh thickness**		**Lobules number**		**Fruit shape index**	
	I	**DS**	**I**	**DS**	**I**	**DS**	**I**	**DS**	**I**	**DS**
H^2%	7.6	6.9	8.5	8.1	7.1	6.8	25.6	36.6	7.2	8.0

I= Irrigated control ,DS=drought stress,. H^2%=broad sense heritability.

Table 5b : Broad sense hertability of tomato genotypes for the characters fruit firmness, total soluble solids and average fruit weight.

	Fruit firmness		**Total Soluble Solids**		**Average fruit weight**	
	I	**DS**	**I**	**DS**	**I**	**DS**
H^2%	8.7	8.4	10.3	11.0	18.8	32.1

I= Irrigated control ,DS=drought stress,. H^2%=broad sense heritability.

Analysis of variance of combining ability(GCA,SCA)

The analysis of variance showed significant GCA the characters fruit length, fruit diameter, fruit flesh thickness, locules number, fruit firmness, total soluble solids and average fruit weight, which indicates the involvment of additive gene actions in the inheritance of those characters.

The analysis of variance showed significant SCA the characters fruit length, fruit diameter, fruit flesh thickness, Lobules number, fruit shape index, fruit firmness, total soluble solids and average fruit weight, which indicates the involvment of the non-additive genetic effects in the inheritance of those characters.

The ratio of GCA/SCA were less than one for all studied characters, i.e. fruit length, fruit diameter, fruit flesh thickness, locules number, fruit shape index, fruit firmness, total soluble solids and average fruit weight. This means that the non-additive gene actions is more important in the inheritance of all studied characters comparing to the additive gene actions. In addition, these results also explain the intermediate to low broad sense heritability estimates which were calculated for these characters (tables 5a&b).

Table 6a: Mean squares of general and specific compining ability for the characters fruit length, fruit diameter, fruit flesh thickness, Locules number and fruit shape index.

Source of Variance	**Degrees of Freedom**	**Fruit length (cm)**		**Fruit diameter (cm)**		**Fruit flesh thickness (cm)**		**locules number**		**Fruit shape index**	
		I	**DS**	**I**	**DS**	**I**	**DS**	**I**	**DS**	**I**	**DS**
General compining ability	5.000	2.385 *	1.507*	3.813*	3.184*	0.025*	0.021*	7.304*	5.204*	0.063	0.102
Spesific compining ability	15.000	15.731 *	16.891*	17.781*	19.067*	0.263*	0.283*	11.824*	8.878*	0.588*	0.564*
Error	40.000	0.043	0.050	0.071	0.136	0.001	0.001	0.154	0.248	0.003	0.002
gca/sca		0.152	0.089	0.214	0.167	0.096	0.075	0.618	0.586	0.108	0.181

*** significance at 5% level.**

Table 6b : Mean squares of general and specific compining ability for the characters fruit firmness, total soluble solids and average fruit weight.

Source of Variance	**Degrees of Freedom**	**Fruit firmness (g/3mm)**		**Total Soluble Solids (Brix)**		**Average fruit weight (g)**	
		I	**DS**	**I**	**DS**	**I**	**DS**
General compining ability	5.000	107553.009 *	68114.167*	6.808*	8.404*	4229.414*	3442.748 *
Spesific compining ability	15.000	506021.898 *	366358.889 *	20.239*	22.929*	8201.574*	8459.945 *
Error	40.000	3729.636	2910.608	0.052	0.064	120.222	415.625
gca/sca		0.213	0.186	0.336	0.367	0.516	0.407

*** significance at 5% level.**

Effect of General combing ability (GCA)

The parental cultivar Super Strain B was the best combiner showed high values of GCA for fruit length, fruit dimeter, fruit flesh thickness, locules number, fruit shape index , fruit firmness and average fruit weight under drought and irrigation conditions comparing to other parental genotypes, i.e. (0.803 cm and 0.821 cm), (0.639 cm and 0.687

cm),(0.081 cm and 0.045 cm),(0.472 and 0.486),(0.112 and 0.097), (135.208 $g/_{3mm}$ and 197.639 $g/_{3mm}$) and (20.76g and 13.45 g), respectively. These results indicate that cultivar Super Strain B is the best combiner in forming hybrids with desirable levels of performance for these characters .

The parental cultivar Edkawi showed the highest values of GCA effects for the characters fruit dimeter, locules number and average fruit weight under drought and irrigation conditions comparing to other parents, i.e.(0.724 cm and 0.550 cm),(0.847 and 0.903) and (24.88 g and 17.17 g), respectively. These results indicate that cultivar Edkawi is the best combiner in forming hybrids with desirable levels of performance for these characters .

The parental line LA411 showed the highest value of GCA effects for total soluble solids under drought and irrigation conditions comparing to other parental genotypes, i.e.(1.228 and 1.260). These results indicate that the parental line LA411is the best combiner in forming hybrids with fruits containing high total soluble solids.

The parental cultivar Super Marmand was showed high values of GCA for fruit shape index and fruit firmness under drought conditions comparing to other parental genotypes, i.e. (0.058 cm) and (55.625 $g/_{3mm}$), respectively. These results indicate that cultivar Super Marmand is good combiner in forming hybrids with desirable levels of performance for these characters.

Table 7a : General compining ability of tomato genotypes for the characters fruit length, fruit diameter, fruit flesh thickness, locules number and fruit shape index.

parents	Fruit length		Fruit diameter		Fruit flesh thickness		locules number		Fruit shape index	
	I	DS	I	DS	I	DS	I	DS	I	DS
P1	-0.133	-0.387*	-0.242	-0.368*	-0.062*	-0.057*	0.153	0.347	0.089*	0.096*
P2	-0.017	-0.049	0.550*	0.724*	0.015	0.002	0.903*	0.847*	-0.014	0.008
P3	0.381*	0.103	0.558*	0.286	0.052*	0.023	0.819*	0.347	0.032	0.058*
P4	0.821*	0.803*	0.687*	0.639*	0.045*	0.081*	0.486*	0.472	0.097*	0.112*
P5	-0.750*	-0.346*	-0.900*	-0.739*	-0.079*	-0.054*	-1.056*	-0.861*	-0.109*	-0.164*
P6	-0.302*	-0.125	-0.654*	-0.542*	0.029	0.004	-1.306*	-1.153*	-0.095*	-0.110*
CD	0.209	0.225	0.268	0.373	0.037	0.033	0.396	0.504	0.051	0.048

I=irrigated control, DS=drought stress, P1= LA411, P2= Edkawi, P3= Super Marmmande, P4= Super Strain B, P5= Castle Rock, P6= Peto 86

Table7b : General compining ability of tomato genotypes for the characters fruit firmness, total soluble solids and average fruit weight.

parents	Fruit firmness		Total Soluble Solids		Average fruit weight	
	I	DS	I	DS	I	DS
P1	38.472	27.500	1.260*	1.228*	-14.59*	-0.26
P2	-101.528*	-21.042	0.510*	0.740*	17.17*	24.88*
P3	34.722	55.625*	0.010	0.099	29.92*	-1.40
P4	197.639*	135.208*	0.333*	0.394*	13.45*	20.76*
P5	-105.069*	-82.292*	-0.885*	-1.272*	-24.35*	-13.85
P6	-64.236*	-115.000*	-1.229*	-1.189*	-21.59*	-30.13*
CD	61.712	54.517	0.231	0.255	11.08	20.60

I=irrigated control, DS=drought stress, P1= LA411, P2= Edkawi, P3= Super Marmmand, P4= Super Strain B, P5= Castle Rock, P6= Peto 86

Effects specific combing ability (SCA):

The cross combinations in (Table 8a&b) show high significant specific combining ability effect.

The F1hybrid Edkawi × Super Marmand showed positive and high values of SCA for fruit length, fruit dimeter, fruit flesh thickness ,fruit shape index and average fruit weight under drought conditions comparing to irrigation conditions. The F1hybrid Super Marmand×Castle Rock showed positive and high values of SCA for fruit length, fruit dimeter, fruit flesh thickness , locules number, fruit shape index and average fruit weight under drought conditions comparing to irrigation conditions. The F1hybrid Super Marmand×Super Strain B showed positive and high values of SCA for fruit length, fruit firmness under drought conditions comparing to irrigation conditions. The F1hybrid Super Marmand× Peto 86 showed positive and high values of SCA for fruit dimeter, fruit flesh thickness , locules number, fruit firmness under drought conditions comparing to irrigation conditions. The F1hybrid Edkawi× Peto 86 showed positive and high values of SCA for fruit length, fruit flesh thickness and average fruit weight under drought conditions comparing to irrigation conditions. The F1hybrid Edkawi× Castle Rock showed positive and high values of SCA for fruit length under drought conditions comparing to irrigation conditions. The F1hybrid LA411×Peto 86 showed positive and high values of SCA for fruit dimeter, fruit flesh thickness under drought conditions comparing to irrigation conditions. The F1hybrid Super Strain B × Castle Rock showed positive and high values of SCA for fruit shape index and fruit firmness under drought conditions comparing to irrigation conditions. The F1hybrids LA411× Super Strain B, LA411× Castle Rock and Super Strain B × Peto 86 showed positive and high values of SCA for total soluble solids under drought conditions comparing to irrigation conditions. The F1hybrid Edkawi× Super Strain B showed positive and high values of SCA for average fruit weight under drought conditions comparing to irrigation conditions. This mean of these F1hybrids were good combiners to form such hybrids with good performance concerning the previously mentioned these characters. In addition , the response of selection in the segregations generations of these hybrids will be reliable in improving these characters.

The F1hybrid Edkawi × Super Strain B showed relatively high and positive values of SCA effects under irrigation condition comparing to values observed under drought conditions for fruit dimeter, fruit flesh thickness and locules number. The F1hybrid Edkawi ×Castle Rock showed relatively high and positive values of SCA effects under irrigation condition comparing to values observed under drought conditions for fruit dimeter, fruit flesh thickness , locules number, fruit shape index, fruit firmness and average fruit weight. The F1hybrid Edkawi× Peto 86 showed relatively high and positive values of SCA effects under irrigation condition comparing to values observed under drought conditions for fruit dimeter, locules number, fruit firmness and total soluble solids. The F1hybrid Super Marmand× Peto 86 showed relatively high and positive values of SCA effects under irrigation condition comparing to values observed under drought conditions for fruit length and average fruit weight. The F1hybrid Super Strain B × Peto 86 showed relatively high and positive values of SCA effects under irrigation condition comparing to values observed under drought conditions for fruit shape index and fruit firmness. The F1hybrid Super Strain B × Castle Rock w showed relatively high and positive values of SCA effects under irrigation condition comparing to values observed under drought conditions for fruit shape index. The F1hybrid Edkawi× Super Marmand showed relatively high and positive values of SCA effects under irrigation condition comparing to values observed under drought conditions for fruit firmness. This means that the parental genotypes involved in the previously mentioned hybrids could be good combiners under drought condition but in another combinations different from that used in this study. In addition, response to selection in the segregating generations of these hybrids under drought condition could be reliable in improving those characters under drought stress.

The F1hybrid Edkawi × Peto 86 showed positive and high values of GCA& SCA effects under drought and irrigation conditions for fruit diameter. These results confirmed that parent Edkawi and parent Peto 86 were good combiners as shown in Table 7a.Transgresive segregations are expected to be found in the segregating generations of this hybrid.

Table 8a : Spesific compining ability of 15 F_1 tomato crosses for the characters fruit length, fruit diameter, fruit flesh thickness, Locules number and fruit shape index.

crosses	Fruit length		Fruit diameter		Fruit flesh thickness		locules number		Fruit shape index	
	I	DS	I	DS	I	DS	I	DS	I	DS
P1×P2	-0.971*	-1.442*	-1.658*	-2.607*	-0.284*	-0.264*	-2.833*	-2.798*	0.022	-0.026
P1×P3	-1.919*	-1.745*	-3.008*	-3.044*	-0.328*	-0.311*	-2.833*	-2.464*	0.073	0.046
P1×P4	-2.276	-2.582*	-3.288*	-3.547*	-0.341*	-0.452*	-3.167*	-1.923*	0.009	0.094
P1×P5	-3.207	-2.684*	-3.546*	-3.049*	-0.462*	-0.406*	-3.083*	-2.423*	-0.037	-0.100
P1×P6	0.866*	0.627*	0.863*	1.239*	0.138*	0.087*	-0.625	0.536	0.064	0.156*
P2×P3	1.964*	2.056*	0.400	1.331*	0.212*	0.248*	-1.417*	0.369	0.056	0.222*
P2×P4	0.474	0.156	2.871*	1.911*	0.252*	0.184*	4.583*	2.577*	-0.340*	-0.392*
P2×P5	1.829*	1.900*	1.433*	1.097*	0.383*	0.316*	1.708*	1.077	0.274*	0.230*
P2×P6	0.981*	1.196*	1.188*	1.101*	0.225*	0.224*	0.958	0.702	0.141*	0.097
P3×P4	0.426	0.800*	-0.262	0.391	-0.012	0.077	-0.750	-0.089	0.015	0.027
P3×P5	1.679*	1.855*	1.625*	2.389*	0.216*	0.342*	0.458	0.911	0.068	0.200*
P3×P6	1.597*	1.317*	1.963*	2.259*	0.185*	0.200*	1.375*	1.536*	-0.011	0.108
P4×P5	-0.092	0.448	0.129	1.116*	0.169*	0.154*	-0.875	-0.214	0.063	0.118*
P4×P6	0.826*	0.477	0.933*	0.319	0.111*	0.063	0.375	0.077	0.212*	0.145*
P5×P6	-8.369*	-7.628*	-7.729*	-7.253*	-1.081*	-0.986*	-4.417*	-4.256*	-1.648*	-1.686*
CD	0.511	0.551	0.658	0.914	0.092	0.081	0.970	1.234	0.126	0.117

I=irrigated control, DS=drought stress, P1= LA411, P2= Edkawi, P3= Super marmmande, P4= Super strain B, P5= Castle rock, P6= Peto 86

Table 8b : Spesific compining ability of 15 F_1 tomato crosses for the characters fruit firmness, total soluble solids and average fruit weight.

crosses	Fruit firmness		Total Soluble Solids		Average fruit weight	
	I	DS	I	DS	I	DS
P1×P2	-212.500*	-84.792	0.217	0.364	-70.969*	-93.213*
P1×P3	-87.083	-116.250	0.967*	0.160	-114.138*	-92.252*
P1×P4	-160.000*	0.833	0.978*	1.030*	-98.446*	-111.698*
P1×P5	-256.250*	44.167	0.644*	1.339*	-111.007*	-86.530*
P1×P6	135.625*	-52.292	0.707*	0.422	-11.315	-35.993
P2×P3	476.250*	135.208*	-0.783*	-0.328	20.461	47.392
P2×P4	-223.333*	-102.708	-1.939*	-2.124*	83.363*	130.746*
P2×P5	486.042*	271.667*	0.196	0.364	40.747*	20.433
P2×P6	231.875*	181.042*	1.374*	1.114*	20.129	24.225
P3×P4	15.417	87.500	-0.689*	-0.661*	-31.513*	8.150
P3×P5	182.708*	-10.208	0.613*	-0.290	26.469	38.360
P3×P6	271.875*	309.167*	-0.043	-0.707*	49.235*	23.375
P4×P5	50.208	145.417*	1.374*	0.876*	18.852	-7.641
P4×P6	282.708*	246.458*	0.634*	2.460*	16.214	13.934
P5×P6	-1451.250*	-1341.042*	-8.231*	-10.374*	-117.827*	-91.408*
CD	151.163	133.538	0.565	0.624	27.140	50.462

I=irrigated control, DS=drought stress, P1= LA411, P2= Edkawi, P3= Super marmmande, P4= Super strain B, P5= Castle rock, P6= Peto 86

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تحليل النصف دائرى لبعض الصفات الكميه فى الطماطم تحت ظروف الجفاف.

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هذه التجربة تعمل على تقييم احسن تألف بين الاباء والهجن لمكونات الجودة فى الطماطم تحت ظروف الاجهاد المائى مقارنة بالرى العادى.يتم استخدام تحليل النصف دائرى لستة اباء و خمسة عشر هجين تشملCastle rock وSuper Marmande و86 Peto و Super strainBو Edkawy و LA411 لدراسة الصفات الاتية : طول الثمرة , قطر الثمرة, سمك لحم الثمرة, عدد مساكن الثمرة, دليل شكل الثمرة, صلابه الثمرة, المواد الصلبة الذائبة الكلية و متوسط وزن الثمرة.

وتمت دراسه قوة الهجين على مستوى متوسط الابوين, درجه التوريث فى المعنى العام وكذلك ايضا قوة التآلف العامة والخاصة. وقد لوحظ فروق معنوية بين اغلب الهجن.

حيث الهجين Edkawi xSuper Marmand اعطى اعلى قوه هجين فى صفات طول الثمرة وسمك لحم الثمرة و دليل شكل الثمرة ودرجه الصلابة ،والهجين Edkawi x Super Strain B اعطى اعلى قوة هجين فى صفات قطر الثمرة وعدد المساكن و ووزن الثمرة. وايضا هذه الهجن اظهرت قيم عالية للقدرة الخاصة على التآلف بالاضافة الى ان احسن اباء قادرة على التآلف كانت LA411 لصفة المواد الصلبة الذائبة الكلية ، Edkawi لصفة قطر الثمرة و عدد المساكن ووزن الثمرة و Super Strain B لصفة طول الثمرة و دليل شكل الثمرة وصلابة الثمرة.