J. of Plant Production, Mansoura Univ., Vol. 12 (2):161 - 169, 2021

Journal of Plant Production

Journal homepage: www.jpp.mans.edu.eg
Available online at: www.jpp.journals.ekb.eg

Screening of Tomato Genotypes under High Temperature in North Sinai

Cross Mark

Mahmoud I. M. Ibrahim and Ahmed B. El-Mansy*

Plant Production Dept. (Vegetables), Fac. Environ. Agric. Sci., Arish Univ., Egypt

ABSTRACT

The present study was conducted at the Experimental Farm, Fac., Environ. Agric., Sci., Arish Univ., during successive summer seasons of 2018 and 2019, to screening twenty one genotypes of tomato as well as Galaxy 040 F1 as check to high temperature under North Sinai conditions. The analyses of variance for all studied traits revealed that mean squared of genotypes were highly significant under high average day/night-time temperature (34.6 oC and 23.9 oC, respectively) of two seasons. The studied lines CLN 1621F, Rio Grande and CLN2514A were the best for floral traits. However, the superior genotypes for fruit set percentage were CLN2026D and Rio Grande. Results of screening revealed that CLN2514A was the best for no. fruits/plant, CLN2413D and CLN1466EA for average fruit weight and CLN1621F for fruit yield /plant (2.84 kg). The highest content of proline recorded by CLN1621F and CLN3125L. Tomato genotypes ranked based on cumulative score to tolerant, moderately tolerant, moderately sensitive and sensitive groups. The clustering pattern of tomato entries grouped into five clusters. The clusters 1, 3 and 4 consisted of three genotypes, whereas the clusters 2 and 5 involved nine and four ones, respectively. Principal component analysis revealed that first two components participating 81.3% of total variability. The highest contribution towards total variability in PC1 and PC2 reflected by no. pollen grains/anther, pollen viability%, branches/plant, fruit set%, fruit yield/plant, average fruit weight, no. seeds/fruit and proline content traits, suggesting that these traits might be taken in concern for successful selection of tomato genotypes under high temperature.

Keywords: tomato, high temperature, cluster analysis, principal component analysis, proline content.

INTRODUCTION

Tomato (*Solanum lycopersicum*) is one of important vegetable crops broadly grown and consumed around the world. It grow well and gave high productivity in temperature range about 18-28^{o}C (Saeed *et al*., 2007). Heat stress has become an important determining factor for tomato cultivation and production. In Egypt, tomato fruit prices are increase about 300 to 400 % during months of September and October as a result of rising of day/night temperature above optimum range in the period from June to August which effect on growth, flowering, setting and productivity of tomato. The climatic analysis in the next decades for places which tomato is cultivated predicted that temperature will increase in both intensity and quantity above normal range (Bell *et al*., 2000).

Tomato plants grow under high temperature showed morphological, physiological, anatomical and molecular responses to tolerant this conditions, and both of reproductive and productivity stages were extremely affected by high temperature (Faruq *et al*., 2012). High temperature caused significant increase of flower drop during reproductive development, decreased fruit set percentage and increased incidence of abnormalities fruits (blossom end rot, immature fruit and small size) consequently decreased total yield of tomato crop (Abdul-Baki, 1991; Sato *et al*., 2006; Singh *et al*., 2015; Xu *et al*., 2017). Increase of temperature up to 2-4^{o}C over the optimal degree negatively affects on gamete development, reduce the ability of pollinated flowers to developed seeded fruit, so reduced productivity of tomato (Peet *et al*., 1997; Sato *et al*., 2001; Firon *et al*., 2006; Solankey *et al*., 2017 and 2018). Most of tomato genotypes cultivated under high temperature exhibited stigma exertion. Stigma position is highly affected, and thus prevent pollination and eventually productivity reduced (Dane *et al*., 1991; Borgohain and Swargiary, 2008). Pollen production and viability are also adversely affected by heat stress before flower anthesis (Kinet and Peet, 1997; Borgohain and Swargiary, 2008; Zhou *et al*., 2016; Xu *et al*., 2017). Both of fruit number and average fruit weight were the important components of yield and were extremely affected by heat stress and eventually yield was clearly reduced (Singh *et al*., 2015; Solankey *et al*., 2018). Roy *et al*. (2011) reported that the powerful method to improve tolerance to high temperature of tomato is to identify natural variations in tolerance among studied genotypes (lines, varieties, landraces and wild species). These variations can be utilized to develop tomato lines tolerant to this condition and used as suitable parents in future breeding program.

To get specific information on genetic variations in studied genotypes depend on different techniques used for measurement like as plant characteristics (morphological, physiological and agronomical traits). Multivariate statistical analysis based on cluster analysis (Mahalonobis's D^2 statistics) and principal component analysis (PCA) are mostly utilized to determine the nature and magnitude of genetic diversity among tomato germplasm (Mohammadi and Prasanna, 2003; Sudre *et al*., 2007) and beneficial to describe phenotypic variations in studied population. Hierarchical cluster analysis is valuable tool for measuring

---

*** Corresponding author.**
E-mail address: aelmansy@Aru.edu.eg
DOI: 10.21608/jpp.2021.154345

divergence among a set of populations on the basis of genetic distances, and grouping entries based on degree of similarity and dissimilarity (Van Hintum, 1995). Principal component analysis is a descriptive method which shows the pattern of trait variation among individual genotypes (Jackson, 1991). This gives a set of multivariate data into components that account for a meaningful amount of variation in a given population. Keeping in view these facts the present investigation was to screening and identifying twenty two genotypes of tomato to high temperature under North Sinai conditions for floral and vegetative traits, yield attributes and fruit quality based on performance and multivariate analysis.

MATERIALS AND METHODS

Field trials were conducted in the Experimental Farm, Fac., Environ. Agric., Sci., Arish Univ., Arish (having a Latitude: 31° 6′ 55.8″ North and Longitude: 33° 46′ 46.2″ East), North Sinai Governorate during summer seasons of 2018 and 2019, to screening twenty one genotypes of tomato to high temperature under North Sinai conditions as well as Galaxy 040 F_1 (USA Galaxy Seed Com.) as check. The genetic material collected from two sources, 15 lines imported from Asian Vegetable Research and Development Center (AVRDC), *viz*. CLN1466EA, CLN1462A, CLN1621F, CLN2026D, CLN2413D, CLN2463E, CLN2514A, CLN3070J, CLN3078A, CLN3078C, CLN3125A-23, CLN3125O-19, CLN3125L, CLN3125E and CLN5915-206D4) however, the rest 6 lines and/or cultivars (Castle Rock, Peto 86, FM–9, Super Strain B, Super Marmande and Rio Grande) were obtained by personal communication with Prof. Dr. El-Mahdy Ibrahim Metwally Hort. Dep., Fac., Agric., Kafr El-Sheikh University. The mean monthly agro-meteorological data were recorded during the two seasons (Fig. 1) using digital thermometer device TP50. For evaluation trials, seeds of 22 tomato genotypes were sown on 29th March in two seasons in the nursery trays.

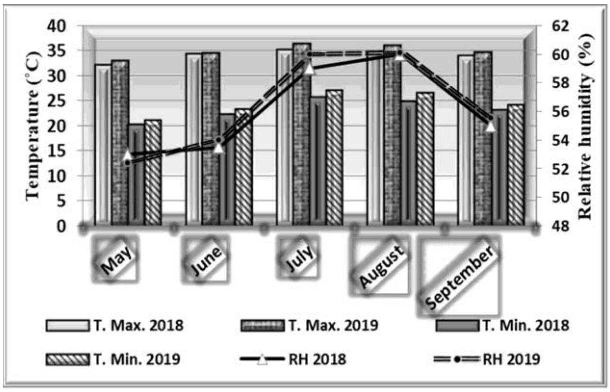


Fig. 1. Average monthly of maximum and minimum temperature and relative humidity during the growing seasons of 2018 and 2019.

The genotype seedlings were transplanted at 45 days after sowing. Tomato genotypes were laid out in a randomized complete block design with three replications. Each replication comprised 22 plots. The field plot area was 18 m^2 (15 m length x 1.2 m width), each genotype planted on dripper line 1.2 m a part and 0.5 m spaced between plants in the same line. The other normal agriculture practices were done according to requirements of tomato crop production.

Data collected: To assess the genetic diversity of tomato genotypes, numbers of quantitative and qualitative traits were studied including number of pollen grains/anther (NPG), pollen viability (PV) and stigma position (mm, SP) as floral traits; plant height (cm, PH), number of branches/plant (NB/P) and fruit set percentage (FS) as vegetative traits (three months after transplanting); number of fruits/plant (NF/P), fruit yield/plant (kg, FY/P) and average fruit weight (g, AFW) as yield components in addition to total soluble solids (TSS%) using a hand refractometer according to A.O.A.C. (1990) and number of seeds/fruit (NSF) as fruit traits as well as proline content (PC, mg/100g F.W) after 90 days from transplanting was calculated according to Bates *et al*. (1973) as the following formula: PC (mg/g FW) = $[(mg\ proline/\mathrm{ml} \times ml\ toluene)/115.5] \times [5/(g\ sample)]$ and converted to mg/100g FW. Where, 115.5 is the molecular weight of proline. As for, ranking of tomato genotypes, the score of each genotype in each trait was made based on mean performance, and then total score for all traits was calculated for every genotype. From total score for all genotypes, range was calculated and divided on four categories (tolerant, moderately tolerant, moderately sensitive and sensitive).

Statistical analysis: Recorded data of both seasons of 2018 and 2019 for all the studied traits were subjected to analysis of combined data over the two seasons according to Cochran and Cox (1957), and the comparison among means was applied using Duncan Multiple Range Test (Duncan, 1955). Cluster analysis was carried out by the hierarchical cluster analysis procedure of the program SPSS-V.13 for windows. Principal component analysis (PCA) was performed using Minitab statistical software -V.17. The PCA was used to determine the extent of genetic variation. Eigen values were obtained from PCA, which were used to determine the relative discriminative power of the axes and their associated characters (Pradhan *et al.* 2011).

RESULTS AND DISCUSSION

The investigation was conducted using twenty two genotypes to evaluate their performance under high average day /night-time of temperature (34.6 ºC and 23.9 ºC) of two seasons (Fig.1). The analyses of variance for all studied traits revealed that mean squares of genotypes were highly significant, indicating the wide rang of variability and diversity among entries under this condition. In this concern, many researchers found wide variability among tomato cultivars for most of the studied characters under heat stress (Sato *et al*., 2000 and 2006; Ansary, 2006; Solankey *et al*., 2017; El-Saka, 2018).

Regarding floral traits, results in Table 1 show that there are highly significant differences for number of pollen grains/anther, pollen viability and stigma position among genotypes. The studied traits were sensitive to high temperature and genotypes greatly varied in the degree of sensitive. As for number of pollen grains /anther, values range from 213.3 for Super Strain B to 4283.0 for CLN 1621F with over all mean 2471.7, both lines CLN 1621F and Rio Grande exceeded the check Galaxy 040 by 4.9 and 0.56%. However, pollen viability was extremely decreased under high temperature and the genotypes severely varied, the maximum viability recoded by CLN1621F (69.97%), followed by Rio Grande (58.73%), CLN2514A (58.37%) and CLN5915-206D4 (53.20%), however minimum value reflected by Super Strain B (5.97%). Also, data show that all studied genotypes exhibited stigma exertion with values range from 0.20 mm for CLN1621F to 1.27 mm for both Super Strain B and Super Marmande. Therefore, plant breeders endeavors must be toward selected genotypes that have lower stigma tube under heat stress to increase fruit yield and utilize in future breeding program. In general, we can conclude that the genotypes CLN 1621F, Rio Grande, CLN2514A, CLN3125O-19, CLN3125E, CLN5915-206D4 are the best for floral traits. Many studies have revealed that pollen viability screening is particularly important for its positive and strong association with fruit setting (Sato *et al*., 2000; Firon *et al*., 2006; Xu *et al*., 2017).

Pollen viability as a key trait for heat tolerance was reported in several other crops, such as soybean, cotton, canola, wheat and rice, and capsicum species (Kakani *et al*., 2005; Reddy and Kakani, 2007; Singh *et al*., 2008; Mesihovic *et al*., 2016), confirming its importance as a key indicator of thermo-tolerance status of genotypes. Using pollen number as a screening trait can be misleading as it is not consistently associated with fruit set (Sato *et al*., 2000 and Paupière *et al*., 2017). Significant decreases in pollen number and pollen viability were recorded in tomato screening studies under heat stress (Xu *et al*., 2017 and Driedonks *et al*., 2018). A plant can produce high number of pollen but their release will be greatly impaired by humidity (Weerakoon *et al*., 2008 and Yan *et al*., 2010). Levy *et al.* (1978) reported that flower abscission was highly correlated with style exertion under high temperatures (36–39 ˚C) and style protrusion out of the antheridia cone of more than 1 mm caused total absence of fruit set, revealing a negative association between those traits. Development of tomato lines with high pollen number and pollen viability is important for yield improvement under heat stress (Ayenan *et al*., 2019). Interestingly, under heat stress, some cultivated tomatoes showed good thermo-tolerance potential especially in regard to number of pollen number/flower such as CLN1621F (Paupière *et al*., 2017) and for pollen viability (Driedonks *et al*., 2018).

On the other hand, the results indicate that high temperature badly affects on vegetative growth *via* defected of supply and transport pathway of carbohydrate in specific organs and at specific development stages (Sato *et al*., 2006). Moreover, allocation of assimilates severely reduced under high temperature, reduced production of growth regulators and supply of photosynthesis to plant organs compared with normal temperature (Ranjodh *et al*., 2005). Variations among genotypes may be owed to lower supply of photosynthates and low production of growth regulators in sink tissues because abnormalities of reproductive tissues of male and female (Dane *et al*., 1991 and Ansary, 2006). Failure of fruit setting ability because of poor inflorescence and fertility, bud drop, abnormal flower growth and low pollen creation at high temperature (Hazra *et al*., 2007).

Yield and its components (number and average fruit weight) are important criteria to selection for tolerance to high temperature conditions of tomato. Results of screening presented in Table 1 revealed that, number of fruits/plant significantly varied from 7.10 for CLN1462A to 97.50 for CLN2514A with grand mean 38.28. It is obvious that, genotypes produced high fruit number have low average fruit weight, indicating negative correlation between them under this condition (El-Saka, 2018). Line CLN2413D displayed the heaviest fruit weight (85.96g) followed by CLN1466EA (78.59g), Super Marmande (76.18g) and Castle Rock (73.13g), however the lowest values recorded by highest fruit number lines CLN2514A and CLN2463E (16.16 and 17.93g, respectively) with general mean 58.02 g. The reduction in average fruit weight may be due to negative impacts of high temperature on imbalance of carbohydrate supply and transport pathway to economic organs (Sato *et al*., 2006), as well as the effect on production of auxins in fruits. Main target of any breeding program is the yield and very useful criteria for selection under high temperature. Out of the 21 tomato genotypes, CLN1621F (2.84 kg) line did not significantly differs than the check Galaxi 040 (2.91 kg), however the rest entries varied from 0.42 kg for CLN1462A to 2.78 kg for CLN3125L with overall mean 1.94 kg. From results, there are eleven tomato genotypes gave fruit yield exceeded than 2 kg/plant, these promising lines would be heat tolerant for yield and should be evaluated and retested in differ environmental conditions before employing in future breeding program to mitigate high temperature risk in order to increase tomato productivity. The reduction of yield/plant is a result of high temperature and its impact on physiological and biochemical process in diverse genotypes (Abdul-Baki, 1991; Saeed *et al*., 2007; El-Sayed *et al*., 2015; Rashwan, 2016; Solankey *et al*., 2018).

Therefore, tomato yield improvement under heat stress may require simultaneous increase in fruit weight and fruit number, both being major yield components. Understanding molecular and physiological mechanisms involved in the negative association between fruit set and fruit size is important to efficiently improve tomato yield in heat prone environments (Ayenan *et al*., 2019).

Among studied genotypes, Peto 86, CLN3125L and CLN3125O-19 recoded the highest values for TSS% 8.33, 8.20 and 8.17%, respectively (with no significant differences between them) followed by Rio Grande (7.73%) and CLN5915-206D4 (7.40) compared with the check genotype (7.17%). While the lowest value reflected by CLN3125A-23 (4.73%) with grand mean 6.51%. It is appeared from results of yield and TSS% that all genotypes produced high productivity have moderate to high content of TSS, indicating that TSS is important criteria for selection and screening under high temperature. In this respect, Solankey *et al.* (2015 and 2017) found that heat tolerant genotypes have more content of TSS% than susceptible ones. On the other hand, El-Sayed *et al.* (2015) reported that this trait was not affected by heat stress in open field. Concerning number of seeds/fruit, the values varied from 21.83 for CLN1462A to 100.40 for CLN5915-206D4 with overall mean 71.87 (Table 1). Eight and two genotypes significantly exceeded and equal the check Galaxy 040 (79.27), respectively. Results clear that the genotypes produced low number of seeds also have low values of pollen viability, fruit set and average fruit weight, therefore these genotypes consider as sensitive to high temperature and accordingly led to reduction of tomato production (Abdul-Baki, 1991). Under high temperature, Ansary (2006) reported that the reduction of seed number may be due to few ovules are fertilized and also to low fruit weight. Under constant high temperature, tomato plants cumulating organic compounds with low molecular mass like proline amino acid. Data presented in Table 1 showed that the highest content of proline recorded by CLN1621F (16 mg), followed by CLN3125L (14.8 mg), Rio Grande (13.77 mg) and CLN3078A (13.6 mg) compared with the check genotype (14.1 mg). However, the lowest values reflected by Super Strain B (6.9 mg) and CLN1462A (7.4 mg).

Table 1. Mean performance of 22 tomato genotypes under high temperature for all studied traits (combined the two summer seasons).

Item	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**
NPG	1150.^{g}	305^{k}	4283^{a}	2400^{g}	3033^{e}	2010^{h}	3803^{c}	1567^{i}	3150^{e}	3050^{e}	1015^{j}	3465^{d}	2800^{f}	3183^{e}	2267^{g}	268.3^{k}	3513^{d}	1663^{i}	213.3^{k}	3053^{e}	4103^{ab}	4080^{b}
PV(%)	19.1^{o}	6.2^{q}	70^{a}	48.23^{e}	43.2^{h}	23.17^{n}	58.37^{c}	26.43^{l}	44.87^{f}	41.23^{j}	24.3^{m}	44.13^{g}	48.3^{e}	42.9^{hi}	53.2^{d}	14.3^{p}	42.4^{i}	23.17^{n}	5.97^{q}	32.3^{k}	58.73^{c}	68.5^{b}
SP(mm)	1.26^{a}	1de	0.20^{k}	0.57^{i}	0.74^{gh}	1.15^{abc}	0.60^{i}	1.10^{bcd}	0.65^{hi}	0.83^{fg}	1.1^{bcd}	0.84^{fg}	0.76^{gh}	0.78^{gh}	0.51^{i}	1.2^{ab}	0.95^{ef}	1.03^{cde}	1.27^{a}	1.27^{a}	0.36^{j}	0.36^{j}
PH(cm)	60.6^{i}	66.17^{g}	83.03^{b}	85.13^{a}	74.13^{e}	60.7^{i}	77.77^{c}	57.53^{k}	65.5^{g}	59.5^{j}	67.47^{f}	75.6^{d}	77.5^{c}	58.47^{jk}	78.57^{c}	45.7^{o}	51^{n}	43.73^{p}	50.1^{n}	53.7^{m}	55.67^{l}	62.3^{h}
NB/P	5.83^{efg}	4.57^{kl}	9.4^{a}	7.07^{c}	5.4^{ghi}	5.17^{hij}	7.03^{c}	5.6^{fgh}	6.9^{cd}	6.3^{e}	5.17^{hij}	6.2^{ef}	8.1^{b}	6.37^{de}	8.3^{b}	4.5^{kl}	7.2^{c}	4.93^{ijk}	4.1^{l}	6.2^{ef}	7.4^{c}	7.17^{c}
FS(%)	34.93^{q}	18^{t}	80.1^{a}	63.4^{e}	55.5^{i}	38.03^{o}	75.1^{c}	40.4^{m}	60.1^{g}	51.1^{j}	39.6^{n}	57.5^{h}	62.5^{f}	49.9^{k}	65.27^{d}	29.7^{r}	50.5^{k}	36.8^{p}	21^{s}	48.47^{l}	77.23^{b}	80.5^{a}
NF/P	17.53^{m}	7.1^{o}	38.83^{h}	37.87^{h}	27.37^{j}	79.17^{b}	97.5^{a}	32.7^{i}	45.93^{g}	50.73^{e}	24.1^{k}	47.53^{f}	57.23^{c}	31.77^{i}	53.8^{d}	11.3^{n}	38.8^{h}	21.1^{l}	12.87^{n}	24.77^{k}	38.47^{h}	45.77^{g}
FY/P(kg)	1.38^{k}	0.42^{n}	2.84^{ab}	2.59^{d}	2.35^{fg}	1.42^{k}	1.58^{j}	1.85^{i}	2.55^{de}	2.29^{g}	1.41^{k}	2.46^{ef}	2.78^{bc}	2.15^{h}	2.67^{cd}	0.83^{m}	2.09^{h}	1.14^{l}	0.75^{m}	1.89^{i}	2.42^{f}	2.91^{a}
AFW(g)	78.5^{9b}	60.1^{gh}	73.1^{cd}	68.54^{de}	85.96^{a}	17.9^{n}	16.2^{n}	56.6^{hij}	55.6^{hij}	45.1^{m}	58.6^{ghi}	51.75^{kl}	48.5^{lm}	67.8^{ef}	49.64^{klm}	73.1^{cd}	53.9^{ijk}	54^{ijk}	58.6^{ghi}	76.18^{bc}	62.82^{fg}	63.7^{efg}
TSS(%)	6.33^{e}	5.07^{gh}	7.17c	6.47^{de}	7.30c	6.4^{de}	5.47^{f}	5.67^{f}	6.27^{e}	5.67^{f}	4.7^{h}	8.17^{a}	8.2^{a}	6.77^{d}	7.4^{bc}	5.43^{fg}	8.33^{a}	6.53^{de}	5.37^{fg}	5.57^{f}	7.73^{b}	7.17^{c}
NSF	62.83^{j}	21.83^{n}	97^{b}	93.67^{c}	84.2^{e}	63.73^{j}	50.6^{k}	66.2^{i}	88^{d}	70.2^{h}	76^{g}	84.1^{e}	89.5^{d}	81^{f}	100.4^{a}	39.5^{l}	76.6^{g}	51.7^{k}	34.3^{m}	81^{f}	89.6^{d}	79.3^{f}
PC(mg/ 100g F.W)	10.1^{fg}	7.43^{i}	16^{a}	13.43^{c}	13.1^{cd}	8.96^{gh}	9.63^{g}	10.1^{fg}	13.6^{bc}	13.1^{cd}	9.37^{g}	13.1^{cd}	14.8^{b}	11.2^{ef}	13.1^{cd}	7.87^{hi}	12.1^{de}	7.98^{hi}	6.93i	11.2^{ef}	13.8^{bc}	14.1^{bc}
	MS	S	T	T	MT	MS	MT	MS	MT	MS	MS	MT	MT	MT	T	S	MT	S	S	MS	T	T

- Means followed by the same alphabetical letter (s) within each column are not significantly different at 5% level according to Duncan's Multiple Range Test.

- Where NPG (pollen grains/anther), PV(pollen viability), SP (stigma position), PH (plant height), NB/P (number of branches/plant), FS (fruit set percentage), NF/P (number of fruits/plant), FY/P (fruit yield/plant), AFW (average fruit weight), TSS (total soluble solids percentage), NSF (number of seeds/fruit) and PC (proline content)

1: CLN1466EA, 2: CLN1462A, 3: CLN1621F, 4: CLN2026D, 5: CLN2413D, 6: CLN2463E, 7: CLN2514A, 8: CLN3070J, 9: CLN3078A. 10: CLN3078C, 11: CLN3125A-23 12: CLN3125O-19, 13: CLN3125L, 14: CLN3125E, 15: CLN5915-206D4, 16: Castle Rock, 17: Peto 86, 18: FM-9, 19: Super Strain B, 20: Super Marmande, 21: Rio Grande, 22: Galaxy 040.

T: Tolerant, MT: Moderately tolerant, MS: Moderately sensitive, S: Sensitive to high temperature.

Results obviously revealed that most of tomato entries exhibited best values for pollen viability, fruit set percentage, fruit yield and seed number show the highest content of proline, suggesting that this trait is very important criteria to identify tolerant and sensitive genotypes under high temperature (Hare *et al.*, 1998; Sairam and Tyagi, 2004). Accordingly, comparing the performance of the 21 genotypes on the basis of total yield per plant (kg/plant) and highest desirable increment of yield (% over the check and/or the general mean of all genotypes under high temperature stress as well as the performance of other traits was done. The best genotypes, which classified on the basis of these parameters, are shown in Table 2.

Table 2. The best genotypes chosen on the basis of mean yield along with desirable significant effect for other traits comparing with the average of all genotypes under high temperature stress.

Genotypes	**Number of clusters and Ranking of studied tomato genotypes for 12 traits**			**Yield Kg/ plant**	**Increment over the average of all genotypes under high temperature stresses**						**DSI/E**
	Number of Cluster	**Total Score**	**Ranking***		**% yield/ plant**	**Range % of traits group**					
						Floral traits	**Vegetative traits**	**Yield attributes**	**Fruit traits**	**Proline content**	
Tolerant/moderately tolerant to stress											
CLN1621F	I	148	1	2.84	46.4%	(-)76.2 -83.5%	29.6 - 55.2%	1.4 - 46.4%	10.4 - 35%	40.4%	All
CLN3125L	II	117.5	2	2.78	43.3%	(-)9.5 - 26.6%	20.9 - 28.4%	(-)16.3 -49.5%	24.6 - 26%	29.8%	d,e,i,j
CLN5915-206D4	IV	126.5	1	2.67	37.6%	(-)39.3 -39.5%	22.6 - 31.5%	(-)14.4 -40.5%	13.7-39.7%	14.9%	d,e,i,j
CLN2026D	IV	123	1	2.59	33.5%	(-)32.1 -26.5%	12 - 32.8%	(-)1.1 - 33.5%	(-)0.6-30.3%	17.8%	d,e,h,i
CLN3078A	II	110.5	2	2.55	31.4%	(-)22.6 -27.4%	2.2 - 16.5%	(-)4.2 - 31.4%	(-)3.7 - 22.4%	19.6%	d,e,j
Sensitive to stress											
CLN1462A	III	34	4	0.42	-78.4%	(-)87.7 - 19%	(-)65.1 -3.2%	(-)81.5 - 3.7%	(-)69.6 - (-)22.1%	(-) 34.8%	d,h
Super Strain B	III	27	4	0.75	-61.3%	(-)91.4 -51.2%	(-)59.3 - (-)21.8%	(-)66.4 - 1%	(-)52.2 - (-)17.5%	(-) 39.2%	h
Castle Rock	III	37.5	4	0.83	-57.2%	(-)89.1 -42.9%	(-)42.5 - (-)28.6%	(-)70.4 - 26.1%	(-)45 - (-)16.6%	(-) 31%	h
FM–9	V	43.5	4	1.14	-41.2%	(-)39.2 -22.6%	(-)31.8 - (-)21.9%	(-)44.9 - (-)6.9%	(-)28.1 – (+)0.3%	(-) 30%	i

***Ranking: 1: Tolerant to high temperature (148.0-117.75), 2: Moderately tolerant to high temperature (<117.75-87.50), 3: Moderately sensitive to high temperature (<87.50-57/.25), 4: Sensitive to high temperature (<57.25- 27.00) DSI E: Desirable significant increasing or equal for other traits due to compare with the check a: NPG/A , b: PV%, c: SP, d: PH, e: NB/P, f: FS%, g: NF/P, h: AFW, i: TSS%, j: NS/F, k: PC.**

Five out of the 21 studied genotypes were classified as the heaviest genotypes for yield under stress and exhibited significant increase for plant height and number of seeds per fruit comparing with the check genotype in addition to surpassing the general average for PV, SP, NB/P, FS, NSF and PC. Three out of these five genotypes namely:

CLN1621F, CLN3125L and CLN5915-206D4 exhibited significant desirable positive increment for number of branches and TSS% compare with the check and superior over the general mean for PV, SP and FS. Two out of these three genotypes (CLN1621F and CLN3125L) along with the CLN3078A recorded the highest desirable positive increment for NPG over the general mean under stress, indicating the possibility of combine both high yield and good quality characters under abiotic stress. The five genotypes, which exhibited significant positive increment for yield/plant, were also combined significant/highly significant desirable negative or positive (due to the point of view) three or more important studied characters particularly vegetative growth, average fruit weight ….etc. The opposite of these results, as shown in the same Table 2, appears in the performance of the four genotypes that are very sensitive to heat stress, i.e., CLN1462A, Super Strain B and Castle Rock in cluster III as well as F M – 9 in cluster V. Again, these results reveal that tomato genotypes ranked based on cumulative score to tolerant group (CLN1621F, Galaxy 040 F_1 and Rio Grande from cluster I along with both CLN5915-206D4 and CLN2026D genotypes of cluster IV), moderately tolerant group (CLN3125L, CLN3078A, CLN3125O-19, CLN2514A, CLN2413D, CLN3125L and Peto 86 all from cluster II), moderately sensitive and Sensitive groups (FM-9 (cluster V) as well as each of Castle Rock, CLN1462A and Super Strain B from cluster III). However, genotype with high yield did not necessarily produce high other traits, especially qualitative traits and vice versa.

Our results reveal that the abovementioned genotypes might be of prime importance in breeding program and for traditional agricultural procedures for high yield and/or some of its important components under high temperature stress. As for ranking of 22 tomato genotypes on the basis of mean performance of the studied traits (Table 3), based on score of each genotype for each trait, genotypes arranged from high to low performer and ranked based on cumulative score to four tolerance groups.

However, CLN1621F, Galaxy 040 F_1, CLN5915-206D, CLN2026D and Rio Grande which represent about 22.7% of total entries, were identified as the most heat-tolerant genotypes and have total score ranged from 148.00 to 117.75. Of the 22 genotypes evaluated, 31.8% (<117.75-87.50) was classified as moderately tolerant, 27.3% (87.50 to 57.25) was moderately sensitive, and 18.2% of total tomato entries (57.25 to 27.00) sensitive as shown in Tables 3&4. In this concern, El-Saka (2018) classified five tomato genotypes and the obtained four crosses under high temperature based on scale from 1 for heat sensitive to 10 for highly tolerant using leaf and stem sunburns, leaf rolling and draying for the assessment to three categories: highly tolerant from 8-10, moderately tolerant from 4-7 and heat sensitive from 1-4.

Cluster analysis and genetic distance:

The clustering pattern of studied genotypes was graphically obtained as dendrogram that provide visual idea about clusters and variability existing in each tomato population. Accordingly, cluster analysis distributed twenty two genotypes into five clusters comparison (Table 3 and Fig.2).

Table 3. Clustering pattern, total score and ranking of tomato genotypes

CL	Genotypes	TSc	R	T
I	Rio Grande	121.5	1	MS
	Galaxy 040	131	1	S
	CLN1621F	148	1	T
II	CLN3078A	110.5	2	T
	CLN3125E	94	2	MT
	CLN2413D	106	2	MS
	Super Marmande	76.5	3	MT
	CLN3078C	86.5	3	MS
	CLN3125L	117.5	2	MT
	CLN3125O-19	108.5	2	MS
	Peto 86	90	2	MS
	CLN2514A	107	2	MT
III	CLN1462A	34	4	MT
	Castle Rock	37.5	4	MT
	SuperStrain/B	27	4	T
IV	CLN2026D	123	1	S
	CLN5915/206D4	126.5	1	MT
	CLN2463E	60	3	S
V	CLN3070J	65	3	S
	FM – 9	43.5	4	MS
	CLN1466EA	59	3	T
	CLN3125A-23	61.5	3	T

CL: No of Cluster TSc: total score T: tolerance level

***R: Ranking: 1): Tolerant to high temperature (148.0-117.75), 2): Moderately tolerant to high temperature (<117.75-87.5), 3): Moderately sensitive to high temperature (<87.50-57.25) and 4): Sensitive to high temperature (<57.25- 27)**

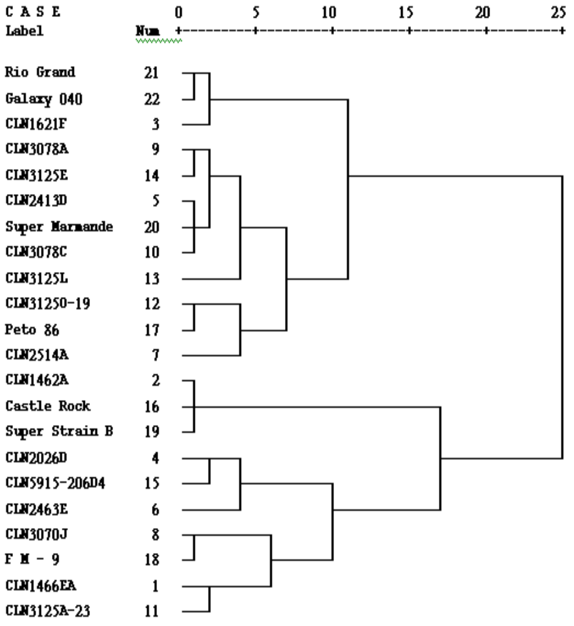


Fig. 2. Dendrogram, using average linkage (Between Groups), for twenty two genotypes of tomato based on 12 studied traits

Three genotypes (Rio Grande, Galaxy 040 and CLN1621F) amounting to 13.6% of entire genotypes, were grouped in cluster-I. Cluster-II was the largest among all the five clusters, where nine (40.9%) genotypes were grouped together. Both Clusters-III&IV comprised of three (13.6% each) genotypes, while four (18.2%) genotypes (CLN3070J, FM - 9, CLN1466EA and CLN3125A-23) were grouped in Cluster-V.

Our results were comparable to findings of Krasteva *et al.* (2010) wherein they grouped determinate accessions of tomato using cluster analysis. Based on similarity and dissimilarity (Table 4), Euclidean distance values among 22 tomato genotypes were significant for all pairs of comparison. The dissimilarity coefficient ranged from 29.2 to 4071.7, Rio Grande and Galaxy 040 were nearest genotypes with lowest dissimilarity followed by CLN2413D and Super Marmande (33.3). On the other hand, pairs of genotypes CLN1621F and Super Strain B, CLN1621F and Castle Rock showed the highest dissimilarity index (4071.7 and 4016.4, respectively), these pairs of greatest divergence could be used in breeding program for developing new cultivars and hybrids with high yielding and adapted to high temperature.

Table 4. Euclidean distance among twenty two genotypes of tomato.

Genotypes	Euclidean distance																				
	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
1	846.6*	3134.4*	1251.5*	1883.8*	864.4*	2655.9*	417.7*	2000.8*	1900.8*	137.6*	2315.7*	1651.6*	2033.7*	1119.3*	882.2*	2363.8*	514.4*	937.6*	1903.5*	2954.1*	2931.0*
2	0.0	3980.2*	2097.5*	2729.8*	1707.8*	3500.8*	1263.1*	2846.6*	2746.3*	712.8*	3161.4*	2497.2*	2879.5*	1965.0*	49.6*	3209.4*	1359.2*	94.1*	2749.4*	3799.9*	3776.7*
3		0.0	1883.5*	1250.8*	2275.6*	489.4*	2717.7*	1134.1*	1234.9*	3269.1*	819.5*	1483.9*	1101.2*	2017.0*	4016.4*	772.2*	2621.6*	4071.7*	1231.5*	182.9*	205.5*
4			0.0	633.9*	398.9*	1406.3*	835.0*	750.4*	651.6*	1385.7*	1065.3*	401.1*	784.0*	136.0*	2133.4*	1114.2*	740.3*	2188.8*	654.8*	1703.7*	1680.5*
5				0.0	1027.5*	777.5*	1467.3*	122.5*	54.1*	2018.7*	433.5*	238.5*	152.1*	768.3*	2765.9*	481.9*	1371.4*	2821.2*	33.3*	1070.8*	1047.8*
6					0.0	1794.3*	447.5*	1141.8*	1041.0*	997.5*	1456.2*	792.3*	1175.7*	266.2*	1744.1*	1504.6*	354.0*	1798.8*	1046.6*	2095.0*	2071.8*
7						0.0	2238.6*	658.0*	756.4*	2790.2*	346.2*	1005.6*	627.3*	1538.5*	3537.2*	302.1*	2142.6*	3592.2*	757.8*	312.6*	287.6*
8							0.0	1583.8*	1483.6*	551.9*	1898.7*	1234.4*	1616.9*	702.5*	1299.1*	1946.8*	99.6*	1354.2*	1486.9*	2537.3*	2514.1*
9								0.0	102.9*	2135.4*	315.2*	350.5*	40.9*	883.6*	2882.7*	364.0*	1487.8*	2937.9*	103.5*	953.7*	930.6*
10									0.0	2035.4*	415.7*	251.9*	137.0*	784.4*	2782.5*	463.7*	1387.4*	2837.6*	43.5*	1054.2*	1031.0*
11										0.0	2450.3*	1785.7*	2168.5*	1253.0*	748.3*	2498.5*	649.3*	803.4*	2038.5*	3088.8*	3065.7*
12											0.0	665.1*	283.2*	1198.5*	3197.7*	56.0*	1802.7*	3252.8*	413.9*	639.3*	616.2*
13												0.0	385.5*	533.5*	2533.4*	714.3*	1139.0*	2588.5*	259.1*	1303.9*	1280.6*
14													0.0	917.7*	2915.6*	330.5*	1520.6*	2970.8*	131.0*	920.6*	897.7*
15														0.0	2000.8*	1247.4*	608.6*	2056.1*	788.7*	1837.0*	1813.7*
16															0.0	3245.6*	1395.3*	58.6*	2785.5*	3836.0*	3812.8*
17																0.0	1850.4*	3300.7*	460.9*	591.1*	568.3*
18																	0.0	1450.3*	1390.6*	2441.0*	2417.9*
19																		0.0	2840.7*	3891.3*	3868.1*
20																			0.0	1050.9*	1028.1*
21																				0.0	29.2*
22																					0.0

*** Significant compared with $X^2 = 21.03$ at df = 12 and 0.05 level of probability.**

1: CLN1466EA, 2: CLN1462A, 3: CLN1621F, 4: CLN2026D, 5: CLN2413D, 6: CLN2463E, 7: CLN2514A, 8: CLN3070J, 9: CLN3078A. 10: CLN3078C, 11: CLN3125A-23 12: CLN3125O-19, 13: CLN3125L, 14: CLN3125E, 15: CLN5915-206D4, 16: Castle Rock, 17: Peto 86, 18: FM-9, 19: Super Strain B, 20: Super Marmande, 21: Rio Grande, 22: Galaxy 040.

The results of genotypes distributions and cluster means of contributed traits in each cluster (Table 5 and Fig. 3) show that the three genotypes included in first cluster recorded the highest values for 83.3% of studied traits compared to the other clusters, suggesting that these genotypes tolerant to high temperature as previously mentioned and could be extensively used for breeding program to achieve this goal.

All high yielding (2.72 kg per plant) genotypes were grouped in cluster-I whereas minimum low yielding (0.67 kg per plant) in cluster-III. However, genotypes of cluster-III contributed the lowest mean values for 91.7% of studied traits. For NPG, PV, PH, FS, NF/P, FY/P and NSF, genotypes of cluster-IV had the higher mean values (2225.6, 41.5, 74.8, 55.57, 56.94, 2.23 and 85.93, respectively) than the genotypes of cluster-III with the lowest mean values (262.2, 8.8, 54, 22.9, 10.43, 0.67 and 31.89, respectively) indicating the degree of diversity among cluster-III and cluster-IV for these traits.

Principal Component Analysis (PCA)

It is evident from Fig. 4 that 99.8% of the total variability present among the 22 genotypes of tomato is explained by the first ten principal components but-out of twelve. The first two principal components were the most influential with a cumulative contribution to the total variation of 81.3%.

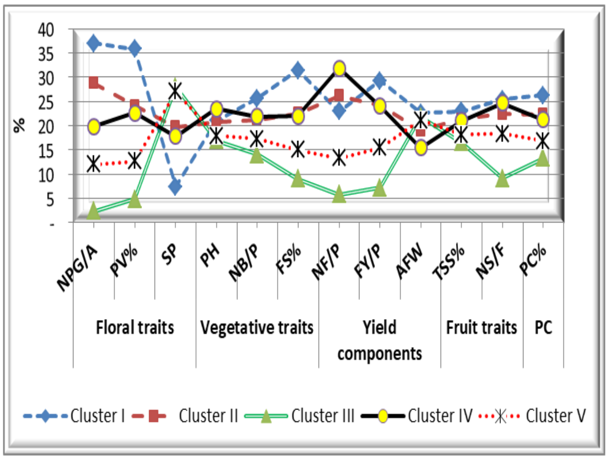


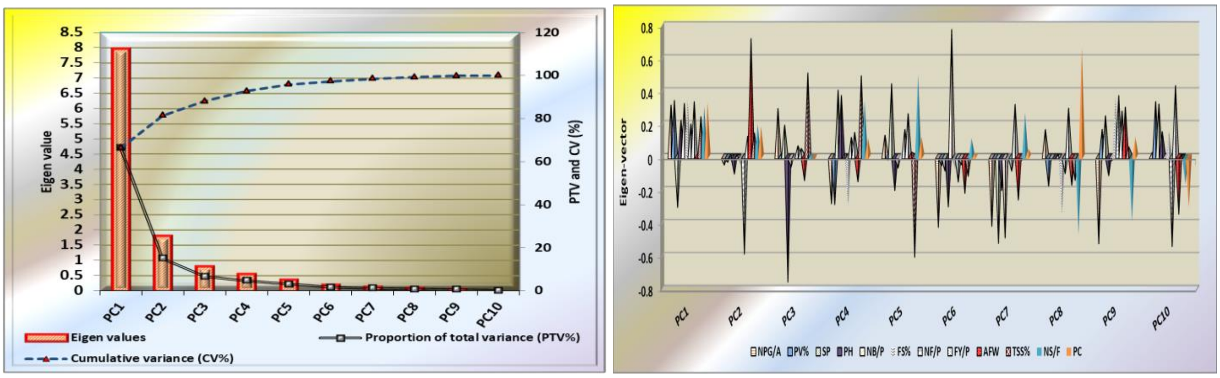
Fig. 3. Cluster-wise percentage contribution of different characters among the studied tomato genotypes

Where NPG (pollen grains/anther), PV(pollen viability), SP (stigma position), PH (plant height), NB/P (number of branches/plant), FS (fruit set percentage), NF/P (number of fruits/plant), FY/P (fruit yield/plant), AFW (average fruit weight), TSS (total soluble solids percentage), NSF (number of seeds/fruit) and PC (proline content)

Table 5. Distribution of twenty-two genotypes of tomato into clusters and cluster means % of the contributed traits.

Item		No of clusters					Contribution %
		I	II	III	IV	V	
Floral traits	NPG	4155.6	3228	262.2	2225.6	1348.8	86.78%
	PV (%)	65.7	44.2	8.8	41.5	23.3	1.42%
	SP (mm)	0.31	0.82	1.16	0.74	1.12	0.03%
Vegetative traits	PH (cm)	67	65.91	54	74.8	57.33	2.47%
	NB/P	7.99	6.63	4.39	6.84	5.38	0.24%
	FS (%)	79.28	56.74	22.9	55.57	37.94	1.95%
Yield components	NF/P	41.03	46.84	10.43	56.94	23.85	1.39%
	FY/P (Kg)	2.72	2.24	0.67	2.23	1.44	0.07%
	AFW (g)	66.52	55.66	63.95	45.37	61.94	2.27%
Fruit traits	TSS (%)	7.36	6.86	5.29	6.76	5.82	0.25%
	NSF	88.61	78.35	31.89	85.93	64.18	2.70%
Proline content	PC (mg/100g)	14.61	12.42	7.41	11.83	9.39	0.43%
Percentage (%)		35.5%	27.9%	3.7%	20.2%	12.7%	100%

- **Where NPG (pollen grains/anther), PV(pollen viability), SP (stigma position), PH (plant height), NB/P (number of branches/plant), FS (fruit set percentage), NF/P (number of fruits/plant), FY/P (fruit yield/plant), AFW (average fruit weight), TSS (total soluble solids percentage), NSF (number of seeds/fruit) and PC (proline content)**



a. Eigen values **b. Eigen vector**

Fig. 4. a. Scree plot of Eigen values, variability proportion and cumulative variability (%) and b. Eigen vector for studied traits of twenty two genotypes of tomato

Where NPG (pollen grains/anther), PV(pollen viability), SP (stigma position), PH (plant height), NB/P (number of branches/plant), FS (fruit set percentage), NF/P (number of fruits/plant), FY/P (fruit yield/plant), AFW (average fruit weight), TSS (total soluble solids percentage), NSF (number of seeds/fruit) and PC (proline content).

Both had Eigen values above 1.0, presenting cumulative variance of 81.3%. Principal component one (PC_1), with Eigen value of 7.96, contributed 66.3% of the total variability, while PC_2 with Eigen values of 1.8 accounted for15% of total variability, therefore selection of genotypes based on two PCs well be useful. Pradhan *et al.* (2011) reported that PCA for 12 traits out of these only the first two components in the PCA analysis had Eigen values up to 1.0, presenting cumulative variance of 84.1%. The PC_1 exhibited positive factor loadings for most studied traits (Fig. 4b), seven traits contributed more positively in PC_1 compared the other traits. However, PC_2 has positive loading for 7 traits, only AFW contributed more than other traits (0.720). The two dimensional graphical representation of component patterns based on PC_1 and PC_2 is shown in Fig. 5 confirmed the above result that traits viz., NPG/A, PV%, NB/P, FS%, FY/P, AFW, NS/F and PC contributed greatest towards total variability present in the evaluated germplasm.

As a result, the genotypes could be used as contrasting parents for further breeding programs under high temperature for hybridization program to increase genetic base in the population, also to develop elite lines and hybrids. Additionally, selection of genotypes with high yield and its components should be recommended as one of the best breeding approach for tomato improvement. Likewise, on 75 Spanish tomato landraces Cebolla-Cornejo *et al.* (2013) performed diversity analysis using molecular markers and phenotypic and found that PC_1 was related with fruit size traits however the PC_2 was linked with traits related to fruit shape

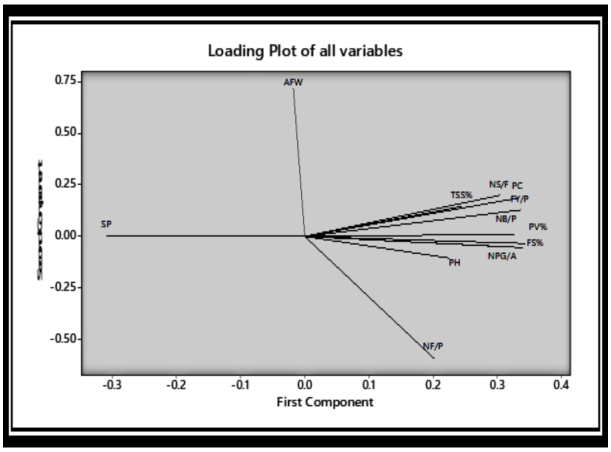


Fig. 5. Principal component analysis, loading plots based on first and second components for all traits of tomato.

CONCLUSION

The results of this study concluded that tomato genotypes CLN1621F, CLN5915-206D, CLN2026D and Rio Grande recorded the best values for most studied traits under high average day/night temperature in North Sinai and could be used as tolerant genotypes in future breeding programs for improvement under high temperature stress. In addition, the traits no. pollen grains/anther, pollen viability, no. branches, fruit set, fruit yield, average fruit weight, no. seeds/fruit and proline content might be used for screening to obtain effective selection under high temperature.

REFERENCES

Abdul-Baki, A.A. (1991). Tolerance of tomato cultivars and selected germplasm to heat stress. J. Amer. Soc. Hort. Sci. 116:1113–1116.

Ansary, S. H. (2006). Breeding tomato (*Lycopersicon esculentum* Mill) tolerant to high temperature stress. PhD Thesis, Bidhan Chandra Krishi Viswavidya-Laya, West Bengal, India, 147pp.

A.O.A.C. (1990). Official Methods of Analysis. 15th Edition, Association of Official Analytical Chemist, Washington DC. The U.S.A.

Ayenan M. A. T., A. Danquah, P. Hanson, C. A.-Dwamena, F. A. K. Sodedji, I. K. Asante and E. Y. Danquah (2019). Accelerating Breeding for Heat Tolerance in Tomato (*Solanum lycopersicum* L.): An Integrated Approach. Agronomy, 9(11):720

Bates, L. S., R. P. Waldren and I. D. Teare (1973). Rapid determination of free proline for water-stress studies. Plant and Soil, 39: 205-207.

Bell, G. D., M. S. Halpert, R. C. Schnell, R. W. Higgins, J. Lowrimore, V. E. Kousky, R. Tinker, W. Thiaw, M. Chelliah and A. Artusa (2000). Climate assessment for 1999. Bull Am. Meteorol. Soc., 81.

Borgohain, R. and A. Swargiary (2008). Evaluation of tomato genotypes for high temperature tolerance. Ind. J. Pl. Gene. Reso., 21(1): 93-94.

Cebolla-Cornejo, J., S. Rosello and F. Nuez (2013). Phenotypic and genetic diversity of Spanish tomato landraces. Scientia Hort. 162:150-164.

Cochran, W.G. and G.M. Cox (1957). Experimental Designs. 2nd ed., John Willey and Sons, New York,USA. 611p.

Dane, F., A. G. Hunter and O. L. Chambliss (1991). Fruit set, pollen fertility, and combining ability of selected tomato genotypes under high-temperature field conditions. J. Amer. Soc. Hort. Sci., 116:906–910.

Driedonks N., M. Wolters-Arts, H. Huber, G. J. de Boer, W. Vriezen, C. Mariani and I. Rieu (2018). Exploring the natural variation for reproductive thermotolerance in wild tomato species. Euphytica, *214*, 67.

Duncan, B.D. (1955). Multiple range and multiple F test. Biometrics, 11: 1-42.

EL-Saka, Z. I. (2018). Genetic variation and heritability among different tomato genotypes for heat tolerance. Egypt. J. Plant Breed., 22(1):145– 158.

El-Sayed, A. Y.A.M., E. M. El-Said and M. H. Rehab (2015). Selection for heat tolerance in tomato *ex situ* germplasm. J. Agric. Chem. and Biotechn., Mansoura Univ., 6 (12): 657- 673.

Faruq G., H. P. Zakaria and N. Arash (2012). Heat tolerance in tomato. Life Sci. J. 9(4):1936-1950.

Firon N., R. Shaked, M. M. Peet, D. M. Pharr, E. Zamski, K. Rosenfeld, L. Althan, and E. Pressman (2006). Pollen grains of heat tolerant tomato cultivars retain higher carbohydrate concentration under heat stress conditions. Sci. Hort., 109: 212–217.

Hare, P. D., W. A. Cress and J. V. Staden (1998). Dissecting the roles of osmolyte accumulation during stress. Pl. Cell Environ., 21:535–553.

Hazra, P., H. A. Samsul, S. Debasis and K. V. Peter (2007). Breeding tomato (*Lycopersicon esculentum* Mill.) resistance to high temperature stress . Int. J. Pl. Breed., 1(1): 31-40.

Jackson, J. E. (1991). A User's Guide to Principal Components, John Wiley & Sons, Inc., New York.

Kakani V. G., K. R. Reddy, S. Koti, T. P. Wallace, P. V. V. Prasad, V. R. Reddy and D. Zhao (2005). Differences in in vitro pollen germination and pollen tube growth of cotton cultivars in response to high temperature. Ann. Bot., *96:* 59–67.

Kinet, J. M. and M. M. Peet (1997). Tomato. In: Wien HC (ed) The physiology of vegetable crops. Cab Int., Wallingford, UK, pp 207–258.

Krasteva L., I. Ivanova and N. Velcheva (2010). Grouping of determinate local tomato varieties on the basis of cluster analysis. Agric. Sci. Tech., 2(3): 113-115.

Levy A., H. D. Rabinowitch and N. Kedar (1978). Morphological and physiological characters affecting flower drop and fruit set of tomatoes at high temperatures. Euphytica, *27,* 211–218.

Mesihovic A., R. Iannacone, N. Firon and S. Fragkostefanakis (2016). Heat stress regimes for the investigation of pollen thermotolerance in crop plants. Plant Reprod., 29: 93–105.

Mohammadi, S. A. and B. M. Prasanna (2003). Analysis of genetic diversity in crop plants –salient statistical tools and considerations. Crop science 43(4):1235-1248.

Paupière M. J., P. van Haperen, I. Rieu, R. G. F. Visser, Y. M. Tikunov and A. G. Bovy (2017). Screening for pollen tolerance to high temperatures in tomato. Euphytica, *213*, 130.

Peet M. M., D. H. Willits and R. G. Gardner (1997). Responses of ovule development and post pollen production processes in male-sterile tomatoes to chronic, sub-acute high temperature stress. J. Exp. Bot. 48: 101-111.

Pradhan A. M., B. C. Nanadeshwar, K. K. Sarkar, and A. Konar (2011). Estimation of genetic parameters and association of traits related to yield in potato (*Solanum tuberosum* L.). J. Crop and Weed 7(2): 229-231.

Ranjodh S., S. Singh, D. S. Cheema and M. S. Dhaliwal (2005). Screening for heat tolerance in tomato (*Solanum Lycopersicum* L.). Veg. Sci. 32(1): 90-91.

Rashwan, A.M.A. (2016). Comparative study in fifteen genotypes of tomato for heat tolerance under Upper Egypt conditions. J. Amer. Sci., 12(6):68-76.

Reddy R. K. and V. G. Kakani (2007). Screening *Capsicum* species of different origins for high temperature tolerance by in vitro pollen germination and pollen tube length. Sci. Hort., 112: 130–135.

Roy, S. J., E. J. Tucker and M. Tester (2011). Genetic analysis of abiotic stress tolerance in crops. Curr. Opin. Pl. Biol., 14:232–239.

Saeed, A., H. Khizar, A. K. Asif and I. Sajid (2007). Heat tolerance studies in tomato (*Lycopersicon esculentum* Mill.) Int. J. Agric. Biol., 9 (4): 649–652.

Sairam, R. K. and A. Tyagi (2004). Physiology and molecular biology of salinity stress tolerance in plants. Curr. Sci., 86:407–421.

Sato, S., M. Kamiyama, T. Iwata, N. Makita, H. Furukawa, H. Ikeda (2006). Moderate increase of mean daily temperature adversely affects fruit set of *Lycopersicon esculentum* by disrupting specific physiological processes in male reproductive development. Ann. Bot. 97: 731–738.

Sato, S., M. M. Peet and J. F. Thomas (2000). Physiological factors limit fruit set of tomato (*Lycopersicon esculentum* Mill.) under chronic, mild heat stress. Plant Cell Environ., 23:719–726.

Sato, S., M. M. Peet and R. G. Gardner (2001). Formation of parthenocarpic fruit, undeveloped flowers and aborted flowers in tomato under moderately elevated temperatures. Sci. Hort. 90: 243-254.

Singh S.K., V. G. Kakani, D. Brand, B. Baldwin and K. R. Reddy (2008). Assessment of cold and heat tolerance of winter-grown canola (*Brassica napus* L.) cultivars by pollen-based parameters. J. Agron. Crop Sci., 194: 225–236.

Singh, U., K. P. Pradeep, K. S. Amit, T. Vivek, K. Rajesh, N. Rai, B. Anant, K. T. Shailesh, S. Major and B. Singh (2015). Screening of tomato genotypes under high temperature stress for reproductive traits. Veg. Sci., 42 (2): 52-55.

Solankey, S. S., A. Shirin, N. Pallavi, K. Meenakshi and K. Radheshyam (2018). Screening and identification of heat tolerant tomato genotypes for Bihar. J. Pharmacognosy and Phytochemistry.4: 97-100.

Solankey, S. S., R. K. Singh, D. K. Baranwal and D. K. Singh (2015). Genetic expression of tomato for heat and drought stress tolerance: an overview. Int. J. Veg. Sci., 21(5):496-515.

Solankey, S. S., S. Akhtar, P. Neha, M. Kumari (2017). Effect of high temperature stress on morpho-biochemical traits of tomato genotypes under polyhouse condition. Ind. J. Eco., 44(5):497-502.

Sudre, C. P., E. Leonardecz, R. Rodrigues, A. T. D. A. Junior, M. D. C. L. Moura and L. S. A. Goncalves (2007). Genetic resources of vegetable crops: a survey in the Brazilian germplasm collections pictured through papers published in the journals of the Brazilian society for horticultural science. Hortic. Bras., 25: 496-503.

Van Hintum, T. J. L. (1995). Hierarchical approaches to the analysis of genetic diversity in crop plants. Awiley Sayce publication, pp 23-34.

Weerakoon W. M. W., A. Maruyama and K. Ohba (2008). Impact of Humidity on Temperature-Induced Grain Sterility in Rice (*Oryza sativa* L). J. Agron. Crop Sci., 194:135–140.

Xu J, M. Wolters-Arts, C. Mariani, H. Huber and I. Rieu (2017). Heat stress affects vegetative and reproductive performance and trait correlations in tomato (*Solanum lycopersicum*). Euphytica, *213:* 1–12.

Yan C., Y. Ding, Q. Wang, Z. Liu, G. Li, I. Muhammad and S. Wang (2010). The impact of relative humidity, genotypes and fertilizer application rates on panicle, leaf temperature, fertility and seed setting of rice. J. Agric. Sci., 148, 329–339.

Zhou, R., K. H. Kjear, E. Rosenqvist, X. Yu, Z. Wu and C. O. Ottosen (2016). Physiological response to heat stress during seedling and anthesis stage in tomato genotypes differing in heat tolerance. J. Agron. Crop Sci., 203:68–80.

فحص التراكيب الوراثية للطماطم تحت الحرارة العالية بشمال سيناء

محمود ابراهيم محمود و أحمد بلال المنسي مصطفى
قسم الانتاج النباتي - كلية العلوم الزراعية البيئية – جامعه العريش - مصر

اجريت الدراسة بالمزرعة التجريبية لكليه العلوم الزراعية البيئية, جامعة العريش خلال الصيف لموسمي ٢٠١٨, و٢٠١٩ بهدف فحص ٢١ تركيب وراثي من الطماطم بالإضافة للهجين التجاري جالاكسي ٠٤٠ F1 بالنسبة للحرارة العالية تحت ظروف شمال سيناء. وقد استخدم تصميم القطاعات الكاملة العشوائية في ثلاث مكررات لتوزيع التراكيب الوراثية.اظهر تحليل التباين معنويه عالية لجميع الصفات المدروسة تحت متوسط درجات حرارة عالية نهار/ليلا (٣٤,٦ /٢٣,٩ درجه مئوية على التوالي) كمتوسط للموسمين. وكانت افضل السلالات المدروسة بالنسبة لمعظم صفات الازهار سي إل إن ١٦٢١ إف, وريو جراند. بينما تفوقت التراكيب سي إل إن ٢٠٢٦ دي, وريو جراند في نسبه العقد. كذلك اوضحت نتائج الفحص تفوق التراكيب سي إل إن ٢٥١٤ ايه بالنسبة لعدد الثمار /نبات, سي إل إن ٢٤١٣دي, وسي إل إن ١٤٦٦ إ إيه لمتوسط وزن الثمرة, وسي إل إن ١٦٢١ إف للمحصول/نبات (٢,٨٤ كجم), في حين سجلت التراكيب سي إل إن ١٦٢١ إف, و سي إل إن ٣١٢٥ إل أعلى محتوى من البرولين. وقد رتبت التراكيب الوراثية للطماطم بناء على نتائجها التراكمية الى مجموعه التراكيب المتحملة, متوسطة التحمل, متوسطة الحساسية, والحساسة للحرارة. وقد توزعت التراكيب الوراثية باستخدام التحليل العنقودي الى خمس مجموعات حيث تكونت العناقيد الاول, الثالث, والرابع من ثلاثة تراكيب والعناقيد الثاني والخامس على تسعه, واربعة تراكيب على التوالي. واظهر تحليل المكونات الاساسية ان المكونين الاول والثاني اكثر أهيمه وساهموا بنسبه ٨١,٣% من التباين الكلى, وكانت اكثر الصفات مساهمه بالتباين فى المكونين عدد حبوب اللقاح/المتك, حيوية حبوب اللقاح, عدد الافرع/نبات, نسبه العقد, محصول الثمار/نبات, متوسط وزن الثمرة, عدد البذور/الثمرة, ومحتوى البرولين, لذا يقترح ان يتم الاعتماد على تلك الصفات لانتخاب تراكيب وراثيه متفوقه من الطماطم تحت ظروف الحرارة العالية.