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AYTÜL BALIK

MUSTAFA KENAN GEÇER

RAFET ASLANTAŞ

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Diversity of biochemical content in fruits of some indigenous mulberry genotypes

Aytül BALIK[1], Mustafa Kenan GEÇER[1,*], Rafet ASLANTAŞ[2]

[1]Department of Horticulture, Faculty of Agriculture, Iğdır University, Iğdır, Turkey

[2]Department of Horticulture, Faculty of Agriculture, Eskişehir Osmangazi University, Eskişehir, Turkey

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Abstract: This research was carried out to assess the biochemical diversity of the fruits of mulberry genotypes grown in Muş Province in the eastern Anatolia region and to determine the genotypes available for breeding. Morphological and biochemical characteristics of 13 mulberry fruit genotypes, including 5 white (*Morus alba*) and 8 black (*Morus nigra*), were determined. Fruit antioxidant capacity was determined by Trolox equivalent antioxidant capacity assay. Fruit weight, pH, soluble solid content, titratable acidity, vitamin C, and antioxidant capacity were 1.38–3.77 g, 4.77–6.79, 14.33%–23.50%, 0.53%–2.20%, 4.47–35.83 mg 100 g^{-1}, and 4.33–13.63 µmol Trolox equivalent g, respectively, indicating enough diversity among genotypes for future breeding activities. Considering all genotypes, malic acid was dominant, and the highest malic acid content was detected in 4 *Morus nigra* genotypes as 8.546 mg g^{-1} fresh weight. Chlorogenic acid, rutin, and gallic acid were determined as the main phenolics among white and black mulberry genotypes. The highest chlorogenic acid, rutin, and gallic acid contents were found in black mulberry genotypes as 2.511 mg g^{-1} (*Morus nigra* 1), 1.285 mg g^{-1} (*Morus nigra* 1), and 1.162 mg g^{-1} (*Morus nigra* 3), respectively. In general, the genotypes sampled and used in the present study exhibited a broad range of variation.

Key words: Mulberry, diversity, phenolic compounds, antioxidant capacity, organic acids

1. Introduction

Turkey is referred to as a small continent with regard to its rich floristic and faunistic diversity due to having 3 different bioclimates and 3 biogeographical regions (Europe–Siberia, Mediterranean, and Iran–Turan) seen in Turkey (Aytepe and Varol, 2007).

Anatolia is known as one of the diversity centers for mulberries. The mulberry trees that have been cultivated in Anatolia over the past 400 years exhibit great morphological, biochemical, and molecular diversity at both intra- and interspecies levels (Erdoğan, 2003; Ercisli and Orhan, 2007; Kafkas et al., 2008; Okatan, 2018). Mulberry fruits are very popular among Turkish people not only for fresh consumption but also in processed forms. The high yielding capacity of mulberry trees makes them profitable for farmers and encourages their cultivation (Ercisli and Orhan, 2008; Vijayan et al., 2008). Each region of Turkey has special mulberry populations mostly produced from seeds in the past; in general, 95% of Turkish mulberry trees belong to *M. alba*, 3% belong to *M. rubra*, and 2% belong to *M. nigra* (Ercisli, 2004).

Mulberry is one of the main traditional fruits in Turkey, and people process mulberry fruits into products such as mulberry molasses, mulberry jam, etc. Like other berry species, mulberry fruits are widely used in making pie, pudding, doughnuts, bread, marmalade, liqueur, wine, and ice cream, along with fresh fruit consumption (Lale and Özçağıran, 1996; Ercisli and Orhan, 2007; Memon et al., 2010; Pérez Gregorio et al., 2011). Additionally, mulberry is also used in the cosmetics industry (Ercisli and Orhan, 2007).

Mulberry is one of the most important fruits produced in temperate and subtropical countries including Turkey, China, India, Pakistan, Iran, Azerbaijan, and Armenia (Ercisli and Orhan, 2007), and its fruits are highly praised for their unique flavor and impressive composition of nutrients. Mulberry fruits are an important component of the regional diet and are consumed both fresh and dried. They contain polyphenols with well-known biological effects. Mulberry fruits and leaves have several health benefits, including the ability to improve digestion, aid in weight loss, lower cholesterol, help circulation, increase bone tissue, and support the immune system. The fruit also helps prevent certain cancers, slow down the aging process, protect eyes, and improve the overall metabolism of the body (Ercisli and Orhan, 2007; Pérez-Gregorio et al., 2011). It has been found that the tea made by boiling fresh mulberry leaves controls blood pressure (Datta, 2002).

* Correspondence: mkenangecer@hotmail.com

Previously, several morphological and biochemical studies were conducted on mulberry fruits in different parts of Turkey. However, there is no report from the Muş region, which has interesting climatic conditions and is differentiated from the other mulberry growing areas in Turkey. Thus, results obtained on morphological and biochemical characteristics of white and black mulberry grown in the Muş region may increase our knowledge of the composition of this special fruit species.

2. Materials and methods

2.1. Fruit materials

In this study, mulberry trees indigenously grown in the Varto district of Muş Province were located and fruit samples were taken. Thirteen mulberry genotypes (5 *Morus alba* and 8 *Morus nigra*) were used. The fruits were harvested in the last week of June 2016. The harvest was performed during periods when the fruits of the analyzed genotypes were completely ripened. Approximately 500 g of fruit sample was taken from each genotype. Homogeneously collected fruits were stored at –80 °C until the laboratory analyses were performed.

2.2. Determination of agromorphological properties

Fruit weight was measured by a digital scale sensitive to 0.01 g. Fruit width and length and peduncle length were measured with a 0.01-mm sensitive compass. Soluble solids content (SSC) (with hand refractometer), pH (with pH meter), and titratable acidity (TA) (by titration method) were determined in 20 fruits, which were randomly taken from each genotype.

2.3. Analysis of phenolic compounds

The analysis of phenolic compounds was done by modifying the method by Rodriguez-Delgado et al. (2001). The samples were centrifuged at 15,000 rpm for 15 min. The supernatant was filtered through 0.45-µm Millipore filters and injected into the HPLC equipment. Chromatographic separation was carried out on an Agilent 1100 HPLC system using a DAD detector and a 250 × 4.6 mm, 4-µm ODS column. Solvent A (methanol–acetic acid–water [10:2:88]) and Solvent B (methanol–acetic acid–water [90:2:8]) were used as mobile phase solvents. The separation was carried out at 254 and 280 nm and the injection volume was 20 µL.

2.4. Analysis of organic acids

In the analysis of organic acids, the method of Bevilacqua and Califano (1989) was modified and used. Five grams of fruit sample was placed in the centrifuge tube. These samples were homogenized with the addition of 20 mL of 0.009 N H_2SO_4. Samples were centrifuged at 15,000 rpm for 15 min. The supernatant was passed through the SEP-PAK C18 cartridge. An Aminex HPX-87H 300 mm × 7.8 mm column and the Agilent packet program were used in the HPLC system. Analyses were performed at wavelengths of 214 and 280 nm using a DAD detector. In the study, 0.009 N H_2SO_4 passed through a 0.45-µm membrane filter was used as a mobile phase.

2.5. Analysis of vitamin C

Five grams of the fruit sample was transferred to the test tube and 5 mL of 2.5% M-phosphoric acid solution was added. The mixture was centrifuged at 6500 × *g* for 10 min at 4 °C, and then 2.5% M-phosphoric solution was added to the supernatant solution (0.5 mL) and 10 mL was used for completion. The mixture was filtered through a 0.45-µm filter and injected into the HPLC system. A C18 column and DAD detector (254-nm wavelength) were used for analysis. Sulfuric acid and ultrapure water were used as the mobile phase (1 mL/min) (Cemeroğlu, 2007).

2.6. Determination of Trolox equivalent antioxidant capacity (TEAC)

For TEAC analysis, ABTS acetate was dissolved in buffer and potassium persulfate was prepared (Ozgen et al., 2006). To maintain long-term stability of the mixture, 20 mM sodium acetate was diluted in acidic medium (pH 4.5) in the buffer solution to give 0.700 ± 0.01 absorbance at 734 nm. For spectrophotometric measurement, 3 mL of $ABTS^+$ solution and 20 µL of fruit extract were incubated for 10 min and the absorbance values were determined at 734 nm.

2.7. Statistical analysis

Four replicates including 20 fruits per replicate were carried out. Descriptive statistics were expressed as average and standard error. One-way variance analysis was used for the study. The Tukey multiple comparison test was used for the identification of significant differences among genotypes. For data analysis, the MINITAB 17 (trial version) statistics program was used.

3. Results and discussion

3.1. Agromorphological properties

We found statistically significant differences ($P < 0.05$) among all agromorphological properties of the 13 mulberry genotypes. Fruit weight was between 1.38 and 3.77 g (Table 1). The fruit width and fruit length were between 10.89 and 17.91 mm and 17.39 and 27.01 mm, respectively. The peduncle length ranged from 7.50 mm to 11.90 mm (Table 1). A study previously conducted on mulberry fruits indicated an average fruit length between 21.66 and 27.04 mm among 28 black mulberry genotypes sampled in the Mediterranean region of Turkey (Koyuncu et al., 2014). Orhan (2009) conducted a mulberry selection study in Erzurum Province in eastern Anatolia and reported the fruit weight, width, and length and the peduncle length as 1.36–5.77 g, 9.97–17.36 mm, 19.75–31.03 mm, and 4.02–12.75 mm, respectively. Yilmaz et al.

Table 1. Some morphological characteristics of mulberry fruits.

Genotypes	Fruit weight (g)	Fruit width (mm)	Fruit length (mm)	Peduncle length (mm)
M. alba 1	2.13	13.02 ± 0.35 de	19.11 ± 0.16 def	8.22 ± 0.66 b
M. alba 2	1.38	10.89 ± 0.12 e	17.39 ± 0.15 f	7.50 ± 0.50 b
M. alba 3	3.10	14.61 ± 0.06 dc	27.01 ± 0.74 a	11.90 ± 0.93 a
M. alba 4	1.71	11.96 ± 0.57 e	20.07 ± 1.26 cdef	10.08 ± 0.35 ab
M. alba 5	3.38	15.42 ± 0.33 bcd	25.38 ± 0.23 ab	8.46 ± 0.39 b
M. nigra 1	3.47	17.33 ± 0.68 ab	22.86 ± 0.67 bcd	7.98 ± 0.74 b
M. nigra 2	2.91	16.89 ± 0.56 abc	22.94 ± 0.78 bcd	8.30 ± 0.97 b
M. nigra 3	3.77	17.91 ± 0.75 a	22.45 ± 1.09 bcde	7.68 ± 1.15 b
M. nigra 4	3.71	17.79 ± 0.38 ab	23.70 ± 0.70 abc	9.75 ± 0.51 ab
M. nigra 5	3.76	17.38 ± 0.78 ab	22.96 ± 0.90 bcd	10.69 ± 0.51 ab
M. nigra 6	1.68	11.95 ± 0.22 e	19.51 ± 1.11 def	8.18 ± 0.41 b
M. nigra 7	1.67	11.90 ± 0.30 e	18.64 ± 0.29 ef	8.53 ± 0.34 b
M. nigra 8	2.13	13.05 ± 0.18 de	21.38 ± 0.98 bcdef	10.37± 0.27 ab
Overall	2.68 ± 0.25	14.62 ± 0.42	21.80 ± 0.47	9.05 ± 0.26

Difference between means represented by a different letter in the same column is significant at 0.05 level.

(2012) identified the average fruit weight of 0.66–3.07 g among a wide number of mulberry genotypes grown in Malatya Province in Turkey. Polat (2013) reported fruit weight as 3.92 g, fruit width as 14.99 mm, and fruit length as 30.94 mm in *Morus laevigata* in Tokat Province located in inner Anatolia. In the Black Sea region of Turkey, fruit weight, width, and length and peduncle length were 5.07 g, 17.26 mm, 30.69 mm, and 23.81 mm, respectively (Erdem, 2015). In Gümüşhane Province, located in northeastern Anatolia, a study was conducted on mulberries and fruit weight (1.92–5.27 g), fruit width (15.24–18.23 mm), fruit length (19.28–33.95 mm), and peduncle length (4.41–12.14 mm) were reported (Keskin, 2016). Gecer et al. (2016) measured the fruit weight between 3.22 and 4.82 g, fruit width between 1.79 and 2.21 cm, fruit length between 2.70 and 3.26 cm, and peduncle length between 0.65 and 0.67 cm in mulberries from the eastern Anatolian region.

Table 2 shows pH, SSC, and titratable acidity of the 13 mulberry genotypes. As indicated in Table 2, there were statistical differences among genotypes for all parameters ($P < 0.05$). pH was found to be between 4.77 and 6.79, SSC content between 14.33% and 23.50%, and titratable acidity between 0.53% and 2.20% (Table 2). Similar results were reported by Çam (2000), who conducted a comprehensive study of mulberries in eastern Anatolia and found SSC between 15.79% and 19.71%, pH between 5.6 and 7.4, and titratable acidity between 0.17% and 0.30% in 25 mulberry genotypes. Several studies conducted in different agroclimatic conditions in Turkey using a wide number of mulberry genotypes revealed pH between 2.29 and 6.59 (Burgut and Turemis, 2006; Orhan, 2009; Erdem, 2015; Keskin, 2016; Okatan, 2018) and SSC between 9.30% and 26.2% (Erdoğan, 2003; Burgut and Turemis, 2006; Orhan, 2009; Keskin, 2016; Okatan, 2018), which is in agreement with our results. Titratable acidity of mulberry fruits was reported between 1.07% and 2.87% by Polat (2013) and Okatan (2018).

3.2. Phenolic acids

Statistically significant differences in terms of phenolic compounds (phenolic acids) among mulberry genotypes were determined (Tables 3 and 4). Mulberry genotypes contained mainly chlorogenic acid (0.107 and 2.511 mg g^{-1}), followed by rutin (0.083 and 1.285 mg g^{-1}) and gallic acid (0.083 and 1.162 mg g^{-1}). Protocatechuic (0.005 and 0.086 mg g^{-1}), vanillic (0.011 and 0.074 mg g^{-1}), ellagic (0.026 and 0.217 mg g^{-1}), quercetin (0.016 and 0.260 mg g^{-1}), catechin (0.021 and 0.255 mg g^{-1}), caffeic (0.067 and 0.806 mg g^{-1}), syringic (0.012 and 0.166 mg g^{-1}), *p*-coumaric (0.013 and 0.183 mg g^{-1}), *o*-coumaric (0.012 and 0.205 mg g^{-1}), and ferulic (0.016 and 0.273 mg g^{-1}) acids were also identified in mulberry fruits in variable concentrations (Tables 3 and 4). Zadernowski et al. (2005) detected caffeic acid as 0.574 mg g^{-1}, ferulic acid as 0.078 mg g^{-1}, and *o*-coumaric acid as 0.072 mg g^{-1} in mulberry fruits. Katsubea et al. (2009) reported the gallic acid content to be between 3.89 and 11.79 mmol 100 g^{-1} in mulberry fruits. Memon et al. (2010) determined the highest gallic acid content as 5.81 mg 100 g^{-1} in mulberry fruits. Similar results were reported by Gundogdu et al.

Table 2. pH, SSC, and acidity contents of mulberry fruits.

Genotypes	pH	SSC (%)	Titratable acidity (%)
M. alba 1	5.69 ± 0.00 d	17.60 ± 0.92 bcd	1.12 ± 0.02 d
M. alba 2	5.46 ± 0.01 f	23.50 ± 0.64 a	1.48 ± 0.11 bc
M. alba 3	5.50 ± 0.01 e	17.20 ± 0.92 bcd	1.64 ± 0.01 b
M. alba 4	6.02 ± 0.01 b	16.90 ± 0.52 bcd	1.38 ± 0.03 c
M. alba 5	5.86 ± 0.01 c	14.53 ± 1.01 d	2.20 ± 0.04 a
M. nigra 1	6.04 ± 0.01 b	16.90 ± 1.04 bcd	1.01 ± 0.01 d
M. nigra 2	5.47 ± 0.01 ef	19.30 ± 0.75 bc	0.73 ± 0.03 e
M. nigra 3	6.79 ± 0.01 a	18.05 ± 0.09 bcd	0.76 ± 0.02 e
M. nigra 4	5.85 ± 0.01 c	16.80 ± 1.46 bcd	0.64 ± 0.01 ef
M. nigra 5	5.06 ± 0.01 g	19.47 ± 0.84 ab	0.78 ± 0.04 e
M. nigra 6	4.92 ± 0.01 h	16.97 ± 0.04 bcd	1.10 ± 0.01 d
M. nigra 7	5.83 ± 0.01 c	15.38 ± 0.36 cd	0.53 ± 0.02 f
M. nigra 8	4.77 ± 0.01 i	14.33 ± 0.09 d	0.98 ± 0.01 d
Overall	5.63 ± 0.08	17.46 ± 0.41	1.10 ± 0.07

Difference between means represented by a different letter in the same column is significant at 0.05 level.

Table 3. Phenolic compounds (mg g^{-1}) in mulberry fruits.

	Protocatechuic	Vanillic	Ellagic	Rutin	Quercetin	Gallic	Catechin
M. alba 1	0.013 ± 0.000 e	0.033 ± 0.002 d	0.094 ± 0.002 d	0.941 ± 1.228 bc	0.043 ± 0.002 f	0.182 ± 0.002 l	0.037 ± 0.002 i
M. alba 2	0.005 ± 0.000 fg	0.031 ± 0.001 d	0.044 ± 0.002 g	0.355 ± 0.004 cd	0,064 ± 0.001 e	0.245 ± 0.004 k	0.021 ± 0.002 j
M. alba 3	0.025 ± 0.001 d	0.011 ± 0.001 g	0.029 ± 0.000 i	0.093 ± 0.003 d	0.035 ± 0.002 g	0.083 ±0.002 m	0.049 ± 0.000 g
M. alba 4	0.075 ± 0.003 b	0.033 ± 0.001 d	0.179 ± 0.003 b	0.083 ± 0.001 d	0.115 ± 0.003 d	0.974 ± 0.002 b	0.077 ± 0.001 e
M. alba 5	0.086 ± 0.001 d	0.054 ± 0.001 b	0.164 ± 0.004 c	0.314 ± 0.002 cd	0.260 ± 0.004 a	0.913 ± 0.002 d	0.095 ± 0.002 b
M. nigra 1	0.033 ± 0.002 c	0.043 ± 0.001 c	0.217 ± 0.002 a	1.285 ± 0.005 a	0.181 ± 0.002 c	0.955 ± 0.004 c	0.090 ± 0.002 c
M. nigra 2	0.005 ± 0.000 fg	0.022 ± 0.001 f	0.182 ± 0.003 b	1.077 ± 0.004 ab	0.016 ± 0.001 j	0.523 ± 0.003 g	0.034 ± 0.001 i
M. nigra 3	0.024 ± 0.002 d	0.032 ± 0.001 d	0.075 ± 0.001 e	1.056 ± 0.003 ab	0.043 ± 0.002 f	1.162 ± 0.003 a	0.042 ± 0.002 h
M. nigra 4	0.013 ± 0.001 e	0.043 ± 0.001 c	0.062 ± 0.002 f	0.509 ± 0.007 bcd	0.193 ± 0.003 b	0.573 ± 0.003 f	0.063 ± 0.002 f
M. nigra 5	0.007 ± 0.000 fg	0.054 ± 0.002 b	0.045 ± 0.002 g	0.385 ± 0.004 cd	0.018 ± 0.001 j	0.252 ± 0.002 j	0.083 ± 0.002 d
M. nigra 6	0.004 ± 0.000 g	0.043 ± 0.001 c	0.065 ± 0.002 f	0.237 ± 0.034 d	0.031 ± 0.001 h	0.815 ±0.004 e	0.024 ± 0.002 j
M. nigra 7	0.008 ± 0.000 f	0.025 ± 0.001 e	0.036 ± 0.001 h	0.215 ± 0.004 d	0.016 ± 0.000 j	0.322 ± 0.002 i	0.024 ± 0.002 j
M. nigra 8	0.022 ± 0.001 d	0.074 ± 0.002 b	0.026 ± 0.003 i	0.260 ± 0.003 d	0.022 ± 0.002 i	0.414 ± 0.004 h	0.255 ± 0.002 a

Difference between means represented by a different letter in the same column is significant at 0.05 level.

(2011). Radojković et al. (2012) measured the gallic acid, chlorogenic acid, rutin, and quercetin contents as 23.10–14.50 mg 100 g^{-1}, 33.00–20.00 mg 100 g^{-1}, 72.60–43.50 mg 100 g^{-1}, and 13.30–3.70 mg 100 g^{-1} in mulberry fruits, respectively. Gecer et al. (2016) determined chlorogenic acid (0.859–2.367 mg g^{-1}), rutin (0.726–1.222 mg g^{-1}), and gallic acid (0.118–0.201 mg g^{-1}) as the main phenolic compounds in mulberry fruits. They also found vanillic acid (0.074–0.075 mg g^{-1}), quercetin (0.108–0.164 mg g^{-1}), catechin (0.032–0.064 mg g^{-1}), caffeic acid (0.078–0.138 mg g^{-1}), syringic acid (0.065–0.115 mg g^{-1}), *p*-coumaric acid (0.015–0.055 mg g^{-1}), *o*-coumaric acid (0.035–0.045 mg g^{-1}), and ferulic acid (0.062–0.112 mg g^{-1}) in mulberry fruits. Gundogdu et al. (2017) reported the main phenolic

Table 4. Phenolic compounds (mg g^{-1}) of mulberry fruits.

	Chlorogenic	Caffeic	Syringic	*p*-Coumaric	*o*-Coumaric	Ferulic
M. alba 1	0.107 ± 0.003 g	0.224 ± 0.004 c	0.078 ± 0.005 c	0.027 ± 0.000 e	0.110 ± 0.000 c	0.019 ± 0.000 fgh
M. alba 2	0.212 ± 0.003 fg	0.108 ± 0.002 i	0.026 ± 0.000 ef	0.016 ± 0.000 f	0.046 ± 0.001 g	0.023 ± 0.002 de
M. alba 3	0.219 ± 0.001 fg	0.096 ± 0.000 j	0.020 ± 0.000 g	0.027 ± 0.000 e	0.033 ± 0.001 h	0.021 ± 0.000 defg
M. alba 4	2.094 ± 0.004 b	0.806 ± 0.004 a	0.112 ± 0.003 b	0.123 ± 0.002 b	0.074 ± 0.002 e	0.119 ± 0.002 b
M. alba 5	1.065 ± 0.001 c	0.067 ± 0.002 k	0.166 ± 0.003 a	0.113 ± 0.001 c	0.015 ± 0.000 j	0.273 ±0.002 a
M. nigra 1	2.511 ± 0.336 a	0.243 ± 0.002 b	0.027 ± 0.002 e	0.031 ± 0.001 d	0.064 ± 0.002 f	0.085 ± 0.004 c
M. nigra 2	0.223 ± 0.003 fg	0.212 ± 0.000 d	0.031 ± 0.002 d	0.183 ± 0.004 a	0.082 ± 0.003 d	0.014 ± 0.000 i
M. nigra 3	1.046 ± 0.003 c	0.153 ± 0.001 f	0.027 ± 0.001 e	0.025 ± 0.001 e	0.075 ± 0.006 e	0.019 ± 0.000 efgh
M. nigra 4	0.124 ± 0.001 g	0.212 ± 0.006 d	0.013 ± 0.000 h	0.017 ± 0.000 f	0.205 ± 0.002 a	0.019 ± 0.002 efgh
M. nigra 5	0.242 ± 0.003 fg	0.166 ± 0.001 e	0.022 ± 0.003 fg	0.019 ± 0.000 f	0.023 ± 0.001 i	0.023 ± 0.001 d
M. nigra 6	0.372 ± 0.002 ef	0.143 ± 0.003 g	0.024 ± 0.001 ef	0.026 ± 0.001 e	0.117 ± 0.005 b	0.018 ± 0.000 gh
M. nigra 7	0.407 ± 0.004 e	0.137 ± 0.002 h	0.024 ± 0.000 fg	0.031 ± 0.002 d	0.012 ± 0.001 j	0.016 ± 0.000 hi
M. nigra 8	0.606 ± 0.006 d	0.209 ± 0.001 d	0.012 ± 0.001 h	0.013 ± 0.000 g	0.016 ± 0.001 j	0.022 ± 0.002 def

Difference between means represented by a different letter in the same column is significant at 0.05 level.

compounds in mulberry fruits as chlorogenic acid (24.84–92.07 mg 100 g^{-1}), rutin (10.54–118.23 mg 100 g^{-1}), and gallic acid (12.85–36.85 mg 100 g^{-1}), respectively. They also reported protocatechuic acid, vanillic acid, ellagic acid, quercetin, catechin, caffeic acid, syringic acid, *p*-coumaric acid, *o*-coumaric acid, phloridzin, and ferulic acid to be present in some mulberry cultivars and genotypes grown in the Malatya region of Turkey. Okatan (2018) identified chlorogenic acid (43.20–97.59 mg 100 g^{-1}), rutin (32.06–133.60 mg 100 g^{-1}), and gallic acid (21.83–40.90 mg 100 g^{-1}) as the main components of phenolic compounds in mulberry fruits from the Aegean region in the western part of Turkey. It is thought that the differences between this study and the above studies are the result of differences in genetics, ecological conditions, and analysis techniques.

3.3. Organic acids

The genotypes exhibited statistically significant differences ($P < 0.05$) in terms of all individual organic acids (Table 5). Among the determined 6 organic acids, malic acid was found to be the dominant organic acid in mulberry fruits, followed by citric, succinic, and tartaric acids, respectively (Table 5). Malic acid varied from 2.484 to 8.546 g 100 g^{-1} and citric acid varied from 0.134 to 1.110 g 100 g^{-1} (Table 5). Fumaric acid was found to have the lowest content, which ranged from 0.005–0.083 g 100 g^{-1}. Corresponding with these results, previous studies conducted on mulberry fruits explained that malic acid had the highest values among organic acids (Koyuncu, 2004; Ercisli and Orhan, 2008; Gundogdu et al., 2011; Sanchez et al., 2014; Gecer et al., 2016). Sanchez et al. (2014) detected malic acid of 0.58–0.79 and 0.41–0.79 g 100 g^{-1} and citric acid of 0.04–0.18 and 0.14–0.66 g 100 g^{-1} in white and black mulberries in Spain. Gecer et al. (2016) observed that citric, tartaric, malic, succinic, and fumaric acid contents in white and black mulberry fruits collected from the eastern part of Turkey were 0.637–0.820 g 100 g^{-1}, 0.150–0.290 g 100 g^{-1}, 2.133–3.073 g 100 g^{-1}, 0.113–0.250 g 100 g^{-1}, and 0.106–0.120 g 100 g^{-1}, respectively. Gundogdu et al. (2017) also detected oxalic, citric, tartaric, malic, succinic, and fumaric acids in mulberry fruits from Turkey: 0.16–1.18 g 100 g^{-1}, 0.70–6.50 g 100 g^{-1}, 0.09–0.82 g 100 g^{-1}, 3.70–12.70 g 100 g^{-1}, 0.44–1.01 g 100 g^{-1}, and 0.01–0.21 g 100 g^{-1}, respectively. Oxalic acid, citric acid, tartaric acid, and malic acid contents detected by Okatan (2018) from mulberry fruits collected from the Aegean region had values of 0.45–1.25 g 100 g^{-1}, 2.00–7.02 g 100 g^{-1}, 0.22–0.86 g 100 g^{-1}, and 6.65–13.65 g 100 g^{-1}, respectively. All of the above results support our findings.

3.4. Vitamin C and antioxidant activity

Vitamin C contents in fruits of white and black mulberry genotypes were detected at between 2.45 and 35.83 mg 100 g^{-1} (Table 6). Ercisli and Orhan (2007) determined the average vitamin C content in white, red, and black mulberries sampled from eastern Turkey as 22.4, 19.4, and 21.8 mg 100 mL^{-1}, respectively. Ercisli and Orhan (2008) measured the vitamin C contents of black mulberry fruits belonging to a number of genotypes grown in the northeastern Anatolian region as between 14.9 and 18.8 mg 100 mL^{-1}. The vitamin C content in white mulberry fruits sampled in the Çoruh Valley, located in northeastern Turkey, was measured between 10.20 and 21.50 mg 100 g^{-1} (Gungor and Sengul, 2008).

Table 5. Organic acid contents (g 100 g^{-1}) in mulberry fruits.

	Malic	Citric	Succinic	Tartaric	Fumaric	Oxalic
M. alba 1	2.486 ± 0.003 l	0.154 ± 0.005 k	0.174 ± 0.002 h	0.074 ± 0.003 i	0.067 ± 0.002 b	0.024 ± 0.001 h
M. alba 2	3.284 ± 0.002 j	0.134 ± 0.006 l	0.167 ± 0.001 i	0.136 ± 0.002 e	0.054 ± 0.000 c	0.005 ± 0.000 i
M. alba 3	2.484 ± 0.002 l	0.210 ± 0.003 j	0.164 ± 0.002 i	0.097 ± 0.002 h	0.045 ± 0.001 d	0.022 ± 0.002h
M. alba 4	3.064 ± 0.003 k	0.241 ± 0.005 i	0.134 ± 0.003 j	0.134 ± 0.003 e	0.016 ± 0.000 f	0.036 ± 0.001 g
M. alba 5	3.364 ± 0.005 i	0.157 ± 0.003 k	0.306 ± 0.003 d	0.023 ± 0.001 k	0.010 ± 0.000 g	0.021 ± 0.001 h
M. nigra 1	4.216 ± 0.004 g	0.663 ± 0.002 h	0.267 ± 0.002 f	0.124 ± 0.002 f	0.016 ± 0.001 f	0.065 ± 0.001 e
M. nigra 2	3.594 ± 0.002 h	0.954 ± 0.004 c	0.124 ± 0.003 k	0.064 ± 0.003 j	0.017 ± 0.000 f	0.061 ± 0.002 e
M. nigra 3	6.194 ± 0.004 c	0.736 ± 0.005 f	0.445 ± 0.003 b	0.155 ± 0.003 c	0.025 ± 0.001 e	0.124 ± 0.002 c
M. nigra 4	8.546 ± 0.003 a	1.110 ± 0.005 a	0.775 ± 0.005 a	0.326 ± 0.004 a	0.005 ± 0.000 h	0.236 ± 0.002 a
M. nigra 5	7.328 ± 0.008 b	0.983 ± 0.002 b	0.284 ± 0.002 e	0.234 ± 0.002 b	0.047 ± 0.001 d	0.233 ± 0.003 a
M. nigra 6	6.164 ± 0.057 d	0.727 ± 0.001 g	0.054 ± 0.002 l	0.119 ± 0.003 f	0.023 ± 0.001 e	0.208 ± 0.005 b
M. nigra 7	4.624 ± 0.005 e	0.841 ± 0.005 d	0.362 ± 0.003 c	0.145 ± 0.002 d	0.047 ± 0.002 d	0.070 ± 0.004 d
M. nigra 8	4.341 ± 0.005 f	0.813 ± 0.001 e	0.209 ± 0.002 g	0.109 ± 0.002 g	0.083 ± 0.002 a	0.057 ± 0.002 f

Difference between means represented by a different letter in the same column is significant at 0.05 level.

Table 6. Vitamin C and TEAC in mulberry fruits.

	Vitamin C (mg 100 g^{-1})	TEAC (μmol TE g^{-1})
M. alba 1	4.41 ± 0.012 l	5.43 ± 0.004 j
M. alba 2	4.47 ± 0.025 k	4.33 ± 0.004 l
M. alba 3	2.45 ± 0.038 m	6.12 ± 0.003 i
M. alba 4	4.93 ± 0.025 j	4.33 ± 0.001 l
M. alba 5	6.56 ± 0.025 i	5.13 ± 0.008 k
M. nigra 1	11.20 ± 0.025 h	7.56 ± 0.007 h
M. nigra 2	18.88 ± 0.025 e	9.14 ± 0.006 g
M. nigra 3	27.07 ± 0.038 c	11.13 ± 0.004 d
M. nigra 4	35.83 ± 0.025 a	12.17 ± 0.005 c
M. nigra 5	35.45 ± 0.025 b	13.63 ± 0.002 a
M. nigra 6	25.44 ± 0.025 d	11.01 ± 0.005 e
M. nigra 7	11.88 ± 0.025 g	12.24 ± 0.004 b
M. nigra 8	13.83 ± 0.025 f	10.16 ± 0.005 f

Difference between means represented by a different letter in the same column is significant at 0.05 level.

Imran et al. (2010) determined the vitamin C content in white and black mulberry genotypes sampled from Pakistan as 15.20 and 15.37 mg 100 g^{-1}, respectively. Gecer et al. (2016) measured vitamin C content in black and white mulberries between 12.73 and 16.42 mg 100 g^{-1}, respectively. Gundogdu et al. (2017) reported the vitamin C content in some mulberry cultivars and genotypes grown in Malatya as between 18.15 and 31.34 mg 100 g^{-1}. In addition, vitamin C content in black mulberry fruits from the Aegean region was identified as between 19.73 and 31.24 mg 100 g^{-1} (Okatan, 2018). These results are also in agreement with the above findings.

Results for antioxidant activity are shown in Table 6; statistically significant differences ($P < 0.05$) emerged among both white and black mulberry genotypes in terms of antioxidant activity. Overall, black mulberry genotypes exhibited higher antioxidant activity (7.56–13.63 μmol TE g^{-1}) compared to white mulberries (4.33–6.12 μmol TE g^{-1}) (Table 6). Parallel to antioxidant activity, black mulberry fruits had higher vitamin C content (11.20–35.83 mg 100 g^{-1}) than white mulberries (2.45–6.56 mg 100 g^{-1}) (Table 6). Ozgen et al. (2009) found antioxidant capacity between 6.8 and 14.4 μmol TE g^{-1} in mulberry fruits. Previously, antioxidant activity in *Morus nigra* L. genotypes was determined as between 15.037 and 24.443 μmol TE g^{-1} (Özkaya, 2015). Gecer et al. (2016) identified higher antioxidant capacity in black mulberries (9.17 μmol TE g^{-1}) and lower in white mulberries (6.17 μmol TE g^{-1}). Gundogdu et al. (2017) measured antioxidant capacity of 6.17–21.13 μmol TE g^{-1} in a number of mulberry genotypes.

In conclusion, in this study, some morphological and biochemical characteristics of 5 white and 8 black mulberry genotypes grown in the Varto district (Muş Province) have been analyzed. To the best of our knowledge, there is very limited research on this subject. The results indicate the

importance of diversity in both white and black mulberry genotypes, not only for human nutrition, but also to use their genetic resources in future breeding activities. It is thought that these genetic resources grown endogenously in many regions of our country are important for the development of new mulberry cultivars and for the benefit of new scientific studies.

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