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Screening of High Temperature Tolerant Tomato Genotypes for Their Fruit Mineral Content

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Abstract: Agriculture is at the forefront of the sectors that will be most affected by climate change. It is inevitable that Turkey is exposed to the negative effects of climate change due to its geographical location. The development of new high temperature tolerant varieties is seen as an important economic measure in the adaptation to climate change. In this study, heat temparature tolerant tomato genotypes were investigated for their fruit mineral content. For this purpose, twenty tolerant tomatoes from the gene pool of the Çukurova University, Department of Horticulture the and two commerical cultivars were grown in the open field conditions during 2016 spring and summer periods in Adana, Turkey. Tomato fruits grown under control and high temperature stresses conditions were analyzed for phosphorus, potassium, calcium, magnesium, iron, manganese, copper and zinc. According to heat stress effects on the tomato fruit mineral content, the macro-nutrients were ordered P, K, Ca, Mg from the least affected to the most affected. Moreover, the micro-nutrients were ordered Cu, Fe and Zn from the least affected to the most affected. In the present study heat tolerant tomato genotypes showed better performance and their mineral content most cases were higher than mineral content of the control trade cultivars.

Key words: Calcium, copper, iron, magnesium, phosphorus, potassium, *Solanum lycopersicum* L., zinc

Yüksek Sıcaklık Stresine Tolerant Domates Genotiplerinin Meyvede Mineral İçeriği Bakımından Taranması

Özet: Tarım, iklim değişikliğinden en fazla etkilenen sektörlerin başında gelmektedir. Türkiye'nin coğrafi konumu nedeniyle iklim değişikliğinin olumsuz etkilerine maruz kalması kaçınılmaz görülmektedir. Yeni yüksek sıcaklık stresine toleranslı çeşitlerin geliştirilmesi, iklim değişikliğine uyumda önemli bir ekonomik önlem olarak görülmektedir. Bu çalışmada, meyve mineral içeriği açısından yüksek sıcaklık stresine toleranslı domates genotipleri araştırılmıştır. Bu amaçla, Çukurova Üniversitesi Bahçe Bitkileri Bölümü gen havuzunda bulunan yirmi adet toleranslı domates genotipi ve ticari iki çeşit kullanılarak Adana-Çukurova ekolojik koşullarında 2016 ilkbahar ve yaz aylarında açık alanda yetiştirilmiştir. Kontrol ve yüksek sıcaklık koşulları altında eld edilen domates meyvelerinde fosfor, potasyum, kalsiyum, magnezyum, demir, manganez, bakır ve çinko mineralleri analiz edilmiştir. Domates meyvesi mineral içeriği üzerindeki yüksek sıcaklık stresi etkisine göre, makro-minerallerde en az stresden etkilenenden en çok etkilenene göre P, K, Ca ve Mg olarak sıralanmıştır. Ve mikro-mineraller ise Cu, Fe, Zn olarak en az etkilenenden en çok etkilenene doğru sıralanmıştır. Bu çalışmada yüksek sıcaklık stresine toleranslı domates genotipleri meyvenin mineral içeriğini korumak için iyi performans göstermiş ve mineral içeriği çoğu durumda kontrol olarak kullanılan ticareti çeşitlerin mineral içeriğinden daha yüksek bulunmuştur.

Anahtar kelimeler: Kalsiyum, Bakır, Demir, Magnezyum, Fosfor, Potasyum, *Solanum lycopersicum* L., Çinko

Introductıon

Tomato (*Solanum lycopersicum* L.) fruit is the most popular as well as important vegetable in the world for consumption and also for production, the source of high nutritional contents with antioxidant compounds, minerals, vitamines and fibres. Tomato furit contain the largest quantities of potassium, although the quantities of calcium, magnesium and iron are also significant. Tomato also contains sodium, copper, zinc, manganese and numerous other minerals (Bjelić et al., 2005). Tomato crop has high commercial value since it is widely used not only as fresh fruit but also in processed forms in diets. Over 177 million and 12.6 million metric tons of tomatoes are produced each year on a world basis and Turkey, respectively (FAO, 2016). Tomato fruit provides high nutrition in many forms such as raw in salads, cooked in meals, preserves, purees, ketchup, sauces, pickled and in other forms.

Tomato fruit quality is determined mainly by color, texture, and flavor. Demand and acceptance of fresh tomato fruit are based largely on these parameters. However, in recent years, antioxidant content such as phenols, flavanoids, carotenes, vitamin C, provitamin A and minerals of the tomato fruit have been prominent which are thought to protect and possibly prevent cancer. Nowadays, the increasing consumer fresh vegetables preference with high nutritional content is very important (Kowalczyk et al., 2011). Fruit composition and their desirability are affected by many factors such as growth environment, climatic factors, media, fertilizers, soil physical and chemical propeties and salinity sources (Haglund et al. 1997; Gundersen et al. 2001; Bjelić et al., 2005; Thybo et al. 2006; Kowalczyk et al., 2011).

In Turkey, fresh tomatoes are primarily grown in open field and greenhouses and the tomato fruits are produced all year round. In open field production in recent years drought threat has been emerged with low rains due to climate change symptoms; and low water storage for irrigation. Tomato is highly sensitive to environmental changes such as temperature, light, and water during growing period of plant (Murshed et al., 2013; Klunklin and Savage, 2017). Abiotic stress factors such as drought, heat, salinity, tropospheric ozone and excess UV radiation are causing agricultural yield and crop quality losses and will become even more prevalent in the coming decades due to the effects of global-climate change (Wang and Frei, 2011). The optimum temperatures for tomato cultivation are between 25 and 30ºC during day and 20ºC during night (Camejo et al., 2005). However, in tomato cultivation regions in sub-tropics and tropics where high temperatures are exceeded and often disturb plant growth and development, decrease yield and negatively affect fruit quality. Growth reduction, decrease in the photosynthetic rate and increase in respiration, assimilate partitioning towards the fruits, osmotic and oxidative damage, reduced water and ion uptake/movement, cellular dehydration are detrimental effectes of the heat stress.

The high temperature induces severe damage in the photosynthetic apparatus. Photosynthesis is one of the most heat-sensitive processes and it can be completely inhibited by high temperature before other symptoms of the stress are detected (Berry and Bjôrkman, 1980; Camejo et al., 2005). The electron transport chain is negatively affected in PSII (photosystem II). Moreover, chlorophyll fluorescence is decreased in PSII (Havaux and Tardy, 1996). Sensitivity of Calvin cycle activity and inactivation of Rubisco under high temperature stress are the other reason of the inhibition of photosynthesis (Camejo et al., 2005). Susceptibility of biomembranes to high temperature stress is other important reason of the inactivatipon of the photosynthesis. The membrane disintegration is a primary symptom of heat injury (Ristic et al., 1996). It is reporrted that the most affected plant growth stage is the reproductive growth and the affected process is pollen grain development and ultimately fruit set (Bita and Gerats, 2013). The retardation of carotenoid biosynthesis and red color (lycopene) development by high temperature have been reported (Buescher, 1979; Yakir et al., 1984; Chen et al., 1988). The firmness of tomatoes is negatively affected by high temperature (Chen et al., 1988). In the case of available leaf water status and stomatol opening under high temperature stress, photosynthesis and biomass production were not improved, probably due to non-stomatal limitation of photosynthesis mediated by nutrient deficiency. It is known that supraoptimal temperatures may develop multiple mineral deficiencies in roots and shoots, and this can adversely affect the nutrition of the fruit (Schwarz et al., 2010). There is a susceptibility of tomatoes to blotchy ripening and BER (Blossom end rod). These physiologycal disorders are related to deficiencies of K and Ca. Therefore, screening of tomato for efficiency of these nutrients under heat stress conditions can be a way of increasing tomato fruit K and Ca content (Adams and Ho, 1995).

The aims of this work were (1) to investigate the effect of heat stress on mineral contents of the fruits that are important from the point of view of fruit quality (2) to compare the mineral elements of tomato genotypes that are tolerant to high temperature stress.

Materials and Methods

Plant Material and Growing Conditions

Twenty-two different tomato genotypes including 20 genotypes heat tolerant and 2 commerical cultivars as control which grown commonly in the experiment region by the growers, were used in this study. The study was performed in open field under environmental conditions of Adana-Cukurova ((36º59'N, 35º18'E, 20 m above sea level) in 2016 spring-summer period. Two consecutive experiments were set up in the study; first one was control and second one was heat stress experiments. The heat stress experiment was the warmest time of the summer. Seed sowings were performed on February 27 and April 22, 2016 in control and heat stress experiments, respectively. Seedling transplanting dates were April 14 and May 22, 2016 in successive experiments, respectively. Tomato fruit sampling dates were June 14 and July 22, 2016. Randomized complete block experimental design with 4 replications and 10 plants in each replicate were used in both experiments. Spacings were 120 cm between rows and 50 cm between plants were used. The nutrition of the tomato plants were done equally in the both experiments. For this purpose 140 kg N, 95 kg P_2O_5, 220 kg K_2O, 20 kg MgO and 40 kg CaO were used for ha area.

Table 1. Operation performed in control and heat stress experiments and dates

Operation performed	Dates in 2016
Seed sowing of the control experiment	February 27
Seedling transplantin of the control experiment	April 14
Tomato fruit sampling date in the control experiment	June 14
Seed sowing of the heat stress experiment	April 22
Seedling transplantin of the heat stress experiment	May 22
Tomato fruit sampling date in the heat stress experiment	July 22

Mineral elements analysis

The tomato fruits were washed once with tap water and then twice washed by deionized water. The fruit were sliced and dried in a forced-air oven at 65 ^{o}C for 96 hours and the dried material was ground in a laboratory mill for mineral element analysis. Ground samples were dry-ashed in a muffle furnace at 550 ^{o}C for 6 h. The ash was dissolved in 0.1 M HCl (hydrochloric acid) solution. The concentrations of K, Ca, Mg, Fe, Mn, Zn and Cu were determined using a Varian Spectra FS220 atomic absorption spectrometer (Jones, 2001). Phosphorus analysis was performed according to the colorimetric method Barton which uses vanadate–molybdate reagent in spectrophotometer.

Statistical analysis

Tomato fruit P, K, Ca, Mg, Fe, Mn, Zn and Cu concentrations were examined statistically by analysis of variance. Least significant difference (LSD) was calculated at 0.05 probability level for each parameter.

Results and Discussion

High-temperature stress reduces root growth which affects the growth of aboveground tissue by restricting the supply of water and mineral nutrients (Gri et al., 2017). Therefore it is inevitable that the fruit mineral content is also negatively affected. However, in the present study heat tolerant tomato genotypes showed better performance and their mineral content most cases were higher than mineral content of the control trade cultivars. The nutrient concentrations among the heat tolerant tomatoes and the control cultivars are presented in Table 2 and 3.

Phosphorus

The P content in tomato fruit was increased in the 12 heat tolerant genotypes and decreased in the 8 genotypes under heat stress (Table 2). The highest P increase in relative to control was 35.97% in Tom-230. In heat stress, the highest and lowest P concentrations were 29.9 and 13.2 mg 100 g^{-1} in Tom-201B and Tom-115, respectively. The mean P concentrations in control and heat stress were 18.67 and 20.79 mg 100 g^{-1}, respectively. Among the tolerant tomato genotypes 16 of them showed the higher P concentration than the mean of control cultivars (16.3 mg 100 g^{-1}) under heat stress. In this stdy, P concentration of tomatoes was generally increased under heat stress and mean increase of all genotypes in heat stress was 7.19 in relative to control (Table 2). Hernaéndez Suéarez et al., (2007) reported the P concentration of tomato fruit as 23.7, 25.0 and 29.8 mg100g^{-1} from conventional, organic and hydroponic grown tomato plants. Sainju et al., 2014 reported 27 mg100g^{-1} P in green and red tomato fruits. Our tomato fruit P concnetrations in both control and heat stress were lower than above mentioned literature. This can be due to genotype, variety, environmental conditions.

Potassium

The K content in tomato fruit was decreased under heat stress in 19 tolerant genotypes (Table 2). Tom-230 was only genotype that was not decreased its K concentration under heat stress. The K decreases of tolerant tomatoes in relative to control were changed between 3.97-55.93% under stress. The highest and lowest K concentrations were under heat stress 77.9 and 55.3 mg 100 g^{-1} in Tom-114 and Tom-20, respectively. The mean K concentration in heat stress was recorded as 68.09 mg 100 g^{-1}. Among the tolerant tomato genotypes 14 of them showed the higher K concentration than the mean of control cultivars (65.10 mg100g^{-1}) under heat stress (Table 2). Hernaéndez Suéarez et al., (2007) reported the K concentration of tomato fruit as 247.6, 260.4 and 243.6 mg 100 g^{-1} from conventional, organic and hydroponic grown tomato plants. Sainju et al., 2014 reported 244 mg 100 g^{-1} K in green and red tomato fruits. The K concentrations in this study lower than above mentioned literatures. This may be due to growing and climatic conditions, fertilizers used and genotype characteristics. The K nutrient is quite important for tomato. Tomato fruits often express K deficiency as blotchy ripening, greenback or yellow shoulder. The fruit also lacks firmness and has low brix levels. Potassium has the greatest importance on the quality parameters determining the marketing of fruits, consumer preferences, and the concentration of vital phytonutrients for human health (Lester et al., 2010; Constán-Aguilar et a., 2014). K significantly affects fruit size, soluble solids, Vitamin C concentration and pigments (lycopene and beta-carotene) of tomato fruit (Kanai et al., 2007; Ramıérez et al., 2012).

Magnesium

The Mg content in tomato fruit was decreased under heat stress in all genotypes (Table 2). The Mg decreases of tomatoes in relative to control were changed between 32.50-70.94% under stress. The highest and lowest Mg concentrations under heat stress were 1.3 and 5.3 mg 100 g^{-1} in Tom-173 and Tom-14, respectively. The mean Mg concentration in heat stress was recorded as 2.80 mg100g^{-1}. Among the tolerant tomato genotypes 3 of them showed the higher Mg concentration than the mean of control cultivars (3.30 mg 100 g^{-1}) under heat stress. In the present study fruit Mg content was the most negatively affected nutrient under heat stress. The mean decrease of all genotypes in heat stress was 69.8% in relative to control. Mean Mg concentrations in control and heat stress were 11.4 and 2.8 mg100g^{-1}, repectively (Table 2). Hernaéndez Suéarez et al., (2007) reported the Mg concentration of tomato fruit as 11.6, 12.3 and 9.4 mg 100 g^{-1} from conventional, organic and hydroponic grown tomato plants. In the present experiment tomato plants were well fed with Mg fertilizer and the control fruits showed better Mg content; however, Mg concentration in the fruits were dramatically decreased under heat stress. Magnesium nutrition is particularly important in ensuring even ripening of well-formed tomato fruit. Fruits appear to ripen evenly but maturity is often delayed.

Calcium

The Ca content in tomato fruit was decreased under heat stress in all genotypes (Table 2). The Ca decreases of tolerant tomatoes in relative to control were changed between 48.68-75.85% under stress. The highest and lowest Ca concentrations under heat stress were 14.10 and 47.90 mg 100 g^{-1} in Tom-111 and Tom-115, respectively. The mean Ca concentration in heat stress was recorded as 26.42 mg 100 g^{-1}. Among the tolerant tomato genotypes 11 of them showed the higher Ca concentration than the mean of control cultivars (22.55 mg 100 g^{-1}) under heat stress (Table 2). Hernaéndez Suéarez et al., (2007) reported the Ca concentration of tomato fruit as 66.74, 65.01 and 87.4 mg 100 g^{-1} from conventional, organic and hydroponic grown tomato plants. In the present study fruit Ca content was second most negatively affected nutrient (after Mg) under heat stress. The mean decrease of all genotypes in heat stress was 62.9% in relative to control. Mean Ca concentrations in control and heat stress were 75.73 and 26.42 mg100g^{-1}, repectively. Exposure of cells to suboptimal temperature results in membrane injury. Calcium magnifies the heat tolerance of the membrane (Starck et al., 1995). Optimal Ca content and proper distribution in individual organs prevents the incidence and severity of physiological disorders that are caused in many cases by unfavorable external conditions (Poovaiab, 1993; Starck et al., 1995). In spite of their very low Ca content, fruits are sensitive to Ca decrease. Low calcium concentrations are observed with blossom-end rot in tomato fruits. The above physiological disease is often described under adequate Ca supply of the whole plant, indicating some perturbation in its distribution, especially its supply to the fruits (Adams and Ho, 1992; Starck et al., 1995)

Zinc

The Zn content in tomato fruit was decreased under heat stress in all genotypes (Table 3). The Zn decreases of tolerant tomatoes in relative to control were changed between 31.25-80.74% under stress. The highest and lowest Zn concentrations were 1.62 and 2.75 mg 100 g^{-1} in Tom-19 and Tom-119, respectively. The mean Zn concentration in heat stress was recorded as 2.30 mg 100 g^{-1}. Among the tolerant tomato genotypes 17 of them showed the higher Zn concentration than the mean of control cultivars (1.74 mg 100 g^{-1}) under heat stress. In the present study fruit Zn content was the most negatively affected micro-nutrient under heat stress. The mean decrease of all genotypes in heat stress was 62.69% in relative to control. Mean Zn concentrations in control and heat stress were 6.64 and 2.08 mg100g^{-1} repectively (Table 3). Bjelić et al., (2005) reported greenhouse grown tomato fruits Zn concentration was 0.154 mg $100g^{-1}$ fruit and open field grown tomato fruits contained 0.123 mg Zn in 100g fruit. Bosiacki et al., (2009) reported that Cu concentration in tomato fruit was ranged between 0.49-3.19 mg $100g^{-1}$.

Iron

The Fe content in tomato fruit was decreased under heat stress in all genotypes (Table 3). The Fe decreases of tolerant tomatoes in relative to control were changed between 16.67-87.07% under stress. The highest and lowest Fe concentrations were 3.47 and 2.15 $mg100g^{-1}$ in Tom-19 and Tom-233, respectively. The mean Fe concentration in heat stress was recorded as 3.07 mg 100 g^{-1}. Among the tolerant tomato genotypes 18 of them showed the higher Fe concentration than the mean of control cultivars (2.21 mg 100 g^{-1}) under heat stress. In the present study fruit Fe content was second most negatively affected micro-nutrient (after Zn) under heat stress. The mean decrease of all genotypes in heat stress was 59.30% in relative to control. Mean Fe concentrations in control and heat stress were 7.86 and 2.74 mg 100 g^{-1}, repectively (Table 3). Bjelić et al., (2005) reported greenhouse grown tomato fruits Fe concentration was 0.223 mg $100g^{-1}$ fruit and open field grown tomato fruits contained 0.283 mg Fe in 100g fruit. Bosiacki et al., (2009) reported that Fe concentration in tomato fruit was ranged between 1.29-5.54 mg 100 g^{-1}. Iron is the most abundant microelement in the plant. It has significant influence on the quality of tomato. Iron plays a key role, since it is involved in metabolic processes, such as photosynthesis and respiration. It is also implied in many enzymatic systems like chlorophyll synthesis (Houimli et al., 2017). Immobility or slow transfer through the plant (the phloem) is characteristic for iron, so that it mostly remains in the root and in young leaves. This results in low and unstable content of this element in the fruits and in the seed (Bjelić et al., 2005).

Cupper

The Cu content in tomato fruit was decreased under heat stress in 18 tolerant genotypes (Table 3). Tom-20 and Tom-225 were two genotypes that were not decreased their Cu concentrations under heat stress. The Cu decreases of tolerant tomatoes in relative to control were changed between 14.81-80.00% under stress. The highest and lowest Cu concentrations were 2.17 and 0.47 mg 100 g^{-1} in Tom-20 and Tom-108, respectively. The mean Cu concentration in heat stress was recorded as 0.99 mg 100 g^{-1}. Among the tolerant tomato genotypes 19 of them showed the higher Cu concentration than the mean of control cultivars (0.53 mg 100 g^{-1}) under heat stress. In the present study fruit Cu content was the least negatively affected micro-nutrient under heat stress. The mean decrease of all genotypes in heat stress was 34.82% in relative to control. Mean Cu concentrations in control and heat stress were 1.78 and 0.99 $mg100g^{-1}$ repectively. Bjelić et al., (2005) reported that copper is very resistant to various influences (temperature, moisture, time of harvest, etc.) and greenhouse grown tomato fruits Cu concentration was 0.0499 mg $100g^{-1}$ fruit and open field grown tomato fruits contained 0.0488 mg Cu in 100 g fruit. So the authors concluded that the copper content in tomato was substantially stable. Bosiacki et al., (2009) reported that Cu concentration in tomato fruit was ranged between 0.12-0.76 mg $100g^{-1}$. The Cu concentrations in our study were higher than above mentioned two literatures. This is may be related soil, environment, genotype and fertilisers used in the study.

Conclusion

High-temperature stress reduces root growth which affects the growth of aboveground tissue by restricting the supply of water and mineral nutrients (Gri et al., 2017). Therefore, it is inevitable that the fruit mineral content is also negatively affected. However, in the present study heat tolerant tomato genotypes showed better performance and their mineral content most cases were higher than mineral content of the control trade cultivars. According to heat stress effects on the tomato fruit mineral content, the macro-nutrients were ordered P, K, Ca and Mg from the least affected to the most affected. And, the micro-nutrients were ordered Cu, Fe and Zn from the least affected to the most affected. It is recommended to use heat tolerant genotypes in tomato cultivation in hot regions. Thus, the mineral content of the fruit will be preserved from the stress negative effects.

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Table 2. Tomato fruit **macro-nutrient content** of the tolerant genotypes and control cultivars under heat stress and control conditions (mg $100g^{-1}$ of dry weight).

	P			K			Mg			Ca		
Tolerant Tom	Control	Stress	CRC*	Control	Stress	CRC*	Control	Stress	CRC*	Control	Stress	CRC*
Tom-12	28.5 a	27.2 ab	-4.56	130.4 a-c	75.1 a	-42.41	17.6 b	5.10 ab	-70.94	51.0 f-h	25.7 e-g	-49.61
Tom-14	27.2 ab	28.2 a	3.68	142.9 a	74.6 a	-48.15	19.2 ab	5.30 a	-72.35	50.4 f-ı	19.8 g-ı	-60.71
Tom-19	18.3 c-g	18.1 b-g	-1.09	110.8 de	68.2 a-e	-38.45	10.5 c-d	2.00 c-e	-80.71	48.8 f-ı	16.2 g-ı	-66.80
Tom-20	17.4 c-g	14.4 e-g	-17.24	107.7 e	55.3 f	-48.65	9.2 c-f	2.80 a-e	-69.63	44.1 f-ı	17.3 g-ı	-60.77
Tom-26	21.7 a-d	21.4 a-g	-1.38	67.0 ı	61.9 c-f	-7.61	7.0 d-f	4.60 a-c	-34.71	37.5 ı	16.6 g-ı	-55.73
Tom-40	21.7 a-d	21.4 a-g	-1.38	71.1 ı	67.3 a-e	-5.34	8.0 d-f	3.1 a-e	-61.01	42.5 g-ı	17.7 g-ı	-58.35
Tom-47	20.6 a-f	16.4 c-g	-20.39	71.9 hı	63.5 b-f	-11.68	10.4 c-e	3.10 a-e	-70.73	38.0 hı	19.5 g-ı	-48.68
Tom-108	17.0 c-g	13.6 fg	-20.00	73.0 hı	70.1 a-e	-3.97	9.8 c-e	2.20 c-e	-77.48	41.5 g-ı	15.3 hı	-63.13
Tom-111	19.68 b-g	21.4 a-g	8.74	135.3 a-c	72.7 a-c	-46.27	23.6 a	1.50 de	-93.64	43.4 f-ı	14.1 ı	-67.51
Tom-114	24.5 a-c	22.6 a-f	-7.76	141.8 a	77.9 a	-45.06	19.0 ab	3.3 a-e	-82.79	130.9 a	41.3 a-c	-68.45
Tom-115	13.0 f-g	13.2 fg	1.54	138.6 a	63.2 c-f	-54.40	19.3 ab	3.1 a-e	-84.16	130.9 a	47.9 a	-63.41
Tom-119	21.2 a-e	23.7 a-e	11.79	137.2 ab	60.6 d-f	-55.83	18.5 a-b	2.4 c-e	-87.01	125.4 ab	42.3 ab	-66.27
Tom-165	22.3 a-c	25.6 a-c	14.80	91.1 f	69.7 a-e	-23.49	7.1 d-f	2.7 b-e	-62.52	113.1 bc	36.0 b-d	-68.17
Tom-173	1.84 c-g	20.5 a-g	11.41	76.6 g-ı	67.9 a-e	-11.36	7.9 d-f	1.3 de	-83.48	110.5 cd	37.2 bc	-66.33
Tom-201-B	20.6 a-f	29.9 ab	35.87	76.2 g-ı	72.0 a-c	-5.51	6.5 d-f	2.6 b-e	-60.47	108.9 cd	26.3 d-g	-75.85
Tom-211	18.3 c-g	23.0 a-f	25.68	79.0 f-ı	68.9 a-e	-12.78	7.3 d-f	1.4 de	-81.38	106.1 cd	34.1 b-e	-67.86
Tom-225	13.1 e-g	16.8 c-g	28.24	75.8 g-ı	71.4 a-d	-5.80	4.9 e-f	3.0 a-e	-38.37	99.3 de	25.4 e-h	-74.42
Tom-230	13.9 d-g	18.9 a-g	35.97	69.1 ı	69.7 a-e	0.87	4.0 f	2.7 b-e	-32.50	92.2 e	31.9 c-f	-65.40
Tom-232	19.6 b-g	24.7 a-d	26.02	123.9 b-d	72.4 a-c	-41.57	9.8 c-e	1.6 de	-84.01	48.7 f-ı	24.4 e-h	-49.90
Tom-233	13.0 e-g	14.8 d-g	13.85	114.8 de	59.3 ef	-48.34	9.2 c-f	2.9 a-e	-68.26	51.3 f-h	19.4 g-ı	-62.18
Mean Tolerant	18.67	20.79	7.19	101.71	68.09	-27.79	11.4	2.8	-69.8	75.73	26.42	-62.98
Control Tom.												
Hazera 56 F_1	16.4 c-g	20.0 a-g	21.95	87.3 fg	71.2 a-d	-18.44	5.4 d-f	3.7 a-d	-31.11	37.2 ı	22.0 f-ı	-40.86
H2274	12.1 g	12.6 g	4.13	85.4 f-h	59.0 ef	-30.91	6.7 d-f	2.8 a-e	-58.96	41.7 g-ı	23.10 f-ı	-44.60
Mean Controls	14.25	16.30	13.04	86.35	65.10	-24.68	6.1	3.3	-45.0	39.45	22.55	-42.73

*: Changes in relative to control. Values with the same letter are not significantly different. Data represent means of five independent fruits.

Table 3. Tomato fruit **micro-nutrient content** of the tolerant genotypes and control cultivars under heat stress and control conditions (mg 100g^{-1} of dry weight).

	Fe			Zn			Cu		
Tolerant Tom.	Control	Stress	CRC (%)*	Control	Stress	CRC*	Control	Stress	CRC (%)*
Tom-12	13.17 a-b	2.72 b-g	-79.35	11.42 a	2.20 b-e	-80.74	1.57 c-e	1.20 bc	-23.57
Tom-14	7.27 e-h	2.55 d-ı	-64.92	6.02 c-e	2.05 c-h	-65.95	1.65 b-e	0.79 b-g	-52.12
Tom-19	14.40 a	2.15 h-ı	-85.07	9.62 a-b	1.62 h	-83.16	2.50 a-c	0.90 c-h	-64.00
Tom-20	5.40 h-	2.35 f-ı	-56.48	5.60 c-f	2.10 c-g	-62.50	1.20 c-e	2.17 a	80.83
Tom-26	5.57 g-j	2.55 d-ı	-54.22	5.52 c-f	2.50 a-c	-54.71	1.80 b-e	1.17 b-d	-35.00
Tom-40	6.57 f-ı	2.65 c-h	-59.67	5.87 c-e	2.00 d-h	-65.93	1.10 d-e	0.62 e-h	-43.64
Tom-47	6.10 g-ı	2.27 g-h	-62.79	5.17 d-f	1.75 e-h	-66.15	0.92 e	0.77 c-h	-16.30
Tom-108	8.77 c-f	2.77 b-g	-68.42	11.77 a	1.97 d-h	-83.26	2.35 a-d	0.47 g-h	-80.00
Tom-111	9.32 c-e	3.22 a-b	-65.45	12.20 a	2.12 b-d	-82.62	2.97 a-b	0.65 d-h	-78.11
Tom-114	9.85 c-d	2.52 d-ı	-74.42	11.02 a	2.00 d-h	-81.85	2.92 a-b	1.45 b	-50.34
Tom-115	10.62 c	3.20 a-b	-69.87	8.00 b-c	1.70 g-h	-78.75	2.95 a-b	1.15 b-e	-61.02
Tom-119	3.60 j-k	3.00 a-e	-16.67	4.00 e-f	2.75 a	-31.25	1.35 c-e	1.15 b-e	-14.81
Tom-165	10.70 b-c	2.82 b-f	-73.64	4.22 e-f	2.15 b-g	-49.05	1.35 c-e	0.72 c-h	-46.67
Tom-173	5.30 h-j	2.75 b-g	-48.11	4.20 e-f	2.47 a-c	-41.19	2.47 a-c	0.97 b-g	-60.73
Tom-201-B	4.37 ı-k	3.37 a	-22.88	3.77 e-f	2.07 c-h	-45.09	0.95 e	0.75 c-h	-21.05
Tom-211	4.60 ı-j	3.00 a-e	-34.78	4.12 e-f	2.17 b-f	-47.33	0.67 e	0.57 f-h	-14.93
Tom-225	4.25 ı-k	2.50 e-ı	-41.18	3.00 f	1.82 e-h	-39.33	0.70 e	0.75 c-h	7.14
Tom-230	7.97 d-g	2.77 b-g	-65.24	5.37 c-f	1.82 e-h	-66.11	1.00 e	0.65 d-h	-35.00
Tom-232	8.62 c-f	2.15 h-ı	-75.06	5.05 d-f	1.72 f-h	-65.94	1.67 b-e	0.95 b-g	-43.11
Tom-233	10.80 b-c	3.47 a	-67.87	6.92 c-d	2.57 a-b	-62.86	3.60 a	2.02 a	-43.89
Mean Tolerant’s	7.86	2.74	-59.30	6.64	2.08	-62.69	1.78	0.99	-34.82
Control Tom.									
Hazera 56 F_1	9.17 c-e	2.12 ı	-76.88	5.65 c-f	1.75 f-h	-69.03	1.05 d-e	0.40 h	-61.90
H2274	2.60 k	2.30 g-ı	-11.54	3.05 f	1.72 f-h	-43.61	1.97 b-e	0.65 d-h	-67.01
Mean Control’s	5.89	2.21	-44.21	4.35	1.74	-56.32	1.51	0.53	-64.46

*: Changes in relative to control. Values with the same letter are not significantly different. Data represent means of five independent fruits.

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