

## Mean Performance and Heterosis for Yield and Fruit Traits of Tomato under Drought Conditions

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The present study was carried out in a private farm, Kaha city, Kalyobiya Governorate, Egypt during summer seasons of 2015 and 2016 to study the mean performance and heterosis for yield and fruit traits for six tomato cultivars, i.e. Tan Shit Star ( $p_1$ ), Real Stone ( $p_2$ ), Pearsons Imp ( $p_3$ ), Super marmande ( $p_4$ ), grown under normal irrigation and drought stress. This investigation was a half diallel  $F_1$  cross experiment to induce genetic variability by hybridization and evaluation and selection for best genotypes of tomato compared with the parents under drought conditions and normal irrigation. Two adjacent experiments were conducted. Where, the first experiment was irrigated every month (environment 1) and the second one was normally irrigated, i.e., every 2 week (environment 2). The data of the two experiments were subjected to proper statistical analysis of variance and estimate the mean performance of parents and their crosses. Data indicated that the  $P_6$  gave the highest values for total yield per plant under drought stress and combined analysis, respectively while the cross  $P_1 \times P_4$  and  $P_1 \times P_6$  expressed the highest values for total yield per plant under drought stress, normal irrigation and combined analysis. Moreover the highest number of fruits was detected for the parent  $P_5$  and the cross  $P_5 \times P_6$  in drought condition, normal irrigation and combined analysis. Three, three and two crosses expressed significant or highly significant and positive heterosis relative to mid parent for fruits number in drought condition, normal irrigation and combined analysis, respectively. Moreover, highly significant and positive better parent heterosis were detected in 3, 2 and 2 crosses in drought stress, normal irrigation and combined analysis, respectively. It was clear that the cross  $P_1 \times P_4$  expressed the highest desirable heterosis relative to mid parent and better parent in the two environments treatments and combined analysis of them.

**Key words:** Heterosis, Yield, Tomato, Drought.

### Introduction

Tomato (*Lycopersicon esculentum* Mill.) is the most popular and widely grown vegetables in Egypt. The cultivated area estimated by 468510 fed. with an average yield of 16.493 tons per fed. (Ministry of Agriculture and Land Reclamation A. R. Egypt, 2015). The hybrid cultivars in tomato have generated increased interest among the breeders for the last few years. The commercial exploitation of hybrid vigor has received greater importance on account of several advantages of hybrids over pure line varieties with response to marketable fruit yield and its component traits.

The most important problems facing horizontal expansion of tomato is water shortage especially in the new reclaimed lands. Where, deficit irrigation had an opposite influences on many aspects of plants physiology, water balance, nutrient, absorption and consequently photosynthetic capacity so that, plant growth (Ibrahim, 2005; Harmanto *et al.*, 2005; Sibomana *et al.*, 2013) and production are severely decreased (Birhanu and Tilahun, 2010; Panigrahi *et al.*, 2010; Aksic *et al.* 2011 and Olanik and Madramootoo, 2014). So, drought is a major limiting factor in the production of tomato in many areas of the world including Egypt and there is considerable interest in trying to increase drought tolerance in tomato. Improving drought tolerance is, therefore, a

major objective in plant breeding programs for the new reclaimed lands. Knowledge of genetic behavior and type of gene action controlling target traits is a basic principle for designing an appropriate breeding procedure for the purpose of genetic improvement. Hence, the success of any selection or hybridization breeding program for developing drought-tolerant varieties depends on precise estimates of genetic variation components for traits of interest consisting of additive, dominant and non-allelic interaction effects (Farshadfar *et al.*, 2008; Nouri *et al.*, 2011).

The main objectives of the present investigation was assessing the variation amongst 6 genotypes and their available crosses for drought and normal conditions as well as estimate the magnitude of heterosis to improve tomato productivity under drought condition.

### Materials and Methods

The present study was carried out in a private farm, Kaha city, Kalyobiya Governorate, Egypt during summer seasons of 2015 and 2016 to study the genetic behavior of some economic traits for six tomato cultivars grown under normal irrigation and drought stress. This investigation was a half diallel  $F_1$  cross experiment to induce genetic variability by hybridization and evaluation and selection for best

genotypes of tomato compared with the parents under drought conditions and normal irrigation.

The six parental genotypes of tomato (*Solanum Lycopersicom*), i.e. Tan Shit Star (p<sub>1</sub>), Real Stone (p<sub>2</sub>), Pearsons Imp (p<sub>3</sub>), Super marmande (p<sub>4</sub>), Tomato Golden (p<sub>5</sub>) and Peto mech (p<sub>6</sub>) and their F<sub>1</sub>S hybrids were planted in successive summer plantings of 2016 under open field conditions. Two adjacent experiments were conducted. Where, the first experiment was irrigated every month (environment 1) and the second one was normally irrigated, i.e., every 2 week (environment 2). Each experiment was designed in a randomized complete block design (R.C.B.D) with three replications. Each replication block had 21 plots (seven parental varieties and their 15 F<sub>1</sub> hybrids under either drought or normal irrigation).

Three plants were selected excluding border plants for recording the observation. These observations were in yield traits viz., fruits number and total yield per plant as well as fruit traits viz., average fruit weight, fruit length, fruit diameter, total soluble solids percentage (According to A.O.A.C., 1990), total sugars (According to Flood and Priestly, 1973) and total polyphenol mg (10 .g f.w) content in the fruit.

The data of the two experiments were subjected to proper statistical analysis of variance according to Snedecor and Cochran (1967). The combined analysis was conducted for the data of the two experiments according to Cochran and Cox (1957).

Heterosis for each trait was computed as parents vs. crosses sum of squares obtained by partitioning the genotypes sum of square to its components. In this procedure, genotypes were subdivided to parents, crosses, and parents vs. crosses. This procedure made it possible to test the significance of the probable heterosis as an average overall the studied crosses.

Heterosis was also determined for individual crosses according to Paschal and Wilcox (1975) as the percentage deviation of F<sub>1</sub> mean performances from either the mid-parent value (MP) or better parent mean (BP) for F<sub>1</sub> date of each experiment as well as the combined analysis as follows:

$$\text{Mid-parent heterosis} = \frac{\bar{F}_1 - \bar{M}\bar{P}}{\bar{M}\bar{P}} \times 100 ; \text{ Better}$$

$$\text{parent heterosis} = \frac{\bar{F}_1 - \bar{B}\bar{P}}{\bar{B}\bar{P}} \times 100$$

**Results and Discussion**

**1. Mean performance:**

Data presented in Table 1 show that the highest number of fruits was detected for the parent P<sub>5</sub> (55.92, 70.00 and 62.96 fruits/plant under drought stress, normal irrigation and combined data, respectively).

**Table 1.** Mean performance of the genotypes for some flowering and yield traits under drought stress and normal irrigation (N) as well as the combined data (C).

Genotypes	Number of fruits / plant			Total fruit yield (kg/plant)		
	Drought	Normal	Combined	Drought	Normal	Combined
P <sub>1</sub>	30.92	41.63	36.27	1.95	2.76	2.35
P <sub>2</sub>	44.83	51.92	48.38	1.99	2.18	2.08
P <sub>3</sub>	25.75	33.67	29.71	1.91	2.85	2.38
P <sub>4</sub>	23.58	28.42	26.00	1.94	2.10	2.02
P <sub>5</sub>	55.92	70.00	62.96	1.48	1.99	1.74
P <sub>6</sub>	42.67	71.83	57.25	2.71	2.58	2.65
P <sub>1</sub> xP <sub>2</sub>	44.67	48.83	46.75	2.22	2.42	2.32
P <sub>1</sub> xP <sub>3</sub>	32.17	33.00	32.58	1.91	2.54	2.22
P <sub>1</sub> xP <sub>4</sub>	45.92	61.75	53.83	3.05	3.54	3.29
P <sub>1</sub> xP <sub>5</sub>	36.83	38.50	37.67	2.29	2.69	2.49
P <sub>1</sub> xP <sub>6</sub>	46.17	59.83	53.00	3.24	3.27	3.25
P <sub>2</sub> xP <sub>3</sub>	43.21	50.58	46.90	2.76	3.42	3.09
P <sub>2</sub> xP <sub>4</sub>	34.25	48.75	41.50	2.72	2.07	2.39
P <sub>2</sub> xP <sub>5</sub>	39.33	43.58	41.46	2.95	3.10	3.02
P <sub>2</sub> xP <sub>6</sub>	35.00	43.92	39.46	2.50	2.84	2.67
P <sub>3</sub> xP <sub>4</sub>	30.97	34.56	32.77	2.13	2.69	2.41
P <sub>3</sub> xP <sub>5</sub>	18.50	27.25	22.88	1.69	2.47	2.08
P <sub>3</sub> xP <sub>6</sub>	27.42	30.00	28.71	2.16	2.34	2.25
P <sub>4</sub> xP <sub>5</sub>	42.42	56.50	49.46	2.08	2.65	2.37
P <sub>4</sub> xP <sub>6</sub>	41.17	47.92	44.54	1.90	2.30	2.10
P <sub>5</sub> xP <sub>6</sub>	77.17	81.33	79.25	2.62	3.00	2.81
LSD <sub>5%</sub>	8.25	8.39	8.13	0.31	0.46	0.38
LSD <sub>1%</sub>	11.03	11.06	10.74	0.42	0.61	0.51

However, parent P<sub>4</sub> gave the lowest number of fruits with values of 23.58, 28.42 and 26.00

fruits/plant under drought condition, normal irrigation and combined analysis, respectively.

Concerning the crosses, the highest number of fruits was detected for the cross P<sub>5</sub>xP<sub>6</sub> in drought condition, normal irrigation and combined analysis with values of 77.17, 81.33 and 79.25, respectively. However, the lowest number of fruits was recorded for the cross P<sub>3</sub>xP<sub>5</sub> under drought condition, normal irrigation and combined analysis with values of 18.50, 27.25 and 22.88, respectively. High mean performance for the number of fruits have been also reported by **Rattan (2007)**, **Abdelmageed and Gruda (2009)**, **Droka et al. (2013)**, **Mehboob et al. (2015)** as well as **Alam et al. (2010)**, **Wahb-Allah et al. (2011)** and **Sacco et al. (2013)**.

Furthermore, P<sub>6</sub> gave the highest values for total yield per plant, i.e. 2.71 and 2.65 kg/plant under drought stress and combined analysis, respectively while parent P<sub>5</sub> recorded the lowest values, i.e. 1.48, 1.99 and 1.74 kg/plant under drought stress, normal irrigation and combined analysis, respectively. The cross P<sub>1</sub>xP<sub>4</sub> and P<sub>1</sub>xP<sub>6</sub> expressed the highest values for total yield per plant under drought stress (3.05 and 3.24 kg/plant, respectively), normal irrigation (3.54 and 3.27 kg/plant, respectively) and combined analysis (3.29 and 3.25 kg/plant, respectively). The genetic differences in number of fruits among tomato genotypes have been reported by **Rattan (2007)**, **Abdelmageed and Gruda (2009)**, **Mehboob et al. (2015)** and **Shakil et al. (2017)** as well as **Rehman et al. (2000)**, **Alam et al. (2010)**, **Wahb-Allah et al. (2011)** and **Sacco et al. (2013)** under stress conditions.

Mean performance of the tested tomato parents and their F<sub>1</sub> hybrids under drought condition and normal irrigation as well as combined analysis for fruit length, diameter and weight, TSS, total sugars (%) and total polyphenol contents are presented in Tables 2 and 3.

Concerning fruit length trait, the parental variety P<sub>2</sub> and P<sub>3</sub> exhibited the highest mean value for fruit length under drought stress and normal irrigation as well as combined analysis. However, the parent P<sub>5</sub> gave the lowest mean values under all environments. Results also indicated that the crosses P<sub>2</sub>xP<sub>3</sub>, P<sub>2</sub>xP<sub>5</sub> and P<sub>2</sub>xP<sub>6</sub> exhibited the highest mean values for fruit length under stress, non-stress conditions and the combined analysis, respectively (**Adhi et al. (2014)**). For fruit diameter, the parental variety P<sub>4</sub> gave the highest mean values for current trait recording 5.15, 5.87 and 5.51cm under drought treatment, normal irrigation and combined analysis, respectively. While, P<sub>5</sub> gave the lowest values, i.e., 3.37 and 3.82 cm under drought treatment and combined analysis, respectively. The cross P<sub>3</sub>xP<sub>5</sub> expressed the highest means value being 5.50 cm under stress condition. Whereas, the cross P<sub>1</sub>xP<sub>3</sub> gave the highest values for this trait in normal irrigation treatment (7.50 cm) and combined data (6.07cm). However, P<sub>1</sub>xP<sub>2</sub> recorded the lowest values under drought treatment and combined analysis with values of 3.75, 3.93 and 3.84, respectively.

**Table 2.** Mean performance of the genotypes for fruit length, fruit diameter and average fruit weight traits under drought stress (D) and normal irrigation (N) as well as the combined data (C) .

Traits	Fruit length			Fruit diameter			Average fruit weight		
	D	N	C	D	N	C	D	N	C
<b>Genotypes</b>									
P <sub>1</sub>	4.63	5.07	4.85	4.28	5.13	4.71	62.98	66.20	64.59
P <sub>2</sub>	4.93	5.23	5.08	3.97	4.07	4.02	41.90	44.44	43.17
P <sub>3</sub>	4.00	5.50	4.75	3.85	6.83	5.34	74.24	84.91	79.57
P <sub>4</sub>	3.47	4.17	3.82	5.15	5.87	5.51	73.97	82.35	78.16
P <sub>5</sub>	2.93	3.77	3.35	3.37	4.27	3.82	26.44	28.47	27.46
P <sub>6</sub>	4.22	5.40	4.81	3.78	4.83	4.31	37.81	60.27	49.04
P <sub>1</sub> xP <sub>2</sub>	4.92	5.60	5.26	3.75	3.93	3.84	45.42	54.13	49.78
P <sub>1</sub> xP <sub>3</sub>	3.72	4.67	4.19	4.63	7.50	6.07	59.59	76.98	68.28
P <sub>1</sub> xP <sub>4</sub>	3.72	4.13	3.93	4.22	5.23	4.73	49.48	77.09	63.28
P <sub>1</sub> xP <sub>5</sub>	5.08	5.23	5.16	5.12	5.00	5.06	62.64	69.75	66.20
P <sub>1</sub> xP <sub>6</sub>	4.27	4.67	4.47	4.17	4.33	4.25	54.19	70.76	62.48
P <sub>2</sub> xP <sub>3</sub>	5.10	5.43	5.27	4.82	5.37	5.09	63.98	67.66	65.82
P <sub>2</sub> xP <sub>4</sub>	4.57	4.83	4.70	4.70	4.93	4.82	55.77	60.57	58.17
P <sub>2</sub> xP <sub>5</sub>	5.00	5.67	5.33	5.10	5.33	5.22	71.04	75.03	73.04
P <sub>2</sub> xP <sub>6</sub>	4.67	5.83	5.25	4.88	4.93	4.91	57.00	81.29	69.15
P <sub>3</sub> xP <sub>4</sub>	4.31	5.12	4.71	4.82	6.38	5.60	71.85	80.21	76.03
P <sub>3</sub> xP <sub>5</sub>	4.73	4.80	4.77	5.50	5.67	5.58	90.81	91.30	91.06
P <sub>3</sub> xP <sub>6</sub>	3.70	5.57	4.63	4.17	7.17	5.67	72.52	85.39	78.96
P <sub>4</sub> xP <sub>5</sub>	3.63	4.17	3.90	3.17	5.67	4.42	36.83	62.58	49.70
P <sub>4</sub> xP <sub>6</sub>	3.93	5.43	4.68	4.17	4.53	4.35	39.82	55.81	47.82
P <sub>5</sub> xP <sub>6</sub>	4.27	4.73	4.50	4.33	4.87	4.60	32.21	38.80	35.50
LSD 5%	0.06	0.03	0.05	0.11	0.02	0.08	3.94	2.02	3.07
LSD 1%	0.08	0.04	0.06	0.15	0.03	0.11	5.27	2.66	4.06

Regarding average fruit weight, the parent P<sub>3</sub> expressed the highest mean values for average fruit weight recording 74.24, 84.91 and 79.57g in the drought, normal irrigation and combined analysis, respectively. Meanwhile, parent P<sub>5</sub> gave the lowest mean values for average fruit weight being 26.44, 28.47 and 27.46 g in the drought, normal irrigation and combined analysis, respectively. Moreover, the cross P<sub>3</sub>xP<sub>5</sub> exhibited the highest mean values for average fruit weight recording 90.81, 91.30 and 91.06 g in the drought, normal irrigation and combined analysis, respectively. Whereas, the cross P<sub>4</sub>xP<sub>6</sub> gave the lowest mean values being 32.21, 38.80 and 35.50 g in the

drought, normal irrigation and combined analysis, respectively. These results are agreed with those of Dhaliwal *et al.* (2003), Sharma and Thakur (2007), Gul *et al.* (2010), Adhi *et al.* (2014).

For TSS %, the parental variety P<sub>5</sub> exhibited the highest mean value for fruit TSS under drought stress and normal irrigation as well as combined analysis. Results also indicated that the crosses P<sub>2</sub>xP<sub>3</sub> and P<sub>2</sub>xP<sub>5</sub> exhibited the highest mean values for fruit TSS under all conditions. This finding in agreement with this reported by Bhnar (2002), Gaikwad *et al.* (2002), Singh *et al.* (2007).

**Table 3.** Mean performance of the genotypes for TSS, total sugars (%) and total polyphenol mg (10 .g f.w) traits under drought stress (D) and normal irrigation (N) as well as the combined data (C) .

Traits	TSS			Total sugars (%)			Total polyphenol mg (10 .g f.w)		
	D	N	C	D	N	C	D	N	C
<b>Genotypes</b>									
P <sub>1</sub>	4.00	3.00	3.50	2.97	2.22	2.59	37.50	32.10	34.80
P <sub>2</sub>	4.00	3.25	3.63	2.33	1.76	2.05	37.40	19.30	28.35
P <sub>3</sub>	4.00	3.75	3.88	2.47	2.17	2.32	32.33	26.57	29.45
P <sub>4</sub>	4.00	3.25	3.63	2.37	2.12	2.25	43.23	23.57	33.40
P <sub>5</sub>	4.25	4.00	4.13	2.57	1.88	2.23	26.37	15.20	20.78
P <sub>6</sub>	3.25	3.00	3.13	1.73	1.57	1.65	37.43	25.13	31.28
P <sub>1</sub> xP <sub>2</sub>	4.00	3.25	3.63	1.83	1.71	1.77	52.27	27.30	39.78
P <sub>1</sub> xP <sub>3</sub>	4.00	3.00	3.50	2.72	1.14	1.93	21.27	17.37	19.32
P <sub>1</sub> xP <sub>4</sub>	3.75	3.50	3.63	2.70	1.62	2.16	34.23	32.20	33.22
P <sub>1</sub> xP <sub>5</sub>	4.00	3.25	3.63	2.16	1.70	1.93	46.07	19.13	32.60
P <sub>1</sub> xP <sub>6</sub>	4.00	3.75	3.88	2.41	1.77	2.09	39.20	35.23	37.22
P <sub>2</sub> xP <sub>3</sub>	4.00	3.00	3.50	2.23	1.77	2.00	37.47	26.10	31.78
P <sub>2</sub> xP <sub>4</sub>	3.00	3.00	3.00	2.54	2.10	2.32	26.47	26.33	26.40
P <sub>2</sub> xP <sub>5</sub>	3.00	2.75	2.88	2.72	1.78	2.25	37.17	29.70	33.43
P <sub>2</sub> xP <sub>6</sub>	3.50	3.00	3.25	2.47	1.55	2.01	29.67	27.37	28.52
P <sub>3</sub> xP <sub>4</sub>	4.25	3.44	3.84	1.51	1.30	1.40	33.87	26.68	30.27
P <sub>3</sub> xP <sub>5</sub>	4.00	3.75	3.88	1.18	1.02	1.10	40.43	37.37	38.90
P <sub>3</sub> xP <sub>6</sub>	5.00	4.00	4.50	1.25	1.15	1.20	36.30	25.87	31.08
P <sub>4</sub> xP <sub>5</sub>	3.75	2.25	3.00	2.32	1.83	2.07	36.13	35.40	35.77
P <sub>4</sub> xP <sub>6</sub>	4.00	3.25	3.63	2.32	2.10	2.21	22.20	17.47	19.83
P <sub>5</sub> xP <sub>6</sub>	5.25	3.25	4.25	3.33	1.81	2.57	34.10	21.67	27.88
LSD 5%	0.32	0.29	0.30	0.23	0.13	0.18	0.53	0.49	0.50
LSD 1%	0.42	0.39	0.39	0.31	0.16	0.24	0.71	0.65	0.66

Concerning total sugars (%), the highest values of total sugars (%) were detected for the parent P<sub>1</sub> (4.28, 5.13 and 4.71 under drought stress, normal irrigation and combined data, respectively). However, the highest values of total sugars (%) were detected for the crosses P<sub>2</sub>xP<sub>5</sub>, P<sub>2</sub>xP<sub>4</sub> and P<sub>5</sub>xP<sub>6</sub> in drought condition, normal irrigation and combined analysis, respectively. Regarding the total polyphenol contents, the parental variety P<sub>4</sub> gave the highest mean value for current trait under drought treatment while, P<sub>1</sub> gave the highest mean value under normal irrigation and combined analysis, respectively. The cross P<sub>3</sub>xP<sub>5</sub> expressed the highest means values being 90.81, 91.30 and 91.06 under drought treatment, normal irrigation and combined analysis, respectively.

## 2. Heterosis:

Data presented in Table 4 show heterosis relative to mid parent and better parent for number of fruits and total yield per plant under normal irrigation and drought stress as well as the combined over them. Regarding number of fruits /plant, 3, 3 and 2 crosses expressed significant or highly significant and positive heterosis relative to mid parent in drought condition, normal irrigation and combined analysis, respectively. However, the cross P<sub>1</sub> x P<sub>4</sub> gave the best heterotic effect under drought condition, normal irrigation and combined analysis being 68.5, 76.32 and 72.9, respectively. Moreover, highly significant and positive better parent heterosis were detected in 3, 2 and 2 crosses in drought stress, normal irrigation and combined analysis, respectively. However, the cross P<sub>1</sub> x P<sub>4</sub> gave the best heterotic effect under drought condition, normal irrigation and combined analysis

being 48.52, 48.35 and 48.42, respectively. It is clear that the cross  $P_1 \times P_4$  expressed the highest desirable heterosis relative to mid parent and better parent in the two environments treatments and combined analysis of them. Significant and positive heterosis effects for number of fruits per plant were detected by **Souza et al. (2012)**, **Solieman et al. (2013)**, **Adhi et al. (2014)**, **Dissanayaka et al. (2014)**, **Mehboob et al. (2015)**, **Aisyah et al. (2016)**, **Marbhal et al. (2016)** as well as **Anita et al. (2013)** under stress conditions.

Regarding fruit yield per plant, 8, 7 and 7 crosses expressed significant or highly significant and positive heterosis relative to mid parent in drought condition, normal irrigation and combined analysis, respectively. Where, the cross  $P_2 \times P_5$  gave the best heterotic effect under drought condition, normal irrigation and combined analysis being 70.11, 48.58 and 58.36, respectively. Concerning heterosis relative to better parent, only cross  $P_1 \times P_4$  exhibited significant and positive heterosis under only drought stress (56.35\*). Significant and positive heterosis were also reported by **Ahmed et al. (2011)**, **Kumari and Sharma (2011)**, **Kumar et al. (2012)**, **Rajan (2012)**, **Singh et al. (2012)**, **Souza et al. (2012)**, **Solieman et al. (2013)**, **Droka et al. (2013)**, **Dissanayaka et al. (2014)**, **Mehboob et al. (2015)**, **Aisyah et al. (2016)**, **Marbhal et al. (2016)** and **Shakil et al. (2017)** as well as **Aref and Abdul-Baki (1991)**, **Borghain and Swargiary (2008)**, **Anita et al. (2013)** under stress conditions.

Heterosis relative to mid- and better- parent for fruit traits i.e., fruit length, diameter and weight as well as TSS, total sugars (%) and total polyphenol contents under drought stress and normal irrigation as well as combined analysis are presented in Tables 5, 6 and 7. Data presented in Table 5 show that 11, 12 and 11 crosses expressed highly significant and positive heterosis effects relative to mid parent for fruit length in drought treatment, normal irrigation and combined analysis, respectively. Also, 3, 3 and 2 crosses exhibited significant and positive better parent heterosis in the same order. However, the most desirable mid parent heterosis effects were detected for the crosses  $P_3 \times P_5$  (36.54),  $P_1 \times P_5$  (18.49), and  $P_2 \times P_5$  (26.48) in drought stress, normal irrigation and combined analysis, respectively. The most desirable heterotic effects relative to better parent were detected for the crosses  $P_3 \times P_5$  in drought condition,  $P_2 \times P_5$  in normal irrigation; and  $P_2 \times P_5$  in the combined analysis being 19.25, 7.87 and 6.42, respectively (Table, 5). In this respect, **Kurian et al. (2001)**, **Gul et al. (2010)**, **Rahmani et al. (2010)**, **Adhi et al. (2014)**, **Dagade et al. (2015)**, **Kumar and Singh (2016)**, **Shakil et al. (2017)** and **Singh and Kumar (2017)** detected significant and positive heterosis effects for fruit length.

Concerning fruit diameter, 9, 10 and 9 crosses expressed significant or highly significant and positive heterosis effects relative to mid parent in

drought treatment, normal irrigation and combined analysis, respectively. Where, the most desirable heterotic effects relative to better parent were detected for the crosses  $P_1 \times P_5$  in drought condition, normal irrigation and the combined analysis being 40.19, 23.33 and 26.75, respectively. However, the cross  $P_3 \times P_5$  was the only cross that expressed highly significant and positive heterosis in drought stress (18.33), whereas the crosses  $P_2 \times P_5$  and gave the significant and positive heterotic effects relative to better parent (8.28 and 8.02, respectively) in the normal irrigation (Table, 5). Significant and positive mid-parent and better- parent heterosis for fruit diameter was reported by **Kurian et al. (2001)**, **Kumar and Singh (2016)** and **Singh and Kumar (2017)**.

Data presented in Table 6 show the heterosis relative to mid- and better- parent for fruit weight and T.S.S. content under drought stress, normal irrigation and combined analysis. Results indicated that 5, 9 and 7 crosses expressed highly significant and positive heterosis effects relative to mid parent in drought treatment, normal irrigation and combined analysis, respectively. Among these crosses which recorded highly significant and positive heterosis over mid parent, 3, 5 and 3 crosses exhibited significant or highly significant and positive better parent heterosis in the same order. However, the most desirable mid and better parent heterosis effects were detected for the crosses  $P_2 \times P_5$  in drought stress, normal irrigation and combined analysis. In this concern **Kurian et al. (2001)**, **Joshi and Thakur (2003)**, **Tiwari and Lal (2004)**, **Asati et al. (2007)**, **Sharma and Thakur (2007)**, **Kumar et al. (2012)** and **Adhi et al. (2014)** found significant and positive mid-parent and better-parent heterosis for fruit weight.

Regarding T.S.S, 4, 4 and 3 crosses expressed significant highly significant and positive heterosis effects relative to mid parent in drought treatment, normal irrigation and combined analysis, respectively. Where, the most desirable mid parent heterosis effects were detected for the crosses  $P_5 \times P_6$  (40),  $P_1 \times P_6$  (25), and  $P_3 \times P_6$  (28.57) in drought stress, normal irrigation and combined analysis, respectively. However, only the crosses  $P_3 \times P_6$  and  $P_5 \times P_6$  exhibited significant and positive better parent heterosis only the drought stress being 25 and 23.53, respectively. Significant and positive heterosis for fruit TSS was reported by **Sharma et al. (2001)**, **Bhnan (2002)**, **Tiwari and Lal (2004)**, **Duhan et al. (2005)**, **Kumar et al. (2013)**, **Adhi et al. (2014)** and **Singh and Kumar (2017)** as well as **Ahmed et al. (2011)** and **Chattopadhyay et al. (2012)** under stress conditions.

Concerning total sugars contents, 4, 2 and 2 crosses expressed significant or highly significant and positive heterosis effects relative to mid parent in drought treatment, normal irrigation and combined analysis, respectively, as shown in Table 7.

**Table 4.** Heterosis relative to mid parent and better parent for number of fruits and total yield per plant under normal irrigation (N) and drought stress (D) as well as the combined over them (C) .

Cross	Number of fruits / plant						Total fruit yield					
	Mid Parent (M.P)			Better Parent ( B.P)			Mid Parent (M.P)			Better Parent ( B.P)		
	Drought	Normal	Combined	Drought	Normal	Combined	Drought	Normal	Combined	Drought	Normal	Combined
P <sub>1xP<sub>2</sub></sub>	17.93	4.41	10.46	-0.37	-5.94	-3.36	12.76	-1.99	4.56	11.55	-12.31	-1.41
P <sub>1xP<sub>3</sub></sub>	13.53	-12.34	-1.23	4.04	-20.72**	-10.17	-1.01	-9.52	-6.05	-1.91	-11.08	-6.67
P <sub>1xP<sub>4</sub></sub>	68.5**	76.32**	72.9**	48.52**	48.35**	48.42**	56.55**	45.75**	50.55**	56.35*	28.43	39.99
P <sub>1xP<sub>5</sub></sub>	-15.16	-31.02**	-24.08**	-34.13**	-45**	-40.17**	33.92**	13.31	21.95*	17.82	-2.39	5.98
P <sub>1xP<sub>6</sub></sub>	25.48*	5.47	13.34	8.2	-16.71**	-7.42	39.11**	22.51*	30.25**	19.47	18.53	23.02
P <sub>2xP<sub>3</sub></sub>	22.43	18.21	20.12	-3.62	-2.57	-3.06	41.68**	36.08**	38.53**	38.88	19.89	29.79
P <sub>2xP<sub>4</sub></sub>	0.12	21.37*	11.6	-23.61**	-6.1	-14.21**	38.12**	-3.02	16.69	36.45	-4.67	14.98
P <sub>2xP<sub>5</sub></sub>	-21.92**	-28.5**	-25.52**	-29.66**	-37.74**	-34.15**	70.11**	48.58**	58.36**	48.26	42.34	45.17
P <sub>2xP<sub>6</sub></sub>	-20*	-29.02**	-25.29**	-21.93**	-38.86**	-31.08**	6.38	19.72*	13.08	-7.8	10.39	1.06
P <sub>3xP<sub>4</sub></sub>	25.55	11.34	17.63	20.27*	2.66	10.29	10.57	8.72	9.53	9.71	-5.63	1.22
P <sub>3xP<sub>5</sub></sub>	-54.69**	-47.43**	-50.63**	-66.92**	-61.07**	-63.67**	-0.6	2.1	0.99	-11.85	-13.32	-12.73
P <sub>3xP<sub>6</sub></sub>	-19.85	-43.13**	-33.97**	-35.74**	-58.24**	-49.85**	-6.46	-13.82	-10.43	-20.28	-18.01	-14.87
P <sub>4xP<sub>5</sub></sub>	6.71	14.82	11.19	-24.14**	-19.29**	-21.44**	21.63*	29.57*	25.96*	7.12	26.23	17.05
P <sub>4xP<sub>6</sub></sub>	24.28	-4.41	7.01	-3.52	-33.29**	-22.2**	-18.36**	-1.79	-10.06	-29.97	-10.86	-20.66
P <sub>5xP<sub>6</sub></sub>	56.55**	14.69*	31.85**	38**	13.23**	25.88**	25.09**	31.24**	28.3**	-3.37	16.36	6.24

\* and \*\* significant at 0.05 and 0.01 levels of probability, respectively.

**Table 5.** Heterosis relative to mid parent and better parent for fruit length and diameter under normal irrigation (N) and drought stress (D) as well as the combined over them (C)

Cross	Fruit length						Fruit diameter					
	Mid Parent (M.P)			Better Parent ( B.P)			Mid Parent (M.P)			Better Parent ( B.P)		
	Drought	Normal	Combined	Drought	Normal	Combined	Drought	Normal	Combined	Drought	Normal	Combined
P <sub>1</sub> xP <sub>2</sub>	2.79**	8.74**	5.87**	-0.35	6.66*	3.48	3.07	7.86**	5.93	-0.34	7.01	3.44
P <sub>1</sub> xP <sub>3</sub>	-13.9**	-11.67**	-12.67**	-20.77**	-14.39**	-13.71**	-15.29**	-10.5**	-12.8**	-19.78**	-15.15**	-13.57**
P <sub>1</sub> xP <sub>4</sub>	-8.23**	-10.47**	-9.42**	-20.77**	-17.5**	-19.26**	-9.05**	-9.42**	-9.52**	-19.78**	-18.42**	-19.07**
P <sub>1</sub> xP <sub>5</sub>	34.36**	18.49**	25.81**	10.2*	3.13	6.42*	40.19**	23.33**	26.75**	9.71*	3.29	6.36
P <sub>1</sub> xP <sub>6</sub>	-3.58**	-10.83**	-7.51**	-8.31	-12.9**	-7.98	-3.94**	-9.75**	-7.58**	-7.91	-13.58**	-7.9
P <sub>2</sub> xP <sub>3</sub>	14.18**	1.24**	7.12**	3.55	-1.15	3.64	15.6**	1.12	7.19**	3.38	-1.21	3.61
P <sub>2</sub> xP <sub>4</sub>	8.73**	2.84**	5.62**	-7.8	-7.26	-7.62	9.6**	2.55**	5.67	-7.43	-7.64	-7.54
P <sub>2</sub> xP <sub>5</sub>	27.12**	25.93**	26.48**	1.42	7.87*	4.97*	29.83**	16.64**	26.05**	1.35	8.28*	4.92
P <sub>2</sub> xP <sub>6</sub>	2**	9.72**	6.15**	-5.68	7.62*	3.31	2.2**	8.75**	6.21*	-5.41	8.02*	3.28
P <sub>3</sub> xP <sub>4</sub>	15.51**	5.86**	10.07**	8.2*	-6.62	-0.75	17.06**	5.28**	10.17**	7.81	-6.97	-0.75
P <sub>3</sub> xP <sub>5</sub>	36.54**	3.6**	17.7**	19.25**	-12.09**	0.35	37.8**	3.24**	17.87**	18.33**	-12.73**	0.35
P <sub>3</sub> xP <sub>6</sub>	-9.94**	2.14**	-3.05**	-12.87*	1.15	-3.68	-10.93**	1.93	-3.08**	-12.25*	1.21	-3.64
P <sub>4</sub> xP <sub>5</sub>	13.54**	5.04**	8.84**	5.05	0	2.21	14.9**	4.54**	8.93**	4.81	0	2.18
P <sub>4</sub> xP <sub>6</sub>	2.39**	13.59**	8.6**	-7.06	0.59	-2.63	2.62	12.23**	8.69**	-6.72	0.62	-2.6
P <sub>5</sub> xP <sub>6</sub>	19.35**	3.27**	10.32**	1.25	-11.73**	-6.48	21.28**	2.95**	10.42**	1.19	-12.35**	-6.41

\* and \*\* significant at 0.05 and 0.01 levels of probability, respectively.

**Table 6.** Heterosis relative to mid parent and better parent for fruit weight and T.S.S. content under normal irrigation (N) and drought stress (D) as well as the combined over them (C) .

Cross	Fruit weight						T.S.S.					
	Mid Parent (M.P)			Better Parent ( B.P)			Mid Parent (M.P)			Better Parent ( B.P)		
	Drought	Normal	Combined	Drought	Normal	Combined	Drought	Normal	Combined	Drought	Normal	Combined
P <sub>1</sub> xP <sub>2</sub>	-13.38**	-2.16	-7.62**	-27.88**	-18.24**	-22.94**	0	4	1.75	0	0	0
P <sub>1</sub> xP <sub>3</sub>	-13.15**	1.88	-5.27*	-19.73**	-9.34**	-14.19**	0	-11.11*	-5.08	0	-20	-9.68
P <sub>1</sub> xP <sub>4</sub>	-27.74**	3.79**	-11.34**	-33.11**	-6.39**	-19.03**	-6.25	12*	1.75	-6.25	7.69	0
P <sub>1</sub> xP <sub>5</sub>	40.09**	47.35**	43.82**	-0.54	5.36*	2.48	-3.03	-7.14	-4.92	-5.88	-18.75	-12.12
P <sub>1</sub> xP <sub>6</sub>	7.52	11.9**	9.96**	-13.96**	6.88**	-3.28	10.34*	25**	16.98**	0	25	10.71
P <sub>2</sub> xP <sub>3</sub>	10.19**	4.62**	7.25**	-13.81**	-20.31**	-17.28**	0	-14.29**	-6.67	0	-20	-9.68
P <sub>2</sub> xP <sub>4</sub>	-3.74	-4.45**	-4.11	-24.61**	-26.45**	-25.58**	-25**	-7.69	-17.24**	-25*	-7.69	-17.24
P <sub>2</sub> xP <sub>5</sub>	107.89**	105.83**	106.82**	69.54**	68.85**	69.19**	-27.27**	-24.14**	-25.81**	-29.41**	-31.25**	-30.3**
P <sub>2</sub> xP <sub>6</sub>	43.01**	55.27**	49.97**	36.04**	34.88**	40.99**	-3.45	-4	-3.7	-12.5	-7.69	-10.34
P <sub>3</sub> xP <sub>4</sub>	-3.04	-4.09**	-3.6	-3.21	-5.53**	-4.45*	6.25	-1.79	2.5	6.25	-8.33	-0.81
P <sub>3</sub> xP <sub>5</sub>	80.4**	61.06**	70.16**	22.33**	7.54**	14.44**	-3.03	-3.23	-3.13	-5.88	-6.25	-6.06
P <sub>3</sub> xP <sub>6</sub>	29.45**	17.63**	22.78**	-2.31	0.57	-0.77	37.93**	18.52**	28.57**	25*	6.67	16.13
P <sub>4</sub> xP <sub>5</sub>	-26.64**	12.93**	-5.88*	-50.21**	-24.01**	-36.41**	-9.09*	-37.93**	-22.58**	-11.76	-43.75**	-27.27*
P <sub>4</sub> xP <sub>6</sub>	-28.75**	-21.73**	-24.82**	-46.17**	-32.22**	-38.82**	10.34*	4	7.41	0	0	0
P <sub>5</sub> xP <sub>6</sub>	0.24	-12.56**	-7.18	-14.83**	-35.63**	-27.61**	40**	-7.14	17.24**	23.53*	-18.75	3.03

\* and \*\* significant at 0.05 and 0.01 levels of probability, respectively.



**Table 7.** Heterosis relative to mid parent and better parent for total sugars and polyphenol contents under normal irrigation (N) and drought stress (D) as well as the combined over them (C) .

Cross	Total sugars						Total polyphenol					
	Mid Parent (M.P)			Better Parent ( B.P)			Mid Parent (M.P)			Better Parent ( B.P)		
	Drought	Normal	Combined	Drought	Normal	Combined	Drought	Normal	Combined	Drought	Normal	Combined
P <sub>1xP2</sub>	-30.82**	-14.09**	-23.65**	-38.2**	-23.01	-31.7*	39.56**	6.23**	26**	39.38**	-14.95**	14.32**
P <sub>1xP3</sub>	0	-47.83**	-21.36**	-8.43	-48.42**	-25.53	-39.09**	-40.8**	-39.87**	-43.29**	-45.9**	-44.49**
P <sub>1xP4</sub>	1.25	-25.35**	-10.68**	-8.99	-26.92	-16.66	-15.19**	15.69**	-2.59**	-20.82**	0.31	-4.55*
P <sub>1xP5</sub>	-22.05**	-17.07**	-19.93**	-27.3	-23.31	-25.59	44.26**	-19.1**	17.3**	22.84**	-40.39**	-6.32**
P <sub>1xP6</sub>	2.7	-6.42	-1.37	-18.65	-20	-19.23	4.63**	23.12**	12.64**	4.53**	9.76**	6.94**
P <sub>2xP3</sub>	-7.22	-9.94**	-8.44*	-9.73	-18.46	-13.81	7.46**	13.81**	9.98**	0.18	-1.76	7.92**
P <sub>2xP4</sub>	8.09	8.25*	8.16	7.32	-1.1	3.34	-34.35**	22.86**	-14.49**	-38.78**	11.74**	-20.96**
P <sub>2xP5</sub>	11.02*	-2.01	5.46	5.97	-5.31	1.2	16.57**	72.17**	36.09**	-0.62	53.89**	17.93**
P <sub>2xP6</sub>	21.48**	-6.91	8.7	5.86	-11.76	-1.71	-20.71**	23.18**	-4.36**	-20.75**	8.89**	-8.84**
P <sub>3xP4</sub>	-37.72**	-39.2**	-38.42**	-38.99*	-39.81*	-39.37*	-10.37**	6.42**	-3.67**	-21.67**	0.41	-9.37**
P <sub>3xP5</sub>	-53.11**	-49.79**	-51.63**	-54.03**	-53.08**	-52.59**	37.76**	78.93**	54.88**	25.05**	40.65**	32.09**
P <sub>3xP6</sub>	-40.48**	-38.32**	-39.46**	-49.32**	-46.77*	-48.13**	4.06**	0.06	2.36**	-3.03	-2.63	-0.64
P <sub>4xP5</sub>	-5.95	-8.82**	-7.23	-9.61	-13.97	-7.65	3.83**	82.63**	32.02**	-16.42**	50.21**	7.09**
P <sub>4xP6</sub>	13.33*	13.62**	13.47**	-1.83	-1.1	-1.48	-44.96**	-28.27**	-38.68**	-48.65**	-30.5**	-40.62**
P <sub>5xP6</sub>	54.73**	4.53	32.36**	29.61	-4.07	15.36	6.9**	7.44**	7.11**	-8.9**	-13.79**	-10.87**

\* and \*\* significant at 0.05 and 0.01 levels of probability, respectively.

Where, the most desirable mid parent heterosis effects were detected for the crosses  $P_5 \times P_6$  (54.73),  $P_4 \times P_6$  (13.62), and  $P_5 \times P_6$  (32.36) in drought stress, normal irrigation and combined analysis, respectively. However, none of the crosses expressed significant and positive heterotic effects relative to mid parent in all environments.

For total polyphenol, 9, 11 and 9 crosses expressed highly significant and positive heterotic effects relative to mid parent in drought stress, normal irrigation and combined data, respectively. The respective crosses for better parent heterosis were 4, 5 and 6 (Table, 7). The most desirable mid parent heterosis effects were detected for the crosses  $P_1 \times P_5$  (44.26),  $P_4 \times P_5$  (82.63), and  $P_3 \times P_5$  (54.88) in drought stress, normal irrigation and combined analysis, respectively. While, the most desirable heterotic effects relative to better parent were detected for the crosses  $P_1 \times P_2$  in drought condition,  $P_2 \times P_5$  in normal irrigation; and  $P_3 \times P_5$  in the combined analysis being 39.38, 53.89 and 32.09, respectively (Table, 7).

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