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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), Pearsone 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_1xP_4 and P_1xP_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_5xP_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 x 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_1), Real Stone (p_2), Pearsone Imp (p_3), Super marmande (p_4), Tomato Golden (p_5) and Peto mech (p_6) and their F_{1S} 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 verities and their 15 F_1 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_1 mean performances from either the mid-parent value (MP) or better parent mean (BP) for F_1 date of each experiment as well as the combined analysis as follows:

$$\text{Mid-parent heterosis} = \frac{\bar{F1} - \bar{MP}}{\bar{MP}} \times 100 \; ; \quad \text{Better parent heterosis} = \frac{\bar{F1} - \bar{BP}}{\bar{BP}} \times 100$$

Results and Discussion

1. Mean performance:

Data presented in Table 1 show that the highest number of fruits was detected for the parent P_5 (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).

Traits	Number of fruits / plant			Total fruit yield (kg/plant)		
Genotypes	**Drought**	**Normal**	**Combined**	**Drought**	**Normal**	**Combined**
P_1	30.92	41.63	36.27	1.95	2.76	2.35
P_2	44.83	51.92	48.38	1.99	2.18	2.08
P_3	25.75	33.67	29.71	1.91	2.85	2.38
P_4	23.58	28.42	26.00	1.94	2.10	2.02
P_5	55.92	70.00	62.96	1.48	1.99	1.74
P_6	42.67	71.83	57.25	2.71	2.58	2.65
P_1xP_2	44.67	48.83	46.75	2.22	2.42	2.32
P_1xP_3	32.17	33.00	32.58	1.91	2.54	2.22
P_1xP_4	45.92	61.75	53.83	3.05	3.54	3.29
P_1xP_5	36.83	38.50	37.67	2.29	2.69	2.49
P_1xP_6	46.17	59.83	53.00	3.24	3.27	3.25
P_2xP_3	43.21	50.58	46.90	2.76	3.42	3.09
P_2xP_4	34.25	48.75	41.50	2.72	2.07	2.39
P_2xP_5	39.33	43.58	41.46	2.95	3.10	3.02
P_2xP_6	35.00	43.92	39.46	2.50	2.84	2.67
P_3xP_4	30.97	34.56	32.77	2.13	2.69	2.41
P_3xP_5	18.50	27.25	22.88	1.69	2.47	2.08
P_3xP_6	27.42	30.00	28.71	2.16	2.34	2.25
P_4xP_5	42.42	56.50	49.46	2.08	2.65	2.37
P_4xP_6	41.17	47.92	44.54	1.90	2.30	2.10
P_5xP_6	77.17	81.33	79.25	2.62	3.00	2.81
$LSD_{5\%}$	8.25	8.39	8.13	0.31	0.46	0.38
$LSD_{1\%}$	11.03	11.06	10.74	0.42	0.61	0.51

However, parent P_4 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_5xP_6 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_3xP_5 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_6 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_5 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_1xP_4 and P_1xP_6 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_1 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_2 and P_3 exhibited the highest mean value for fruit length under drought stress and normal irrigation as well as combined analysis. However, the parent P_5 gave the lowest mean values under all environments. Results also indicated that the crosses P_2xP_3, P_2xP_5 and P_2xP_6 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_4 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_5 gave the lowest values, i.e., 3.37 and 3.82 cm under drought treatment and combined analysis, respectively. The cross P_3xP_5 expressed the highest means value being 5.50 cm under stress condition. Whereas, the cross P_1xP_3 gave the highest values for this trait in normal irrigation treatment (7.50 cm) and combined data (6.07cm). However, P_1xP_2 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		
Genotypes	D	N	C	D	N	C	D	N	C
P_1	4.63	5.07	4.85	4.28	5.13	4.71	62.98	66.20	64.59
P_2	4.93	5.23	5.08	3.97	4.07	4.02	41.90	44.44	43.17
P_3	4.00	5.50	4.75	3.85	6.83	5.34	74.24	84.91	79.57
P_4	3.47	4.17	3.82	5.15	5.87	5.51	73.97	82.35	78.16
P_5	2.93	3.77	3.35	3.37	4.27	3.82	26.44	28.47	27.46
P_6	4.22	5.40	4.81	3.78	4.83	4.31	37.81	60.27	49.04
P_1xP_2	4.92	5.60	5.26	3.75	3.93	3.84	45.42	54.13	49.78
P_1xP_3	3.72	4.67	4.19	4.63	7.50	6.07	59.59	76.98	68.28
P_1xP_4	3.72	4.13	3.93	4.22	5.23	4.73	49.48	77.09	63.28
P_1xP_5	5.08	5.23	5.16	5.12	5.00	5.06	62.64	69.75	66.20
P_1xP_6	4.27	4.67	4.47	4.17	4.33	4.25	54.19	70.76	62.48
P_2xP_3	5.10	5.43	5.27	4.82	5.37	5.09	63.98	67.66	65.82
P_2xP_4	4.57	4.83	4.70	4.70	4.93	4.82	55.77	60.57	58.17
P_2xP_5	5.00	5.67	5.33	5.10	5.33	5.22	71.04	75.03	73.04
P_2xP_6	4.67	5.83	5.25	4.88	4.93	4.91	57.00	81.29	69.15
P_3xP_4	4.31	5.12	4.71	4.82	6.38	5.60	71.85	80.21	76.03
P_3xP_5	4.73	4.80	4.77	5.50	5.67	5.58	90.81	91.30	91.06
P_3xP_6	3.70	5.57	4.63	4.17	7.17	5.67	72.52	85.39	78.96
P_4xP_5	3.63	4.17	3.90	3.17	5.67	4.42	36.83	62.58	49.70
P_4xP_6	3.93	5.43	4.68	4.17	4.53	4.35	39.82	55.81	47.82
P_5xP_6	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_3 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_5 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_3xP_5 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_4xP_6 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_5 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_2xP_3 and P_2xP_5 exhibited the highest mean values for fruit TSS under all conditions. This finding in agreement with this reported by **Bhnan (2002), Gaikwad** ***et al.*** **(2002), Singh** ***el 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)		
Genotypes	D	N	C	D	N	C	D	N	C
P_1	4.00	3.00	3.50	2.97	2.22	2.59	37.50	32.10	34.80
P_2	4.00	3.25	3.63	2.33	1.76	2.05	37.40	19.30	28.35
P_3	4.00	3.75	3.88	2.47	2.17	2.32	32.33	26.57	29.45
P_4	4.00	3.25	3.63	2.37	2.12	2.25	43.23	23.57	33.40
P_5	4.25	4.00	4.13	2.57	1.88	2.23	26.37	15.20	20.78
P_6	3.25	3.00	3.13	1.73	1.57	1.65	37.43	25.13	31.28
P_1xP_2	4.00	3.25	3.63	1.83	1.71	1.77	52.27	27.30	39.78
P_1xP_3	4.00	3.00	3.50	2.72	1.14	1.93	21.27	17.37	19.32
P_1xP_4	3.75	3.50	3.63	2.70	1.62	2.16	34.23	32.20	33.22
P_1xP_5	4.00	3.25	3.63	2.16	1.70	1.93	46.07	19.13	32.60
P_1xP_6	4.00	3.75	3.88	2.41	1.77	2.09	39.20	35.23	37.22
P_2xP_3	4.00	3.00	3.50	2.23	1.77	2.00	37.47	26.10	31.78
P_2xP_4	3.00	3.00	3.00	2.54	2.10	2.32	26.47	26.33	26.40
P_2xP_5	3.00	2.75	2.88	2.72	1.78	2.25	37.17	29.70	33.43
P_2xP_6	3.50	3.00	3.25	2.47	1.55	2.01	29.67	27.37	28.52
P_3xP_4	4.25	3.44	3.84	1.51	1.30	1.40	33.87	26.68	30.27
P_3xP_5	4.00	3.75	3.88	1.18	1.02	1.10	40.43	37.37	38.90
P_3xP_6	5.00	4.00	4.50	1.25	1.15	1.20	36.30	25.87	31.08
P_4xP_5	3.75	2.25	3.00	2.32	1.83	2.07	36.13	35.40	35.77
P_4xP_6	4.00	3.25	3.63	2.32	2.10	2.21	22.20	17.47	19.83
P_5xP_6	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_1 (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_2xP_5, P_2xP_4 and P_5xP_6 in drought condition, normal irrigation and combined analysis, respectively. Regarding the total polyphenol contents, the parental variety P_4 gave the highest mean value for current trait under drought treatment while, P_1 gave the highest mean value under normal irrigation and combined analysis, respectively. The cross P_3xP_5 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_1 x P_4 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_1 x P_4 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 x 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 x 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_1xP_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), Borgohain 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 11crosses 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 x P_5 (36.54), P_1 x P_5 (18.49), and P_2 x 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 x P_5 in drought condition, P_2 x P_5 in normal irrigation; and P_2 x 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 x 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 x P_5 was the only cross that expressed highly significant and positive heterosis in drought stress (18.33), whereas the crosses P_2 x P_5 and gave the significant and positive hetertotic 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 x 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 x P_6 (40), P_1 x P_6 (25), and P_3 x P_6 (28.57) in drought stress, normal irrigation and combined analysis, respectively. However, only the crosses P_3 x P_6 and P_5 x P_6 exhibited significant and positive better parent heterosis only the drought stress being 25and 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_1xP_2	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_1xP_3	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_1xP_4	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_1xP_5	-15.16	-31.02**	-24.08**	-34.13**	-45**	-40.17**	33.92**	13.31	21.95*	17.82	-2.39	5.98
P_1xP_6	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_2xP_3	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_2xP_4	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_2xP_5	-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_2xP_6	-20*	-29.02**	-25.29**	-21.93**	-38.86**	-31.08**	6.38	19.72*	13.08	-7.8	10.39	1.06
P_3xP_4	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_3xP_5	-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_3xP_6	-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_4xP_5	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_4xP_6	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_5xP_6	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_1xP_2	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_1xP_3	-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_1xP_4	-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_1xP_5	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_1xP_6	-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_2xP_3	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_2xP_4	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_2xP_5	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_2xP_6	2**	9.72**	6.15**	-5.68	7.62*	3.31	2.2**	8.75**	6.21*	-5.41	8.02*	3.28
P_3xP_4	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_3xP_5	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_3xP_6	-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_4xP_5	13.54**	5.04**	8.84**	5.05	0	2.21	14.9**	4.54**	8.93**	4.81	0	2.18
P_4xP_6	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_5xP_6	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_1xP_2	-13.38**	-2.16	-7.62**	-27.88**	-18.24**	-22.94**	0	4	1.75	0	0	0
P_1xP_3	-13.15**	1.88	-5.27*	-19.73**	-9.34**	-14.19**	0	-11.11*	-5.08	0	-20	-9.68
P_1xP_4	-27.74**	3.79**	-11.34**	-33.11**	-6.39**	-19.03**	-6.25	12*	1.75	-6.25	7.69	0
P_1xP_5	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_1xP_6	7.52	11.9**	9.96**	-13.96**	6.88**	-3.28	10.34*	25**	16.98**	0	25	10.71
P_2xP_3	10.19**	4.62**	7.25**	-13.81**	-20.31**	-17.28**	0	-14.29**	-6.67	0	-20	-9.68
P_2xP_4	-3.74	-4.45**	-4.11	-24.61**	-26.45**	-25.58**	-25**	-7.69	-17.24**	-25*	-7.69	-17.24
P_2xP_5	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_2xP_6	43.01**	55.27**	49.97**	36.04**	34.88**	40.99**	-3.45	-4	-3.7	-12.5	-7.69	-10.34
P_3xP_4	-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_3xP_5	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_3xP_6	29.45**	17.63**	22.78**	-2.31	0.57	-0.77	37.93**	18.52**	28.57**	25*	6.67	16.13
P_4xP_5	-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_4xP_6	-28.75**	-21.73**	-24.82**	-46.17**	-32.22**	-38.82**	10.34*	4	7.41	0	0	0
P_5xP_6	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_1xP_2	-30.82**	-14.09**	-23.65**	-38.2**	-23.01	-31.7*	39.56**	6.23**	26**	39.38**	-14.95**	14.32**
P_1xP_3	0	-47.83**	-21.36**	-8.43	-48.42**	-25.53	-39.09**	-40.8**	-39.87**	-43.29**	-45.9**	-44.49**
P_1xP_4	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_1xP_5	-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_1xP_6	2.7	-6.42	-1.37	-18.65	-20	-19.23	4.63**	23.12**	12.64**	4.53**	9.76**	6.94**
P_2xP_3	-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_2xP_4	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_2xP_5	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_2xP_6	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_3xP_4	-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_3xP_5	-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_3xP_6	-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_4xP_5	-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_4xP_6	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_5xP_6	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 x P_6 (54.73), P_4 x P_6 (13.62), and P_5 x 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 x P_5 (44.26), P_4 x P_5 (82.63), and P_3 x 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 x P_2 in drought condition, P_2 x P_5 in normal irrigation; and P_3 x P_5 in the combined analysis being 39.38, 53.89 and 32.09, respectively (Table, 7).

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