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SOURCES AND NATURE OF FRUIT SET HEAT TOLERANCE IN TEN EVALUATED TOMATO ACCESSIONS

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Abstract

An experiment was carried out during the period from 2016 to 2018 at the Faculty of Agriculture, Cairo University, Giza, Egypt to evaluate field performance of 10 tomato accessions for fruit set heat tolerance and related characters in two plantings under each of high and moderate growing conditions. Characters measured were fruit set (%), number of seeds per fruit, number of locules per fruit, proline content of fresh leaves and flowers and total soluble carbohydrates of fresh leaves and flowers. Combined analysis of the two plantings of each of the two evaluation conditions showed that the highest significant values of fruit set percentage were for LAs 0816, 1310, 2661 and 3008. LAs 3320, 3213 and 2661 had the highest content of seeds in both seasons. Evaluated accessions exhibited no significant differences in the number of locules under both evaluation conditions. LAs 0816, 2661, 2662 and 3120 recorded the highest content of proline of both fresh leaves and fresh flowers. LAs 1995, 2661, 2662 and 2706 had the highest content of leaf total soluble carbohydrates under both evaluation conditions. LAs 2661, 2662, 3120 and 1310 were superior in their content of total soluble carbohydrates in fresh flowers. Fruit set percentage, number of seeds per fruit, and total soluble carbohydrates content of both fresh leaves and flowers were higher under moderate temperature than under high temperature. Proline content in both fresh leaves and flowers were higher under high temperature conditions than under moderate temperature.

Evaluation of accessions under heat stress conditions showed that LA0816 was superior in each of fruit set percentage, proline content of fresh leaves and proline content of fresh flowers. LA1310 was superior in fruit set percentage and number of seeds per fruit under heat stress. LA2661 was superior in fruit set, proline content of both fresh leaves and fresh flowers and total soluble carbohydrate in fresh flower under high temperature. A positive correlation was found between fruit set and proline content in both fresh leaves and fresh flowers. An increase in proline content was noticed under heat stress conditions. This increase was higher in some accessions compared to others. This is likely to be an adaptive response to heat stress. There was a negative correlation between number of seeds per fruit and fruit set under high temperature. Under moderate temperature there was also a positive correlation between fruit set and proline content of fresh leaves and flowers, but the increase in proline was less than under heat stress.

***Keywords* :** Tomato, praline content, heat tolerance.

Introduction

Through the normal processes of plant growth and developmental stages, plants are exposed to different kinds of stresses, like heat, drought, salinity, ultraviolet light and pathogen attack (Mckersie and Leshem 1994; Paliyath and Fletcher 1995; Paliyath *et al.,* 1997; Abdelaziz *et al.,* 2019; Abdelgawad *et al.,* 2019). Elevated temperature is increasingly becoming an agricultural problem (Hall, 1992). By exposure to high or low temperature than the optimal for growth, most plants suffer physiological, morphological and biochemical damage (Lyons, 1973). Such damages could lead to reduction in growth capability, commercial yield, and fruit quality (Wang, 1982).

Tomato (*Solanum lycopersicum* L.) is one of the most widespread, widely grown and most consumed fruit vegetable in the world (Miller and Tankslay, 1990). Though tomato plants can grow under high temperature range, fruit setting ability usually suffers under high or low temperature stress. The most common factor in fruit set in tomato plants is the night temperature, where the ideal range is from 15° to 20°C. When day temperature rises above 32°C and the night temperature above 21°C, fruit setting ability is low (Went, 1945; Went and Cosper, 1945). Other factors such as stigma exsertion, poor germination of pollen grains, slow growth of pollen tube and carbohydrates stress are some of the major causes of poor fruit setting at high temperature in tomato plants. Under such conditions, there is need for using heat-tolerant cultivars to maintain fruit production during heat stress (Saeed *et al.*, 2007).

In previous studies, Abdul-Baki (1991) evaluated nine lines and eight commercial cultivars for fruit set and seed set under high temperature. Line Cl1131-0-043-0-6 had the highest fruit set percentage compared with others, while cv. Long Keeper had the highest content of seeds per fruit. Comlekcioglu and Soylu (2010) studied the effect of high temperature conditions on fruit set and number of seeds per fruit in 14 tomato genotypes. CLN1621L had the highest significant value (79.21 %) for fruit set, while the highest significant value for number of seeds per fruit (126.7) was found for U-2-29.

Islam *et al.* (2014) evaluated 18 tomato genotypes for fruit set and number of locules per fruit under high temperature condition. The highest value for fruit setting ability (40.3 %) was found for HT020, while line C71 had the highest significant value (5.1) for number of locules. Din *et al.* (2015) studied the effect of high temperature on fruit set percentage, number of seeds per fruit and proline content of leaves of three tomato genotypes, viz., Suncherry, Walter and CLN-2498d. The highest significant value of fruit set and number of seeds per fruit was for CLN-2498d. As for Proline content the highest significant value (196 μg/g FW) was found for Suncherry.

Xu *et al.* (2017) evaluated 13 tomato cultivars for fruit set under high temperature. The highest significant value (38.8%) was found for cv. Nagcarlang, while the lowest values were found for cvs. M82, Micro-Tom, Moneyberg, Ninja, Red Setter and Rubicon without significant differences among them. Rivero *et al.* (2004) evaluated cv. Tmknvf2 for proline content in tomato leaves under three temperatures (10, 25, and 35°C). The highest content of proline (3.61 µmol/g FW) was found in 35°C.

Johnson and Hall (1953) studied the effect of high temperature on foliage carbohydrate content in tomato. Four cultivars, viz., S-1112B, S-1114C, S-1119N and Marglobe were used. Results showed that cv. S-1119N had the highest content (13.24 % DW) of total carbohydrates. Zhou *et al.* (2017) evaluated two tomato cultivars, viz., Aromata and LA1994 under heat stress condition. LA1994 had the highest content of total soluble sugars in foliage (50 mg/g DW) at the anthesis stage compared with cv. Aromata.

Considering climate change and the increased temperature under field conditions during the summer season in Egypt, this study was conducted to evaluate 10 selected accessions for fruit set capability under both moderate and high temperature conditions in field plantings, and to evaluate some of the characters that may be related to high temperature fruit set tolerance in these accessions.

Materials and Methods

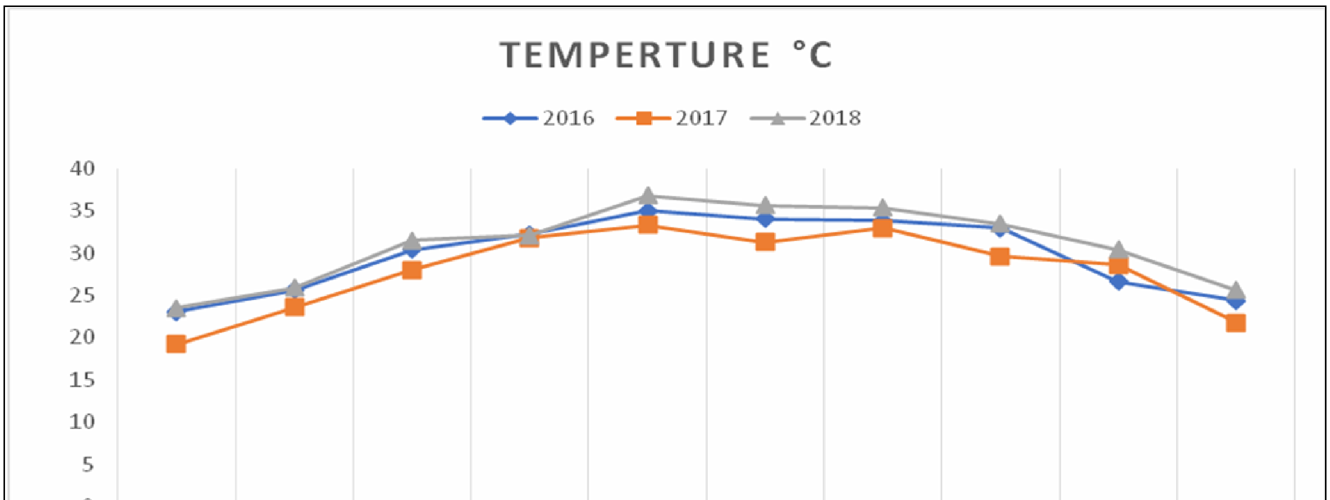
These studies were carried out during the period from 2016 to 2018 at the Faculty of Agriculture, Cairo University, Giza, Egypt.

Evaluation of some tomato genotypes for fruit set heat tolerance

Evaluation of accessions

Ten tomato, *Solanum Lycopersicum* L., genotypes were chosen and evaluated for heat tolerance under field conditions, during the two summer seasons of 2016 and 2017, and also evaluated under moderate temperature during 2017 and 2018. Accessions evaluated were LA0816, LA1310, LA1995, LA2661, LA2662, LA2706, LA3008, LA3120, LA3213 and LA3320. Seeds of LAs were kindly provided by the Tomato Genetics Resource Center, University of California, Davis.

Seeds of all genotypes were sowed in greenhouse during the first half of May in both 2016 and 2017 for heat stress evaluation, and were sowed during the first half of January in both 2017 and 2018 for moderate condition. Seeds were sowed in speedling trays filled with 1:1 mixture of peatmoss and vermiculate. This mixture was enriched with macro and micro elements. Six weeks old seedlings were transplanted in the open field at the Faculty of Agriculture, Cairo University, in a randomized complete block design (RCBD) with three replicates. Each plot consisted of 1 bed 1 m wide and 5 m long. Plants were set 40 cm apart in one row in the bed and were subjected to the common agricultural practices. Maximum temperature during the experimental period are presented in Figure 1 (Central Laboratory for Agriculture Climate).



	February	March	April	May	June	July	August	September	October	November
2016	23.1	25.6	30.4	32.2	35	34	33.8	32.9	26.6	24.4
2017	19.2	23.6	28	31.8	33.3	31.3	32.9	29.6	28.6	21.8
2018	23.48	25.93	31.48	32.1	36.81	35.61	35.34	33.44	30.4	25.6

Fig. 1 : Maximum temperature during the experimental period. Flowering was mostly during April under moderate temperature and mostly during August under heat stress.

Characters measured

The following characters were measured:

1. **Fruit set** as determined in the first three clusters of three plants from each plot.
2. **Number of seeds** as determined in 5 fruits from each plot.
3. **Number of locules** as determined in 5 fruits from each plot.
4. **Proline content** as determined in leaves (fifth leaf) and ovaries (first five clusters) of three plants from each plot according to Bates *et al.* (1973).
5. **Total soluble carbohydrates** as determined in leaves (fifth leaf) and ovaries (first five clusters) of three plants from each plot according to Dubois *et al.* (1956).

Statistical analysis

Data collected were subjected to analysis of variance of a RCBD according to Snedecor and Cochran (1989). Combined analysis of variance across the two seasons was also performed, when the homogeneity test of the transformed data was non-significant, by using Bartlett`s test (Bartlett, 1937). Data analysis for genotypes, revised least significant difference among genotypes (Duncan's multiple range test, DNMART, according to Duncan, 1955), and the interaction among genotypes and other factors were determined. Fruit set, number of seeds per fruit, number of locules per fruit, proline content of fresh leaves, total soluble carbohydrates of fresh leaves and total soluble carbohydrates of fresh flowers data were transformed by using square root. As for proline content of fresh flowers data were transformed by using their logarithms. Correlations among traits were calculated for tomato accessions under both heat stress and moderate temperature. Statistical analyses was carried out using MSTAT-C software package (Freed *et al.* 1989).

Results and Discussion

Evaluation of accessions

Fruit set percentage

Data obtained on fruit set (%) of the studied tomato accessions evaluated under heat stress (2016 and 2017) and under moderate temperature (2017 and 2018) are presented in Table 1.

Under heat stress, fruit set ranged from 63.50 to 82.67 %. The highest significant value was recorded for LA0816, followed by LA1310 and LA2661 without significant differences between them. The lowest significant value was found for LA3213. Under moderate temperature, the range was from 68 to 87.67 %. The highest significant values were recorded for LA0816 (as found under heat stress) and LA1310 without significant differences between them, followed by LA2661 and LA3008. The lowest value was recorded for LA3213 (as found under heat stress).

Combined analysis showed that all evaluated accessions exhibited significantly high fruit set (%) under moderate temperature compared with their percentage under heat stress. Under both evaluation conditions, the highest significant values of fruit set (%) were found in LAs 0816, 1310, 2661, and 3008.

It was reported by Shelby *et al.* (1978) that a tenuous but significant reduction in viability of pollen grains was found in plants exposed to high temperature. They concluded that a major reason for reduction of fruit set under high temperature is due to insufficient pollination, and that reduction in the viability of embryo and pollen grains is a minor factor.

It was reported by Dane *et al.* (1991) that exposure to high temperature for prolonged periods of time caused strong reduction in pollen fertility in most tomato accessions, and that may have reduced their fruit setting ability. Zhou *et al.* (2017) reported that increasing temperature may reduce pollen grains fertility and inhibits fruit setting due to flower wilting and abnormal abscission. Also, a reduction in chlorophyll content, carbohydrates and photosynthetic process in adult leaves of tomato plants may be linked to failure of fruit set at high temperature.

Number of seeds

Data obtained on number of seeds per fruit of the studied tomato accessions evaluated under heat stress (2016 and 2017) and under moderate temperature (2017 and 2018) are presented in Table 2.

Under heat stress, number of seeds per fruit ranged from 35.45 to 107.5. The highest significant value was recorded for LA3320, followed by LA2661, LA1310 and LA3213. The lowest significant value was recorded for LA3008. Under moderate temperature, the range was from 61.23 to 122.7. The highest significant value was recorded for LA3320 (as found under heat stress), followed by LA3213 and LA2661, while the lowest value was recorded for LA3008 (as found under heat stress).

Combined analysis showed that all evaluated accessions exhibited significantly high number of seeds per fruit under moderate temperature compared with their content under heat stress. Under both evaluation conditions, the highest significant values of number of seeds per fruit were found in LAs 3320, 3213 and 2661.

Number of locules

Data obtained on the number of locules for tomato accessions evaluated under heat stress (2016 and 2017) and under moderate temperature (2017 and 2018) are presented in Table 3.

Under heat stress, number of locules ranged from 2.0 to 4.28. The highest significant values were recorded for LA3320 and LA3213 without significant differences between them, followed by LA3120. The lowest significant values were found for LAs 0816, 1310, 1995, 2706 and 3008, without significant differences among them. Under moderate temperature, the range was from 2.0 to 4.18. The highest significant values were recorded for LA3213 and LA3320 (as found under heat stress) without significant differences between them. The lowest values were recorded for LAs 0816, 1310, 1995, 2706 and 3008, without significant differences among them (as found under heat stress).

Combined analysis showed that all evaluated accessions exhibited no significant differences in the number of locules between heat stress and moderate temperature conditions.

Proline content of fresh leaves

Data obtained on proline content in leaves of the studied tomato accessions evaluated under heat stress (2016 and 2017) and under moderate temperature (2017 and 2018) are presented in Table 4.

Under heat stress, proline content of fresh leaves ranged from 9.62 to 21.64 mmole/100 g. The highest significant values were recorded for LAs 0816, 2661, 2662 and 3120 without significant differences among them, followed by LA3320. The lowest significant value was recorded for LA3213. Under moderate temperature, the range was from 3.51 to 9.29 mmole/100g. The highest significant values were recorded for LAs 0816, 2661, 2662 and 3120 (as found under heat stress) in addition to LA3320 without significant differences among them. The lowest value was recorded for LA1995.

Combined analysis showed that all evaluated accessions exhibited significantly high proline content in their leaves under heat stress compared with their content under moderate temperature. Under both evaluation conditions, the highest significant values of proline content were found in leaves of LAs 0816, 2661, 2662 and 3120.

It has been repeatedly reported previously that proline can be accumulated in plants or in foliar tissues under different circumstances of environmental stresses, such as thermal conditions (Huang and Cavaliery, 1979; Bohnert *et al.*, 1995; Kishor *et al.*, 1995; Madan *et al.*, 1995). The increase in proline accumulation in plants under stress might be caused by a breakdown of protein (Becker and Fock. 1986), suppression of protein synthesis (Dhindsa and Cleland, 1975), a reduction in amino acid and amide export (Tully *et al.*, 1979), or inhibition of leaf development (Davies and Van Volkenburg, 1983).

Proline content of fresh flowers

Data obtained on proline content in fresh flowers of the studied tomato accessions evaluated under heat stress (2016 and 2017) and under moderate temperature (2017 and 2018) are presented in Table 5.

Under heat stress, proline content of fresh flowers ranged from 13.38 to 29.56 mmole/100 g. The highest significant values were recorded for LAs 0816, 2661, 2662 and 3120 without significant differences among them, followed by LA3320. The lowest significant value was recorded for LA3213. Under moderate temperature, the range was from 3.05 to 8.77 mmole/100g. The highest significant values were recorded for LAs 0816, 2661, 2662 and 3120 (as found under heat stress) in addition to LA3008 and LA3320 without significant differences among them. The lowest value was recorded for LA3213.

Combined analysis showed that all evaluated accessions exhibited significantly high proline content in their flowers under heat stress compared with their content under moderate temperature. Under both evaluation conditions, the highest significant values of proline content were found in flowers of LAs 0816, 2661, 2662, 3120 and 3320.

Total soluble carbohydrates of fresh leaves

Data obtained on total soluble carbohydrates content in fresh leaves of the studied tomato accessions evaluated under heat stress (2016 and 2017) and under moderate temperature (2017 and 2018) are presented in Table 6.

Under heat stress, total soluble carbohydrates content of fresh leaves ranged from 4.26 to 11.49 mg/g. The highest significant values were recorded for LAs 1995, 2661, 2662 and 2706 without significant differences among them, followed by LA3320. The lowest significant value was recorded for LA3213. Under moderate temperature, the range was from 11.91 to 24.59 mg/g. The highest significant value was recorded for LA2662 followed by LA2706. The lowest value was recorded for LA3213 (as found under heat stress).

Combined analysis showed that all evaluated accessions exhibited significantly high total soluble carbohydrates content in their leaves under moderate temperature compared with their content under heat stress. Under both evaluation conditions, the highest significant values of total soluble carbohydrates content were found in leaves of LAs 1995, 2661, 2662 and 2706.

Stephenson (1981) suggested that increasing temperature during daytime above optimum for tomato growth may decrease carbohydrates available for supporting ovule growth, which may adversely affect fruit set. He also concluded that the influence of rising in temperature above optimum for photosynthesis may reduce the amount of carbohydrates fixed in the plant.

It was suggested by Ueda *et al.* (1996) that the reason for increased abscission under high temperature was changes in sugar metabolism and an increase in of cellulase activity in the abscission zone.

Total soluble carbohydrates of fresh flowers

Data obtained on total soluble carbohydrates content in flowers of the studied tomato accessions evaluated under heat stress (2016 and 2017) and under moderate temperature (2017 and 2018) are presented in Table 7.

Under heat stress, total soluble carbohydrates content of fresh flowers ranged from 3.19 to 9.22 mg/g. The highest significant values were recorded for LAs 3120, 2661, 2662 and 1310 without significant differences among them, followed by LA0816 and LA3320. The lowest significant value was recorded for LA3213. Under moderate temperature, the range was from 12.10 to 22.97 mg/g. The highest significant value was recorded for LA2661 (as found under heat stress) followed by LAs 1310, 1995, 2662, 3008 and 3120 without significant differences among them. The lowest value was recorded for LA3213 (as found under heat stress).

Combined analysis showed that all evaluated accessions exhibited significantly high total soluble carbohydrates content in their flowers under moderate temperature compared with their content under heat stress. Under both evaluation conditions, the highest significant values of total soluble carbohydrate content were found in flowers of LAs 2661, 2662, 3120 and 1310.

Correlation between traits

Correlations among traits measured in tomato accessions evaluated under heat stress condition are presented in Table 8. Fruit set percentage was positively correlated with each of proline content of fresh leaves, proline content of fresh flowers and total soluble carbohydrate of fresh flowers. An increase in proline content was noticed under heat stress conditions. This increase was higher in some accessions compared with others. This is likely to be an adaptive response to heat stress. Proline can be accumulated in plants under stress, such as thermal conditions (Huang and Cavaliery, 1979; Bohnert *et al.*, 1995; Kishor *et al.*, 1995; Madan *et al.*, 1995). The increase in proline accumulation in plants under stress might be caused by a breakdown of protein (Becker and Fock. 1986), a reduction in amino acid and amide export (Tully *et al.*, 1979). The increase in total soluble carbohydrates in accessions tolerant to high temperature is probably due to the availability of reserve food for promoting and maintaining fruit set and preventing flower abscission (Hassan, 2017). Number of seeds per fruit and number of locules per fruit were positively correlated with each other, as well-known in tomato fruits. Also, positive correlation was detected between proline content of fresh leaves and both proline content of fresh flowers and total soluble carbohydrate of fresh flowers. There was a negative correlation between fruit set and each of number of seeds per fruit and number of locules per fruit. This is usually the case with small-fruited cultivars which have fewer locules and fewer seeds per fruit (Hassan, 2017).

Correlations among traits measured in tomato accessions evaluated under moderate temperature are presented in Table 9. Fruit set percentage was positively correlated with each of proline content of fresh leaves, proline content of fresh flowers and total soluble carbohydrate of fresh flowers. Number of seeds per fruit and number of locules per fruit were positively correlated with each other. Also, positive correlation was detected between proline content of fresh leaves and each of proline content of fresh flowers, total soluble carbohydrate of fresh leaves and total soluble carbohydrate of fresh flowers. Total soluble carbohydrate of fresh leaves and total soluble carbohydrate of fresh flowers were positively correlated with each other. Fruit set percentage had a negative correlation with total number of seeds per fruit and number of locules per fruit.

Table 1 : Fruit set (%) of various tomato accessions evaluated under conditions of heat stress (2016 and 2017, plantings) and moderate temperature* (2017 and 2018, plantings).

Accession	Evaluation condition**	
	Heat stress	Moderate temperature
LA0816	82.67 b	87.67 a
LA1310	79.17 cd	86.33 a
LA1995	71.50 fg	73.67 f
LA2661	78.50 cde	80.33 bc
LA2662	77.33 de	80.00 cd
LA2706	70.83 g	73.67 f
LA3008	77.50 de	81.17 bc
LA3120	76.33 e	78.67 cde
LA3213	63.50 i	68.00 h
LA3320	72.17 fg	78.50 cde
Mean	74.95	78.80

*Combined analysis of transformed data by using square root.
**Interaction of temperature condition on fruit set (%). Values followed by a letter in common, over the two evaluation conditions, are not significantly different according to Duncan's multiple range test (P= 0.05).

Table 2 : Number of seeds per fruit in various tomato accessions evaluated under conditions of heat stress (2016 and 2017, plantings) and moderate temperature* (2017 and 2018, plantings).

Accession	Evaluation condition**	
	Heat stress	Moderate temperature
LA0816	52.10 j	76.30 gh
LA1310	83.00 f	92.17 e
LA1995	61.93 i	80.07 fgh
LA2661	90.50 e	106.0 c
LA2662	39.40 k	75.57 h
LA2706	64.13 i	94.07 de
LA3008	35.45 k	61.23 i
LA3120	61.37 i	98.53 d
LA3213	82.03 fg	113.6 b
LA3320	107.5 c	122.7 a
Mean	67.74	92.02

*Combined analysis of transformed data by using square root.
**Interaction of temperature condition on number of seeds per fruit. Values followed by a letter in common, over the two evaluation conditions, are not significantly different according to Duncan's multiple range test (P= 0.05).

Table 3 : Number of locules per fruit in various tomato accessions evaluated under conditions of heat stress (2016 and 2017, plantings) and moderate temperature* (2017 and 2018, plantings).

Accession	Evaluation condition**	
	Heat stress	Moderate temperature
LA0816	2.00 d	2.00 d
LA1310	2.00 d	2.00 d
LA1995	2.00 d	2.00 d
LA2661	3.00 c	3.00 c
LA2662	3.00 c	3.00 c
LA2706	2.00 d	2.00 d
LA3008	2.00 d	2.00 d
LA3120	3.36 b	3.36 b
LA3213	4.26 a	4.18 a
LA3320	4.28 a	4.15 a
Mean	2.79	2.77

*Combined analysis of transformed data by using square root.

**Interaction of temperature condition on number of locules per fruit. Values followed by a letter in common, over the two evaluation conditions, are not significantly different according to Duncan's multiple range test (P= 0.05).

Table 4 : Proline content (mmole/100 g fresh leaves) in various tomato accessions evaluated under conditions of heat stress (2016 and 2017, plantings) and moderate temperature* (2017 and 2018, plantings).

Accession	Evaluation condition**	
	Heat stress	Moderate temperature
LA0816	21.64 a	8.61 fg
LA1310	11.68 d	4.71 h
LA1995	10.93 de	3.51 h
LA2661	18.70 ab	7.70 fg
LA2662	19.70 ab	8.83 fg
LA2706	10.98 de	4.16 h
LA3008	14.33 c	7.15 g
LA3120	19.29 ab	9.29 ef
LA3213	9.62 ef	3.76 h
LA3320	17.92 b	8.19 fg
Mean	15.47	6.59

*Combined analysis of transformed data by using square root.

**Interaction of temperature condition on proline content of fresh leaves. Values followed by a letter in common, over the two evaluation conditions, are not significantly different according to Duncan's multiple range test (P= 0.05).

Table 5 : Proline content (mmole/100 g fresh flowers) in various tomato accessions evaluated under conditions of heat stress (2016 and 2017, plantings) and moderate temperature* (2017 and 2018, plantings).

Accession	Evaluation condition**	
	Heat stress	Moderate temperature
LA0816	29.13 a	8.29 g
LA1310	20.31 cd	6.01 h
LA1995	18.37 de	5.13 i
LA2661	29.56 a	8.53 g
LA2662	24.84 abc	8.77 g
LA2706	16.23 e	5.02 i
LA3008	18.62 de	7.13 gh
LA3120	26.04 ab	8.38 g
LA3213	13.38 f	3.05 j
LA3320	22.85 bc	8.41 g
Mean	21.93	6.87

*Combined analysis of transformed data by using logarithms.

**Interaction of temperature condition on proline content of fresh flowers. Values followed by a letter in common, over the two evaluation conditions, are not significantly different according to Duncan's multiple range test (P= 0.05).

Table 6 : Total soluble carbohydrate content (mg/g fresh leaves) in various tomato accessions evaluated under conditions of heat stress (2016 and 2017, plantings) and moderate temperature* (2017 and 2018, plantings).

Accession	Evaluation condition**	
	Heat stress	Moderate temperature
LA0816	6.41 h	15.13 de
LA1310	4.74 ij	12.19 f
LA1995	10.35 fg	16.29 cde
LA2661	10.45 fg	18.23 c
LA2662	11.43 f	24.59 a
LA2706	11.49 f	21.60 b
LA3008	5.47 hi	14.72 e
LA3120	5.77 hi	16.97 cd
LA3213	4.26 j	11.91 f
LA3320	9.46 g	16.98 cd
Mean	7.98	16.86

*Combined analysis of transformed data by using square root.

**Interaction of temperature condition on total soluble carbohydrate of fresh leaves. Values followed by a letter in common, over the two evaluation conditions, are not significantly different according to Duncan's multiple range test (P= 0.05).

Table 7 : Total soluble carbohydrate content (mg/g fresh flowers) in various tomato accessions evaluated under conditions of heat stress (2016 and 2017, plantings) and moderate temperature* (2017 and 2018, plantings).

Accession	Evaluation condition**	
	Heat stress	Moderate temperature
LA0816	6.69 ghi	15.99 cd
LA1310	7.38 fgh	18.99 b
LA1995	5.72 hi	17.27 bcd
LA2661	9.17 f	22.97 a
LA2662	8.50 fg	19.51 b
LA2706	6.30 hi	15.83 cd
LA3008	5.34 i	17.66 bc
LA3120	9.22 f	18.90 b
LA3213	3.19 j	12.10 e
LA3320	6.68 ghi	14.51 d
Mean	6.82	17.37

*Combined analysis of transformed data by using square root.

**Interaction of temperature condition on total soluble carbohydrate of fresh flowers. Values followed by a letter in common, over the two evaluation conditions, are not significantly different according to Duncan's multiple range test (P= 0.05).

Table 8 : Correlation among traits measured in tomato accessions evaluated under heat stress condition in both 2016 and 2017 plantings.

	Fruit set (%)	Number of seeds/ fruit	Number of locules/ fruit	Proline content of fresh leaves (mmole /100 g)	Proline content of fresh flowers (mmole /100 g)	Total soluble carbohydrates of fresh leaves (mg/g)	Total soluble carbohydrates of fresh flowers (mg/g)
Fruit set (%)	1	-0.310*	-0.495*	0.577**	0.638**	-0.022	0.528**
Number of seeds/fruit		1	0.521**	-0.138	0.011	0.042	0.024
Number of locules/fruit			1	0.123	-0.023	-0.080	-0.057
Proline content of fresh leaves (mmole/100 g)				1	0.777**	0.097	0.454**
Proline content of fresh flowers (mmole/100 g)					1	0.125	0.536**
Total soluble carbohydrates of fresh leaves (mg/g)						1	0.260*
Total soluble carbohydrates of fresh flowers (mg/g)							1

Significant level for correlations: * $P \leq 0.05$, ** $P \leq 0.01$

Table 9 : Correlation among traits measured in tomato accessions evaluated under moderate temperature in both 2017 and 2018 plantings.

	Fruit set (%)	**Number of seeds/ fruit**	**Number of locules/ fruit**	**Proline content of fresh leaves (mmole /100 g)**	**Proline content of fresh flowers (mmole /100 g)**	**Total soluble carbohydrates of fresh leaves (mg/g)**	**Total soluble carbohydrates of fresh flowers (mg/g)**
Fruit set (%)	1	-0.356**	-0.434**	0.477**	0.536**	-0.052	0.410**
Number of seeds/fruit		1	0.722**	-0.054	-0.094	-0.169	-0.208
Number of locules/fruit			1	0.202	0.035	-0.032	-0.268*
Proline content of fresh leaves (mmole/100 g)				1	0.679**	0.256*	0.258*
Proline content of fresh flowers (mmole/100 g)					1	0.386*	0.513**
Total soluble carbohydrates of fresh leaves (mg/g)						1	0.328**
Total soluble carbohydrates of fresh flowers (mg/g)							1

Significant level for correlations: * $P \leq 0.05$, ** $P \leq 0.01$

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