RESEARCH ARTICLE

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Determination of some quality parameters in early maturing tomato lines

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Abstract
In recent years, tomato breeding research, as in many vegetable species, has focused on improving the intrinsic quality of the fruit. To identify the superior lines in terms of biochemical properties, 20 early maturing tomato lines were evaluated. Yields of the lines used in this work ranged from 2.5 to 9.2 kg per plant, with average fruit weights between 86 and 246 g. Consequently, L* values for tomato fruit varied from 30.87 to 45.35, a* values from 8.36 to 21.48 and b* values from 15.28 to 42.17. The values of titratable acidity, pH, brix, total carotene, total xanthophyll, ascorbic acid, and lycopene in tomato fruits changed from 0.27 to 0.40%, from 3.75 to 4.95, from 2.60 to 6.30%, from 80.2 to 197.5 mg/100 g, from 115.3 to 256.6 mg/100 g, from 10.50 to 28.78 mg/100 g, and from 1.6 to 4.09 mg/100 g, respectively. The contents of soluble and reducing sugars ranged from 7.31 to 17.51 mg/g and 2.46 to 6.57 mg/g respectively. According to these values, the lines with the highest biochemical properties were L7, L17 and L3. This data could then be used as a genetic resource in breeding programmes for the development of new varieties.
Keywords: Tomato, Breeding, Quality, Biochemical, *Solanum esculentum*

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INTRODUCTION

Tomato is one of the most produced, consumed, and traded vegetable in the world. It is consumed as fresh or used as processing tomato, which is becoming more significant on a global scale to produce tomato products such as tomato paste, juice, sauce, puree, soup, dried tomatoes, ketchup, and tomato powder (Silva et al., 2019). The total world production of tomato, the most cultivated vegetable in the world, is 189,133,955 tons according to 2021 data, and it is produced in every part of the world except Antarctica. Asia supplies 63.0%, America 12.5%, Europe 12.9%, and Africa 11.3% of the world tomato production. Shares of the continents in tomato production, also show that tomato is a product that can be offered to all world markets. In terms of tomato production, Türkiye ranks 3rd in the world with 13,095,258 tons of production after China (67,636,725 tons) and India (21,181,000 tons). Tomato is the most exported fresh vegetable in the world. Among the countries exporting fresh tomatoes, Mexico ranks first with 1,903,779 tons, while Türkiye ranks 5th with 606,583 tons (FAO, 2023).

Tomato has important effects on human health and nutrition. It is very rich in micronutrients and antioxidants that are important for human nutrition (Carli et al., 2011). Tomato with its low calorie and low fat content, is characterized as a healthy vegetable with lycopene, β-carotene, niacin, vitamins A, B, C, and K, and its mineral substances, such as potassium, calcium, and iron (Willcox et al., 2010; Yahia and Brecht, 2012). It is very important for health, with its powerful antioxidant content (Khalil et al., 2022) such as vitamins A, C, and E, which help to

reduce the risk of cancer. It is also a rich source of lycopene, which gained importance with the development and application of lycopene in food, medicine, cosmetics, and other fields (Xie et al., 2022), and consumption of tomatoes is effective in reducing the risk of cancer death (Mazidi et al., 2020). The ratio of protein and fat in tomatoes is lower than that of carbohydrates indicates that tomatoes are an important source of dietary fiber (Gölükçü et al., 2016), especially in the prevention of common obesity disease (Zhu et al., 2020). The most prevalent phenolic components in tomatoes are quercetin, kaempferol, naringenin, caffeic acid, and lutein. Several of these substances are beneficial in defending the body against various oxidative stress-related disorders and contain antioxidant properties. Tomato consumption reduces oxidative stress by increasing the body's antioxidant levels, trapping reactive oxygen species, and reducing oxidative damage to important macromolecules like DNA, enzymes, proteins, and membrane lipids (Ali et al., 2021).

Until today, phenotypic properties, such as disease resistance, productivity, shelf life for transportation and marketing, fruit color, and fruit size have been emphasized in breeding studies (Şimşek, 2013). Breeding studies on tomatoes have been largely limited to these parameters. Most of the breeding studies have been focused on producers, seed producers and retailers. Quality parameters, such as flavor, aroma, taste, and healthy ingredients (biochemicals compounds), which are the direct focus of the consumer, were not taken into account (Heuvelink, 2005). On the other hand, taste and aroma substances in tomatoes are among the criteria consumers consider (Dorais et al., 2001). Although tomato is the most produced and consumed vegetable, it is necessary to study to improve fruit quality, such as nutritional content, aroma, and functional compounds (Rodrigues et al., 2022; Ruiz-Cisneros et al., 2022). Therefore, the present study aimed to determine superior tomato lines in terms of some fruit quality properties.

MATERIALS AND METHODS

In the study, 20 purified semi-determinate tomato lines showing early maturing characteristics were selected and their general characteristics are given in Table 1. The study was planned according to the randomized plots experimental design with three replications and 10 plants in each replicate. The spacing between plants was planned as 40 cm, between narrow rows as 50 cm, and between wide rows as 150 cm.

The experiment was conducted in the plastic greenhouse (36° 57′ 6″ N, 30° 57′ 42″ E; 16 m above the sea level) of Enza Zaden vegetable breeding station (Antalya, Türkiye), in 2017. Average temperature (20.3°C) and relative humidity (73.1%) values were obtained for 4 months in 2017, where the experiment was conducted (Figure 1).

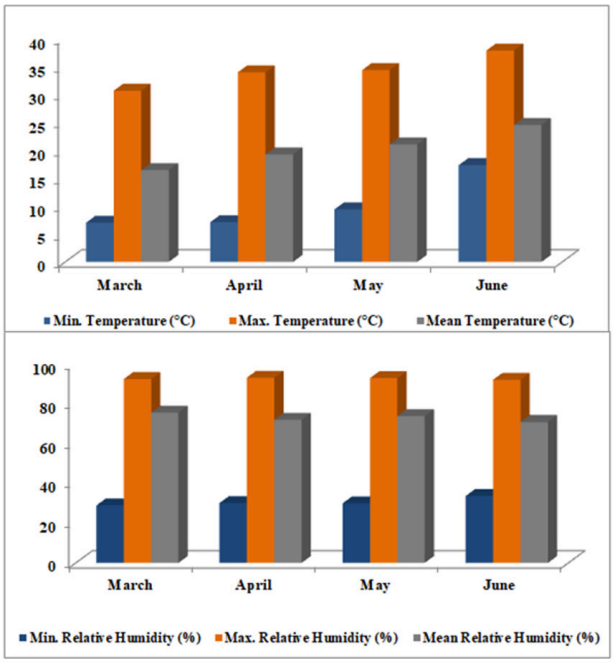

Figure 1. Meteorological data of the research area

The soil texture of the study area was clay-loam structure and its physicochemical properties were given in Table 2.

The physical and chemical analyses of the tomato fruits were carried out in the Horticulture Laboratory of Isparta University of Applied Sciences.

Color determination

L^* (brightness), a^* (redness), and b^* (yellowness) values of fruits were determined by measuring two opposite surfaces in the equatorial region of the fruits with a CR 400 Model Minolta colorimeter (Japan). The values of chroma (C^*) and hue angle (h°) were calculated according to equation 1 and equation 2, respectively (McGuire, 1992).

$$C^* = \sqrt{(a^*2+b^*2)} \quad (1)$$

$$h^\circ = \arctan(b^*/a^*) \quad (2)$$

Determination of pH, titratable acidity (TA) and brix

For the determination of titratable acidity, 10 mL of the prepared fruit juice samples were taken and titrated with 0.1 N NaOH solution until pH reached 8.1. Results were given in % of citric acid (Cemeroğlu, 1992). The pH value was determined by dipping the digital pH meter probe (Hanna HI 2211, Romania) into the prepared fruit juice. Brix values of tomato fruits were determined as % (brix°) using a digital refractometer (Hanna HI96801, Romania).

Determination of total soluble and reducing sugars

For the extraction of sugars, samples (5 g) were first homogenized in 80% ethanol, incubated overnight at -20°C and then centrifuged at 2000 x g for 5 min. The supernatant was used for the determination of both total soluble and reducing sugars. The amount of reducing sugars was measured according to Honda et al. (1980),

Table 1. General properties of early maturing tomato lines

LINES	Generation	Yield per Plant (kg)	Average Fruit Weight (g)	Disease Resistance
Line-1	F10	9.2	186	Clad, Fol, Forl, ToMV, TSWV, Vd
Line-2	F10	5.6	201	Clad, Fol, Forl, ToMV, Vd
Line-3	F17	3.1	86	Fol, Mi, Vd
Line-4	F6	8.1	202	Fol, Forl, Vd
Line-5	F6	5.9	171	Clad, Fol, Vd
Line-6	F7	5.4	135	Clad, Fol, ToMV
Line-7	F8	5.1	170	Clad, Fol, Forl, Mi, ToMV
Line-8	F6	5.2	218	Clad, Fol, Forl, ToMV
Line-9	F6	6.2	124	Clad, Fol
Line-10	F6	6.1	136	Clad, Fol, Forl
Line-11	F7	4.5	190	Clad, Fol, Vd
Line-12	F6	7.0	160	Fol, Forl
Line-13	F6	5.9	153	Clad, Fol, Forl
Line-14	F8	8.7	218	Fol, TYLCV, Vd
Line-15	F7	3.5	175	Fol, TSWV, TYLCV, Vd
Line-16	F7	2.5	235	Fol, TSWV
Line-17	F7	7.9	166	TSWV, TYLCV, Vd
Line-18	F8	2.9	145	Vd
Line-19	F7	3.9	246	Fol, Mi, Vd
Line-20	F5	7.0	195	Fol, Vd

Clad: ***Cladosporium fulvum*** **Fol:** ***Fusarium oxysporum*** f. sp. ***lycopersici*** **Forl:** ***F. oxysporum*** f. sp. ***radicis lycopersici*** **Mi:** *Melodigyne incognita* nematode **ToMV:** Tomato Mosaic Virus **TSWV:** Tomato Spotted Wilt Virus **TYLCV:** Tomato Yellow Leaf Curl Virus **Vd:** ***Verticillium dahliae***

Table 2. Physicochemical properties of the soil of experimental area

Soil Properties	Results	Unit
pH	7.7	-
Electrical conductivity (EC)	1099	µs/cm
Organic matter	1.31	%
Total N	0.103	%
Available P	26.74	kg P_2O_5/da
Available K	114.7	kg K_2O/da
Ca	1774.9	kg CaO/da
Mg	191.5	kg MgO/da
Na	49.20	ppm
Fe	28.10	ppm
Mn	14.96	ppm
Zn	0.70	ppm
Cu	3.61	ppm

and the amount of total soluble sugars was determined by the phenol sulfuric acid method (DuBois et al., 1956). Both assays were conducted using glucose as a standard, which varied at concentrations of 40, 80, 120, and 200 g/ml.

Determination of total carotene and xanthophyll

To extract carotenes and xanthophylls, 1 g of fruit flesh was homogenized with 10 ml of acetone: hexane (4:6) mixture. Samples mixed with vortex for 30 seconds were shaken on a shaker at 200 rpm for 15 min. The upper phase was removed and an equal amount of 20% NaCl solution was added and mixed. Then, the upper phase was taken again and an equal amount of 20% NaCl solution was added and mixed. Readings were performed at wavelengths of 436 nm to detect carotenes in the samples and 474 nm for xanthophylls. Total carotene and xanthophyll content was calculated according to AOAC (1984).

Estimation of total soluble phenolics

Fruit samples (5 g) were homogenized in 10 mL 95% ethanol for 2.5 min and the resulting mixture was boiled for 10 min and then centrifuged at 8000 rpm 10 min. Samples were filtered through filter paper. 10 mL of 80% ethanol was added and boiled for 10 minutes. After boiling, the supernatant was made up to 100 mL with 80% ethanol. Total phenol content analysis was then

performed according to Coseteng and Lee (1987) using the Folin-Ciocalteu reagent. Absorbance values of the samples were read at 760 nm with a spectrophotometer and the results were reported as mg/g.

Determination of ascorbic acid

A homogeneous mixture was obtained by adding an equal amount of 6% metaphosphoric acid solution to 250 g sample. Twenty five grams of slurry was placed in a graduated cylinder and volume was brought to 100 mL with a 3% metaphosphoric acid solution. After shaking the samples, they were filtered and 10 mL of the filtered samples were titrated with 2.6 dichlorophenolindophenol solution. The amount of ascorbic acid in the samples was calculated using the equation specified in Cemeroğlu (1992).

Ascorbic acid (mg/100 g)= (V x Fx 100)/W

V: Volume of 2,6-dichlorophenolindophenol solution used for titration (ml)
F: Factor of 2,6% dichlorophenolindophenol solution
W: Amount of sample in filtrate used for titration (g)

Determination of lycopene and ß-Carotene

Fruit samples were first homogenized in acetone: hexane mixture (4:6) for extraction. Then, readings were made in the spectrophotometer at different wavelengths (663, 645, 505, and 453 nm). Lycopene and ß-Carotene amounts were calculated according to the formulas specified in Nagata and Yamashita (1992), and the results were expressed as mg/100g.

Statistical analysis

Statistical analysis was performed in triplicate using the Minitab (17) Inc. package program. One-way analysis of variance (ANOVA) was used to analyse the data. Significance of means were compared with Tukey's multiple range test at $P < 0.05$ level of significance. Principal component analysis (PCA) was performed using version 4.3.1 of the R statistical package.

RESULTS AND DISCUSSION

In terms of color values, the difference between 20 tomato lines was significant ($P < 0.05$) (Table 3). The L^* values obtained in the lines ranged from 30.87 to 45.35. Lines L3 (45.35), L1 (43.63), L13 (43.42), L10 (42.49), L16 (42.33), and L11 (42.27) came to the fore in terms of L^* values. The lowest L^* values were obtained from the L19, L5, and L17 at 30.87, 31.21, and 31.17, respectively. It was reported that L^* values vary between 32.0-38.6 (Bhandari et al., 2016a), 36.95-45.68 (Borghesi et al., 2011), 40.56-45.07 (Gözükara and Kaplan, 2017). Our findings are in agreement with these reports. The range of chroma values was 16.14-45.88. The highest chroma value was determined from L3 (45.88), followed by L7 (40.39), L10 (39.25), and L16 (38.90), while the lowest chroma values were L19 (16.14), L5 (16.41), and L9 (17.96). According to Viskelis et al. (2015) and Gözükara and Kaplan (2017), the chroma values in various tomato cultivars ranged from 39.20 to 47.23 and 27.36 to 32.81, respectively. The lines' color angles were assessed and it was found that L1 had the highest (69.72) and L17 had the lowest value (45.86). Sacks and Francis (2001) found hue values ranging from 45.8 to 59.7. a^* value represents the red color, the lowest a^* value among the lines was 8.36 (L19) and the highest a^* value was 21.48 (L7) followed by 19.05 (L10). In different studies, a^* values varied between 21.1-25.0 (Hernandez et al., 2007) and 24.70-34.29 (Viskelis et al., 2015). The reason for low a^* values observed in the present study is that the selection criteria of the lines included orange fruit colour. The b^* value was found to be the lowest in L5 (13.59), and the highest in L3 (42.17) followed by L16 and L10. The lowest b^* value was obtained from the L5, L19, and L17. Bhandari et al. (2016a) found that the b^* values ranged from 13.8 to 27.0 in 7 tomato breedin lines; Renna et al. (2018) found that the b^* values for the Regina tomato variety ranged from 30.3 to 41.0.

Table 4 shows that there is a significant difference for pH and titratable acidity values among the tomato lines ($P < 0.05$). The pH range for tomato lines was from 3.75 to 4.95. The pH values of tomato ranged from 3.75 to 4.50 (Acharya et al., 2018), from 3.8 to 4.5 among Kenyan tomato germplasms (Agong et al., 2001), from 4.19 to 4.49 among Tunisian tomato germplasm (Aoun et al., 2013). Different studies also placed pH value of tomato fruits from 3.41 to 5.46 (Dar et al., 2012; Frusciante et al., 2007; Figueiredo et al., 2017; Kumar et al., 2016; Liu et al., 2017; Peixoto et al., 2018; Turhan et al., 2011). In the present study, L6 had the highest pH value (4.95), followed by L16 and L4, whereas L13 (3.75), L9 (3.96) and L8 (4.11) had the lowest pH values, which are consistent with previous reports. Titratable acidity values among the tomato lines were between 0.27 to 0.40%. Line L13 (0.40%) had the highest acidity value followed by L9 (0.38%), L20 (0.36%), and L18 (0.36%). Titratable acidity values were between 0.28 and 0.49% among 40 tomato genotypes (Kumar et al., 2016). Other researchers reported values ranging from 0.35% to 0.46% (Stommel et al., 2005), from 0.27% to 0.75% (Ruggieri et al., 2014), from 0.27 to 0.37% (Sio et al., 2018), and our results were within the reported ranges.

The difference between brix values was also significant at $P < 0.05$ level of signifance. As seen in Table 4, the brix values of the lines have changed between 2.60% and 6.30%. L7 (6.30%), L17 (5.10%), and L2 (4.75%) had the highest brix values, whereas L5 (2.60%) and L20 (2.85%) had the lowest brix values. Brix values of different tomato genotypes ranged from 3.12% to 6.03% (Al-Aysh et al., 2012; Giorio et al., 2007; Pal et al., 2018; Raj et al., 2018). However, Hanson et al (2004) found that brix values ranged from 3.6 to 8.6% among *L. esculentum*, *L. pipinellifolium* genotypes.

The difference in total soluble sugar content between

Table 3. Fruit skin color of tomato lines (L*, C*, h°, a*, b*)

Lines	L*	Chroma (C*)	Hue (h°)	a*	b*
L-1	43.63 a*	36.08 bcd	69.72 a	12.49 c-g	33.84 bc
L-2	39.68 abc	29.79 de	65.79 abcd	12.23 c-g	27.10 de
L-3	45.35 a	45.88 a	66.96 abc	17.97 abc	42.17 a
L-4	34.75 b-f	21.79 g	52.03 ef	13.41 b-g	17.10 f
L-5	31.21 f	16.41 g	55.99 cdef	9.18 efg	13.59 f
L-6	39.41 a-d	32.92 cde	57.66 b-f	17.59 abcd	27.83 de
L-7	39.13 a-e	40.39 ab	57.92 a-e	21.48 a	34.17 bc
L-8	39.07 a-e	30.15 de	59.64 a-e	15.28 a-e	25.98 e
L-9	33.10 def	17.96 g	59.68 a-e	9.06 efg	15.28 f
L-10	42.49 a	39.25 bc	60.86 a-e	19.05 ab	34.23 bc
L-11	42.27 a	32.82 cde	65.68 abcd	13.53 b-g	29.83 cde
L-12	39.08 a-e	29.06 ef	58.99 a-e	14.99 b-e	24.89 e
L-13	43.42 a	34.75 bcde	68.03 ab	12.98 b-g	32.23 bcd
L-14	33.91 c-f	18.99 g	62.87 a-e	8.62 fg	16.91 f
L-15	40.55 ab	33.27 cde	59.60 a-e	16.83 abcd	28.64 cde
L-16	42.33 a	38.90 bc	67.94 ab	14.74 b-f	35.98 b
L-17	31.17 f	20.41 g	45.86 f	14.13 b-g	14.66 f
L-18	35.35 b-f	22.53 fg	54.98 def	12.96 b-g	18.42 f
L-19	30.87 f	16.14 g	58.87 a-e	8.36 g	13.79 f
L-20	32.81 e-f	19.09 g	53.56 ef	11.36 d-g	15.34 f

*Average values with different letters in the same column differ significantly by Tukey test at P < 0.05.

Table 4. pH, titratable acidity, brix, total soluble sugars and reducing sugars values of tomato lines.

Lines	pH	Titratable Acidity (%)	Brix (%)	Total Soluble Sugars (mg/g)	Reducing Sugars (mg/g)
L-1	4.57 bcd*	0.27 fg	4.00 efg	11.59 b-f	5.46 bc
L-2	4.35 cde	0.30 ef	4.75 bc	12.51 bcd	5.85 ab
L-3	4.42 bcde	0.30 def	4.35 cde	11.45 b-f	4.75 cd
L-4	4.66 abc	0.27 fg	3.05 jkl	8.80 efg	3.41 gh
L-5	4.40 cde	0.31 de	2.60 l	8.65 efg	3.32 hı
L-6	4.95 a	0.24 g	4.60 cd	14.16 ab	5.51 bc
L-7	4.45 bcd	0.30 def	6.30 a	17.51 a	6.57 a
L-8	4.11 ef	0.34 cd	4.20 def	11.90 bcde	4.47 d
L-9	3.96 fg	0.38 ab	3.95 efgh	8.75 efg	3.31 hı
L-10	4.48 bcd	0.29 ef	3.50 hıj	10.42 c-g	4.29 def
L-11	4.52 bcd	0.28 ef	3.40 ijk	8.16 fg	3.29 hı
L-12	4.51 bcd	0.29 ef	4.25 def	11.09 b-f	4.50 d
L-13	3.75 g	0.40 a	2.95 kl	7.31 g	2.46 ı
L-14	4.47 bcd	0.30 def	3.60 ghı	9.48 defg	3.37 h
L-15	4.51 bcd	0.29 ef	4.50 cd	12.05 bcde	4.48 d
L-16	4.75 ab	0.27 fg	4.50 cd	12.93 bcd	4.48 d
L-17	4.61 abcd	0.28 ef	5.10 b	13.16 bc	4.46 de
L-18	4.34 cde	0.36 bc	3.80 fghı	10.77 b-g	4.25 defg
L-19	4.48 bcd	0.30 ef	3.45 ij	10.74 b-g	3.46 fgh
L-20	4.30 def	0.36 abc	2.85 l	8.46 efg	3.59 efgh

*Average values with different letters in the same column differ significantly by Tukey test at P < 0.05.

the lines was significant (P < 0.05) (Table 4). The highest value of 17.51 mg/g found in L7, and the lowest value was found in L13 with 7.31 mg/g. Al-Aysh et al. (2012) evaluated 14 different tomato genotypes for yield and quality properties. They reported that the total sugar content of the tomato genotypes ranged from 2.62% to 3.25%. In other studies, total soluble sugar content of tomato genotypes ranged from 2.01% to 3.96% (Kumar et al., 2016), from 1.67% to 3.73% (Turhan and Şeniz, 2009). Table 4 shows a significant difference (P < 0.05) in the amount of reducing sugars among the tomato lines. The range of reducing sugar content was from 2.46 to 6.57 mg/g. Lines L7 (6.57 mg/g) followed by L2 (5.85 mg/g) and L6 (5.51 mg/g) had the highest reducing sugar concentration while L13 (2.46 mg/g) had the lowest amount of reducing sugars, followed by L11

Table 5. Total carotene, xanthophyll, soluble phenolics, ascorbic acid, lycopene and β-carotene content of the tomato lines

Lines	Carotene (mg/100 g)	Xanthophyll (mg/100 g)	Soluble Phenolics (mg/g)	Ascorbic Acid (mg/100 g)	Lycopene (mg/100 g)	β-carotene (mg/100 g)
L-1	80.2 ^{g*}	115.3 ^{h}	0.46 ^{de}	27.47 ^{a}	2.21 ^{hı}	1.24 ^{cde}
L-2	93.6 ^{fg}	145.5 ^{fgh}	0.38 ^{e}	16.61 ^{efg}	2.30 ^{h}	1.22 ^{cde}
L-3	124.6 $^{c-g}$	195.8 $^{b-g}$	0.31 ^{e}	22.47 ^{bc}	4.09 ^{a}	1.41 $^{a-e}$
L-4	97.4 ^{efg}	153.4 ^{efgh}	0.69 ^{cd}	13.99 ^{ghij}	3.54 ^{de}	1.29 ^{bcde}
L-5	130.3 ^{cdef}	203.6 $^{a-f}$	0.83 ^{abc}	19.60 ^{cde}	1.82 ^{j}	1.69 ^{abc}
L-6	121.6 $^{c-g}$	199.8 $^{a-g}$	0.71 ^{bcd}	25.46 ^{ab}	3.69 ^{cd}	1.20 ^{cde}
L-7	144.8 ^{bcde}	232.7 ^{abc}	0.93 ^{abc}	27.13 ^{a}	3.89 ^{b}	1.86 ^{a}
L-8	149.8 ^{abcd}	224.6 ^{abcd}	0.72 ^{bc}	10.50 ^{j}	2.50 ^{g}	1.18 ^{de}
L-9	113.4 ^{defg}	190.4 $^{c-g}$	0.78 ^{abc}	11.79 ^{ij}	2.05 ^{ı}	1.07 ^{e}
L-10	127.6 $^{c-g}$	208.5 $^{a-e}$	0.82 ^{abc}	12.09 ^{hij}	3.79 ^{bc}	1.29 ^{bcde}
L-11	89.6 ^{fg}	140.9 ^{gh}	0.81 ^{abc}	16.02 ^{efg}	2.61 ^{g}	1.23 ^{cde}
L-12	168.8 ^{abc}	241.0 ^{abc}	0.79 ^{abc}	14.78 ^{ghı}	2.57 ^{g}	1.47 $^{a-e}$
L-13	113.8 ^{defg}	186.5 $^{c-g}$	0.86 ^{abc}	19.60 ^{cde}	2.26 ^{h}	1.77 ^{ab}
L-14	144.6 ^{bcde}	219.1 ^{abcd}	0.95 ^{ab}	21.82 ^{cd}	1.6 ^{k}	1.48 $^{a-e}$
L-15	112.4 ^{defg}	171.4 $^{d-h}$	0.92 ^{abc}	15.46 ^{fgh}	3.71 ^{bcd}	1.90 ^{a}
L-16	114.8 ^{defg}	189.5 $^{c-g}$	0.88 ^{abc}	18.51 ^{def}	2.13 ^{hı}	1.31 ^{bcde}
L-17	197.5 ^{a}	256.6 ^{a}	0.97 ^{a}	28.78 ^{a}	3.47 ^{e}	1.54 $^{a-e}$
L-18	164.7 ^{abc}	236.3 ^{abc}	0.95 ^{ab}	21.24 ^{cd}	3.05 ^{f}	1.64 ^{abcd}
L-19	187.5 ^{ab}	251.8 ^{ab}	0.87 ^{abc}	14.40 ^{ghı}	1.85 ^{j}	1.58 ^{abcd}
L-20	150.0 ^{abcd}	235.8 ^{abc}	0.84 ^{abc}	20.74 ^{cd}	2.93 ^{f}	1.16 ^{de}

*: Average values with different letters in the same column differ significantly by Tukey test at $P < 0.05$.

(3.29 mg/g) and L9 (3.31 mg/g) (Table 4). According to a study carried out on four varieties of tomato, the levels of Reducing sugars content could be between 0.64% to 3.86% (Adedeji et al., 2006; Kumar et al., 2016).

There were significant differences for the biochemical indices presented in Table 5 ($P < 0.05$). Tomato line L17 was found to have the highest total carotene concentration with a value of 197.5 mg/100 g. As can be seen, the lines with the highest levels of total carotene are after line L17 were L12, L18 and L19. The lowest total carotene content was found in L1, L11 and L2. Bhandari et al. (2016b) reported that total carotene content of tomato varieties ranged from 76.87 to 110.27 mg/100 g, and carotene content of three high lycopene tomato cultivars from 105-278 mg/kg (Ilahy et al., 2011). Kavitha et al. (2013) investigated ascorbic acid, total phenols, total flavonoids, total carotenes and lycopene levels and total carotene concentrations ranged from 90.4 to 220.8 mg/kg.

Total xanthophyll levels of the tomato lines range from 115.3 to 256.6 mg/100 g. L17 (256.6 mg/100 g) and L19 (251.8 mg/100 g) had the highest xanthophyll levels, while L1 (115.3 mg/100 g), L11 (140.9 mg/100 g) and L2 (145.5 mg/100 g) had the lowest levels of xanthophyll. Schweiggert et al. (2017) investigated different parameters, such as lutein, beta-carotene, lycopene, total carotenoids and xanthophylls, and reported that xanthophyll content ranged from 2.9 to 10.7 g/g among the tomato genotypes.

Total soluble phenolics content of the lines was between 0.31 to 0.97 mg/g, L17, L18 and L14 had the highest total phenolics content among the tomato lines. The lines with the lowest total phenolics content were L3 (0.31 mg/g) and L2 (0.38 mg/g). Pal et al. (2018) found that the total phenolics content of 22 tomato selections ranged from 0.60 to 1.14 mg/g, from 0.11 and 0.31 mg/g (Ilahy et al., 2011) and from 0.20 and 1.34 mg/g (Kavitha et al., 2013).

The highest ascorbic acid content of the tomato lines were 28.78 mg/100 g (L17), 27.47 mg/100 g (L1) and 27.13 mg/100 g (L7). The line with the lowest concentration of ascorbic acid was L8 (10.50 mg/100 g). Ascorbic acid content of green house grown tomates varied between 8.26-22.54 mg/100 g (Bhandari et al., 2016a). Other research also reported different levels of ascorbic acid for different tomato genotypes ranging from 19.77 to 33.41 mg/100 g (Dar and Sharma, 2011), from 8.0-15.6 mg/100 g (Frusciante et al., 2007), and from 11.6-39.7 mg/100 g (Hanson et al., 2004). These reports are consistent with our findings.

Lycopene content of the tomato lines ranged from 1.60 to 4.09 mg/100 g. Results revealed that L3 (4.09 mg/100 g) had the highest lycopene value among the lines, followed by L7 and L10, with values of 3.89 and 3.79 mg/100 g; respectively. The results also showed that L14 had the lowest lycopene content (1.6 mg/100 g), followed by L5 (1.82 mg/100 g) and H19 (1.85 mg/100 g). D'Ambrosio et al. (2004) reported that the lycopene content of tomato genotypes ranged from 1.0 to 4.5 mg/g. Lycopene values were found to vary between 0.95-5.12 mg/100g (Bhandari et al., 2016a), 1.98-4.62 mg/100

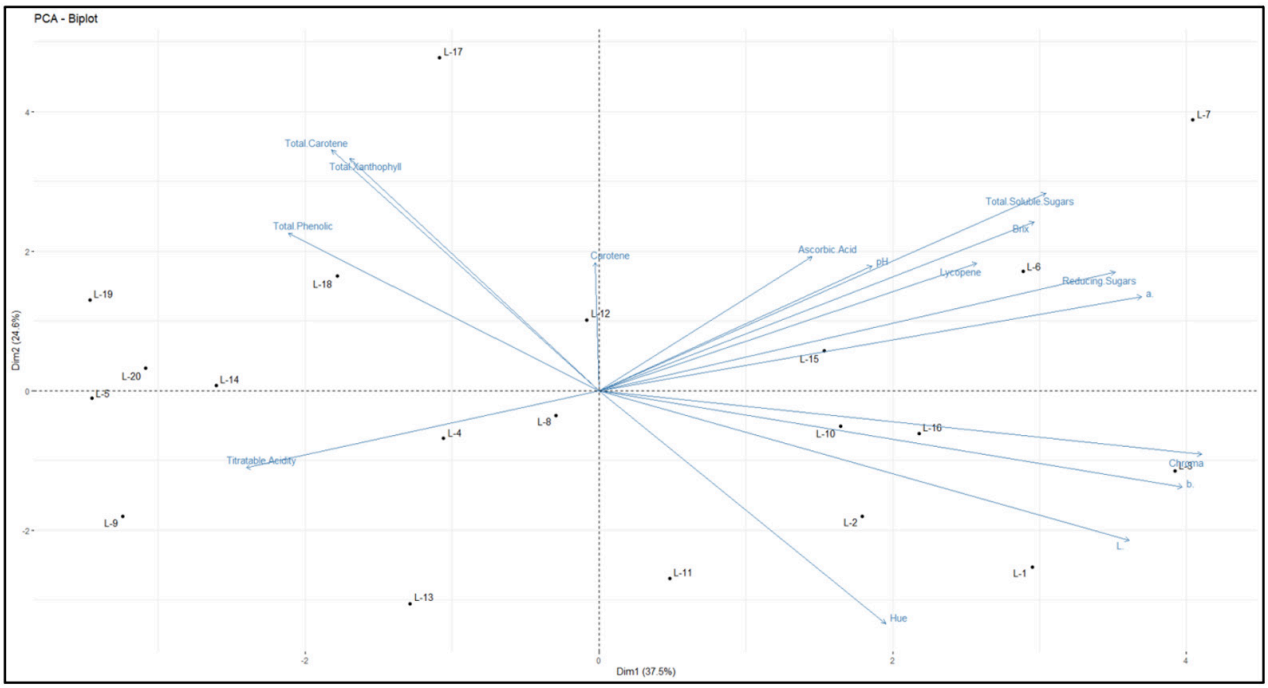

Figure 2. Principal component analysis (PCA) of some biochemical properties of 20 early maturing tomato lines

g (Dar and Sharma, 2011), 0.20-1.85 mg/100 g (Gautam et al., 2018), and 2.84-9.83 mg/100 g (Pal et al., 2018). Our results are in agreement with these literature reports.

The lines with the highest β-carotene levels were L15 and L7, with values of 1.90 mg/100 g and 1.86 mg/100 g, respectively. After the L15 and L7, the highest β-carotene value was found in L13 (1.77 mg/100 g). L9 had the lowest β-carotene value with 1.07 mg/100 g, while L20 and L8 both had low β-carotene values with 1.16 mg/100 g and 1.18 mg/100 g, respectively. β-carotene values of 60 tomato genotypes ranged between 1.09-2.53 mg/100 g (Dar and Sharma, 2011). Tomlekova et al (2007) investigated the lycopene and β-carotene levels of 7 tomato genotypes. They reported that the β-carotene levels of these genotypes varied between 1.28-2.84 mg/100 g.

Principal component analysis (PCA) was performed to minimise the dimensionality of the datasets and to visually identify the differences and similarities between the tomato lines (Figure 2). The biochemical parameters that determine the positions of these lines in the PCA plane are indicated by arrows. While these values were high in the lines in the directions where the biochemical parameters were shown, the parameters in the opposite direction were low. L7, L17 and L3 lines showed high positive collinearity, while L9 and L13 lines showed negative collinearity by clustering on the opposite negative side of the PCA graph. The PCA graph, in which the measured parameters and the tomato lines are plotted together, supports our statistical results.

CONCLUSION

In this study, L7 line was found to be the richest line in terms of redness of skin colour with the highest a* value, brix, total and reducing sugars content. These characteristics of the line will be particularly important in the flavour studies to be carried out. L17 line had the highest values for total carotene, xanthophyll, vitamin C and total soluble phenolics content. Recently, with the growing importance of the relationship between food and health, interest in functional foods has increased. It could be surmised that L17 will have a high antioxidant property and be beneficial in quality parameters. In addition, L3 with high values for L*, a*, b*, chroma and lycopene content, it could be concluded that it is a line that should be particularly evaluated in colour studies.

As a result of the study, it was found that there was a wide variation between the lines for all the parameters studied. The wide variation of lines is very important in terms of being a source of breeding studies for the desired characters of new varieties to be realized. All over the world, the number of studies on the improvement of quality traits in breeding is increasing. To this end, it is hoped that the present study will be useful in breeding studies where quality criteria are prioritized.

COMPLIANCE WITH ETHICAL STANDARDS

This research article complies with research and publishing ethics.

Peer-review

Externally peer-reviewed.

Conflict of interest

All of the authors declare that they have no conflicts of interest.

Author contribution

All authors contributed equally to this study. All authors read and approved the final manuscript. All authors confirm that the text and tables are original and have not been published previously.

Ethics committee approval

Ethics committee approval is not required.

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Data availability

Not applicable.

Consent for publication

Not applicable.

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