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Determination of Fruit Quality Characteristics of Blackberry Genotypes Growing Naturally in Düzce (Türkiye)

Düzce'De (Türkiye) Doğal Olarak Yetişen Böğürtlen Genotiplerinin Meyve Kalite Özelliklerinin Belirlenmesi

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DETERMINATION OF FRUIT QUALITY CHARACTERISTICS OF BLACKBERRY GENOTYPES GROWING NATURALLY IN DÜZCE (TÜRKİYE)

ABSTRACT

In this study, the morphological, physicochemical and biochemical properties of the fruit of the blackberry (*Rubus* spp.) genotypes grown naturally in the village of Dağdibi, Kaynaşlı district of Düzce province were determined. Fruit weights of the genotypes ranged from 1.77 g (81KYN10) to 0.80 g (81KYN2). Fruit width ranged from 13.55 mm (81KYN10) to 9.05 mm (81KYN2). Fruit length was determined between 14.26 mm (81KYN10) and 11.09 mm (81KYN2). In terms of the highest rate of amount of soluble solids content (SSC) in the study, 81KYN1 (16.70%), 81KYN3 (15.65%), 81KYN4 (15.40%), and 81KYN5 (16.20%) genotypes were more important. In terms of the highest titratable acidity (TA) value, 81KYN7 (0.52%) and 81KYN13 (0.51%) genotypes were more dominant. The highest L*, a*, b*, chroma and Hue° angle values in color value parameters were found as 13.88 (81KYN7), 1.34 (81KYN4), 1.12 (81KYN4), 1.77 (81KYN4) and 40.63 (81KYN1), respectively. In terms of biochemical content, the highest total phenolic amounts were detected in 81KYN2 (45.77 mg GAE/g), 81KYN6 (47.55 mg GAE/g), 81KYN7 (52.16 mg GAE/g) and 81KYN13 (46.31 mg GAE/g) genotypes, the highest total antioxidant capacities were seen in 81KYN1 (29.30%) and 81KYN2 (30.57%) genotypes. Additionally, the highest total protein amounts was determined in 81KYN1 (20.48 g/L), 81KYN3 (20.60 g/L) and 81KYN5 (20.87 g/L) genotypes. As a result of the study, it was concluded that the genotypes that stand out in terms of morphological, physicochemical and biochemical characteristics can be evaluated in functional blackberry production.

Keywords: Blackberry, DPPH, Physicochemical, Protein, TPC.

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DÜZCE'DE (TÜRKİYE) DOĞAL OLARAK YETİŞEN BÖĞÜRTLEN GENOTİPLERİNİN MEYVE KALİTE ÖZELLİKLERİNİN BELİRLENMESİ

ÖZ

Bu çalışmada, Türkiye'de Düzce ili Kaynaşlı ilçesi Dağdibi köyünde doğal olarak yetişen böğürtlen (*Rubus* spp.) genotiplerine ait meyvelerin morfolojik, fizikokimyasal ve biyokimyasal özellikleri belirlenmiştir. Genotiplerin meyve ağırlıkları, 1.77 g (81KYN10) ile 0.80 g (81KYN2) arasında değişmiştir. Meyve eni, 13.55 mm

(81KYN10) ile 9.05 mm (81KYN2) arasında değişmiştir. Meyve boyu ise 14.26 mm (81KYN10) ve 11.09 mm (81KYN2) arasında değişmiştir. Çalışmada, en yüksek suda çözünebilir katı madde miktarı (SÇKM) oranı açısından 81KYN1 (% 16.70), 81KYN3 (% 15.65), 81KYN4 (% 15.40) ve 81KYN5 (% 16.20) genotipleri, en yüksek titre edilebilir asitlik (TA) değeri açısından ise 81KYN7 (% 0.52) ve 81KYN13 (% 0.51) genotipleri daha baskın olmuştur. Renk değeri parametrelerinde ise en yüksek L*, a*, b*, kroma ve Hue° açısı değerleri, sırasıyla, 13.88 (81KYN7), 1.34 (81KYN4), 1.12 (81KYN4), 1.77 (81KYN4) ve 40.63 (81KYN1) olarak bulunmuştur. Biyokimyasal içerik açısından, en yüksek toplam fenolik miktarları 81KYN2 (45.77 mg GAE/g), 81KYN6 (47.55 mg GAE/g), 81KYN7 (52.16 mg GAE/g) ve 81KYN13 (46.31 mg GAE/g) genotiplerinde tespit edilirken, en yüksek toplam antioksidan miktarları 81KYN1 (29.30%) ve 81KYN2 (30.57%) genotiplerinde görülmüştür. Ayrıca, en yüksek toplam protein miktarları ise 81KYN1 (20.48 g/L), 81KYN3 (20.60 g/L) ve 81KYN5 (20.87 g/L) genotiplerinde belirlenmiştir. Çalışmada sonuç olarak, morfolojik, fizikokimyasal ve biyokimyasal özellikler açısından öne çıkan genotiplerin fonksiyonel böğürtlen üretiminde ıslah materyali olarak değerlendirilebileceği kanaatine varılmıştır.

Anahtar Kelimeler: Böğürtlen, DPPH, Fizikokimyasal, Protein, TPC.

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1. INTRODUCTION

Blackberry, taxonomically located in the *Rosales* order of the *Rosaceae* family, is a fruit belonging to the *Rubus* spp. genus (Ağaoğlu, 1986). Blackberry, which has a very low ecological selectivity in the environment where it grows, can easily adapt to cold and harsh climatic conditions with this advantageous feature (Orzeł et al., 2016; Gruner, 2019). With the breeding studies carried out in blackberry, which has gone through a very long historical process in terms of cultivation throughout the world, today very productive varieties and genotypes have emerged (Clark and Finn, 2011; Clark et al., 2012; Finn and Clark, 2012; Gündeşli et al., 2019). In addition to the high productivity of varieties and genotypes, many advantages of blackberry such as high resistance to various diseases and pests that may arise make the cultivation of this fruit even more attractive (Takeda et al., 2013; Demir and Aktaş, 2018; Gruner, 2019). Blackberries, which are mostly consumed fresh, are widely used in fruit juice, jam, marmalade, canning, pastry and ice cream industries in addition to the cosmetics industry in today (Di Palma, 2011). Fruit of blackberry, which can reach from small sizes to certain sizes, have a pleasant taste and smell, and a delicate aroma. The fruiting time of blackberries is usually between May and August. Bloom time in blackberry, which prefers medium heavy (sandy-clayy), rich in organic matter, high water holding capacity and well-drained environments as soil demand, usually starts in May and continues until August.

The sizes of blackberry flowers vary between 10 mm and 15 mm. The leaves are small and irregularly distributed on the shoots. The edges of the leaves are serrated and green. It usually has a sharp tip and an elliptical shap. The upper side of the leaves is hairless, and the bottom is covered with lighter colored and white hairs. The height of blackberry fruit trees growing in the form of ivy can reach approximately 3 meters (Gündeşli et al., 2019). According to 2022 production data, a total of 3100 tons of blackberry production was been produced in Türkiye. Mersin, Bursa, Kahramanmaraş and Samsun provinces are leading in blackberry cultivation in the country (FAO, 2022). Blackberry, which is rich in flavonoids, carotenoids, sugars, organic acids, minerals, phosphorus, calcium, magnesium, iron, vitamin C and antioxidants, is one of the fruit groups that have an important role in improving and protecting human health (Sarkar et al., 2016; Lee, 2017; De Gomes et al., 2019). Consumption of blackberry, which has many benefits in terms of healthy and balanced nutrition in humans, is frequently recommended by dietitians and health professionals (Kolbas et al., 2012). Blackberries, which balance blood sugar in humans, are also rich in fatty acids such as omega 3 and omega 6. In addition, blackberry, which contains many beneficial properties such as restoring the nervous system in humans, protecting against depression and enhancing memory, is one of the most preferred fruits with these advantages (Özdal et al., 2016; Selma et al., 2017). This study was carried out to determine the fruit morphological, physicochemical and biochemical properties in some blackberry genotypes. As a result of the analysis, statistical distributions and definitions of blackberry genotypes were carried out morphologically and biochemically.

2. MATERIAL AND METHOD

2.1. Fruit Material

In this study, naturally grown blackberry genotypes were determined in Dağdibi village of Kaynaşlı district of Düzce province. Fruit samples taken from blackberry genotypes were placed in appropriate containers, labeled and brought to the laboratory. After the agro-morphological properties of these fruit samples were determined, the samples were stored at -20°C until analysis to determine some bioactive properties. Morphological-physicochemical analyzes were performed in Bolu Abant İzzet Baysal University, Faculty of Agriculture Laboratory.

2.2. Determination of Agro-Morphological Characteristics of Fruit

Fruit Weight (g): It was determined by randomly taking 20 fruit from each genotype and weighing them separately on a sensitive balance sensitive to 0.01 g. After taking the arithmetic average of the values obtained in the fruit, the fruit weight (g) values of the genotypes were determined separately (Kalyoncu, 1996).

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Fruit Width and Length (mm): It was found by measuring 10 fruit samples taken randomly from each genotype with a caliper sensitive to 0.01 mm (Kalyoncu, 1996).

Leaf width and length (mm): It was found by measuring 10 leaf samples taken randomly from each genotype with a 0.01 mm sensitive caliper (Karadeniz et al., 1996).

Middle Leaf Length (mm): After determining the middle part of the leaves, the arithmetic average of the values obtained was taken and the middle leaf length values of the genotypes were determined separately as 'mm' value (Karadeniz et al., 1996).

Petiole Length (mm): It was measured as the part between petiole and fruit tip. After taking the arithmetic average of the values obtained on the leaf, the petiole length values of the genotypes were determined separately as 'mm' value (Karadeniz et al., 1996).

The Amount of Soluble Solids Content (SSC) (%): It was determined as % value by hand refractometer (Atago PAL-1, Washington, USA) (Eşitken, 1992).

Fruit Juice pH: In order to determine the pH of the fruit (Thermo, OrionStar A111, USA), a homogeneous juice mixture was obtained by squeezing the juice of 20 randomly selected fruit. Measurements were performed when the temperature of the juice was at room temperature. About 10 mL of the juice mixture was taken into a 50 mL beaker and the electrode of the pH meter was immersed in the juice mixture. After waiting until the value stabilized, the value read was recorded as the pH value (Eşitken, 1992).

Titratable Acidity Value (TA) (%): In order to determine the titratable acidity (TA) content of the fruit examined in terms of TA in fruit juice, 20 fruit from each genotype were squeezed in cheesecloth and their juices were extracted. About 10 mL of the fruit juice obtained in this way was diluted to 50 mL with distilled water. The diluted samples were titrated with 0.1 N NaOH to pH 8.1. The TA acid value in terms of malic acid according to the amount of spent NaOH was calculated according to the formula below (Karacali, 2002; Tas et al., 2023).

$$\mathrm{TA} = \frac{\text{NAOH spent (ml) x 0.1 x 0.067 (malic acid) x 100}}{\text{amount of juice used (ml)}}$$

Fruit Skin Color: It was measured in terms of L*, a*, b*, chroma and Hue° angle values with a Konica Minolta CR-400 brand colorimeter. L* is the brightness value, 0 indicates black and 100 indicates white. Accordingly, a* shows red, -a* shows green, b* shows yellow and -b* shows blue. Chroma value expresses the intensity (saturation) of the fruit skin color. The Hue° angle value indicates what the color of the fruit skin is. If Hue° angle is 0, the color is red, if 90 is yellow, if 180 is green, if 360 is blue. Hue° angle is the distance from the vertical axis of the point in the color space. It indicates the intensity of the color. In blackberry, color values were calculated for each fruit with three mutual measurements taken from the equator region of the fruit (Ertekin et al., 2006).

2.3. Determination of Biochemical Properties of Fruit

Determination of total phenolic and DPPH scavenging activity: To determine the total phenolic content (mg GAE/g), the microscale procedure reported by Waterhouse (2002) was used, with modifications. Briefly, 1600 µL of distilled water and 50 µL of Folin–Ciocâlteu agent were added to 50 µL of methanolic extract and mixed gently. Then, 300 µL of 7% (*w*/*v*) calcium carbonate solution was added and vortexed. After the mixture was left in the dark at room conditions for 2 h, its absorbance at 760 nm was read, using a UV–Vis spectrophotometer (SP-UV1100, DLAB, Beijing, China). The obtained absorbance values were converted to real content through the calculation of the equation obtained with the standard curve (R^2 = 0.99) prepared using 0.5, 1, 2, 3, 4, 5, and 6 mM gallic acid with the same procedure.

The 2,2 Diphenyl 1 picrylhydrazyl obtained from Sigma-Aldrich (Darmstadt, Germany) was prepared in ethanol, with a final absorbance within the range of 0.7–0.8, to measure the DPPH scavenging activity. Then, the activity was measured using the following procedure. The most appropriate methanolic extract amount was determined through preliminary trials, with a final volume of 2 mL; 50 µL sample, 1450 µL ethanol, and 500 µL of DPPH solution were added sequentially and vortexed. The prepared solution was measured at a 520 nm wavelength using a UV–Vis spectrophotometer after 15 min, and the DPPH scavenging capacity was calculated using the following formula (Güler ve ark., 2023).

$$\text{DPPH (\%)} = (A_{blank} - As_{ample})/A_{blank}.$$

Determination of total protein amount: The plant samples, which were previously prepared and stored at +4°C, were diluted 10 times to measure their absorbance in the spectrophotometer. The diluted samples were read in triplicate against the blank cuvette at 595 nm with the Bradford Coomassie Blue stain. Obtained absorbance values were recorded and averaged, and protein concentrations were calculated for each sample using the standard curve (Bradford, 1976).

2.4. Statistical Analysis

Student's t (LSD) test was used in the analysis of agro-morphological and biochemical data. Experiments were carried out according to the randomized plot design with 3 replications and 15 plants in each replication. SAS Version 9.1 (SAS Institute Inc., Cary, NC, USA) software was used to evaluate the data (Gentleman et al., 2004).

3. RESULTS AND DISCUSSION

3.1. Agro-Morphological Properties of Fruit

Türkiye has a very rich range of fruit species due to its geographical location. Blackberry fruit is one of the fruits that stand out with the important useful phytochemicals it contains. In this study, fruit samples of selected blackberry genotypes were taken and necessary measurements and analyzes were made to determine the morphological and physicochemical characteristics of the fruit. In the study, statistically significant differences were found between genotypes in terms of fruit weight ($p \leq 0.001$). When genotypes were examined, the highest fruit weight (1.77 g) was found in 81KYN10 genotype, and the lowest fruit weight (0.80 g) was determined in 81KYN2 genotype. 81KYN10 (1.77 g), 81KYN8 (1.68 g), 81KYN6 (1.31 g), and 81KYN9 (1.31 g) genotypes stand out with high fruit weight, respectively (Table 1). Mikulic-Petkovsek et al. (2021) determined the highest fruit weight as 10.08 g and the lowest fruit weight as 5.95 g in blackberry fruit of the variety named 'Cacanska Bestrna'. Yilmaz et al. (2009) determined the maximum fruit weight of 5.4 g in blackberry fruit named 'Bursa 1'. Connor et al. (2005) observed the highest fruit weight of 10.10 g in blackberry fruit named 'Black Butte'. Makus (2011) stated that the highest fruit weight in blackberry fruit named 'Dewitt (black)' was 9.22 g. Duan et al. (2023) determined the highest fruit weight as 9.31 g and the lowest fruit weight as 7.57 g in the blackberry fruit they studied. Meyers et al. (2017) examined the maximum fruit weight of 3.6 g in blackberry fruit of the 'Navaho' variety. Garazhian et al. (2020) reported the highest fruit weight as 1.30 g in blackberry fruit with the 'Sepidan (Roodbal)' variety in Iran. Huang et al. (2022) recorded the highest fruit weight as 6.84 g in blackberry fruit of the 'Chester' variety. Milosevic et al. (2012) reported the highest fruit weight as 7.61 g in blackberry fruit with varieties named 'Čačanska Bestrna' and 'Loch Ness'. Memete et al. (2023) reported the highest fruit weight as 9.11 g in blackberry fruit with 'THRNFR' variety. When the results of the above literature study related to fruit weight in blackberry were evaluated together with the results of this study, it was seen that significantly higher fruit weights were examined in the literature studies. The reason for this difference between this study and literature studies is related to factors such as differences in genotype and varieties.

Table 1. Fruit weight, fruit width, fruit length, leaf length and leaf width values from morphological characteristics of blackberry genotypes

Genotypes	Fruit Weight (g)	Fruit Width (mm)	Fruit Length (mm)	Leaf Length (mm)	Leaf Width (mm)
81KYN1	0.92 ± 0.08 a*	9.76 ± 0.49 a	11.29 ± 0.42 a	9.15 ± 0.05 a	7.30 ± 0.20 a
81KYN2	0.80 ± 0.03 c	9.05 ± 0.19 abc	11.09 ± 0.12 cd	10.05 ± 0.25 bc	7.40 ± 0.20 bc
81KYN3	1.04 ± 0.06 d	10.02 ± 0.31 bcd	12.08 ± 0.28 cd	10.90 ± 0.10 bc	9.55 ± 0.35 bc
81KYN4	1.06 ± 0.08 d	10.25 ± 0.39 cde	11.84 ± 0.21 cd	9.70 ± 0.10 bc	7.25 ± 0.25 bc
81KYN5	1.22 ± 0.04 de	10.84 ± 0.28 de	12.46 ± 0.26 d	11.40 ± 0.20 c	9.10 ± 1.00 bc
81KYN6	1.31 ± 0.09 ef	11.45 ± 0.40 de	12.45 ± 0.34 e	14.20 ± 0.10 c	11.95 ± 0.35 bc
81KYN7	1.18 ± 0.06 f	11.01 ± 0.35 ef	12.19 ± 0.25 f	15.60 ± 0.50 c	12.15 ± 0.85 c
81KYN8	1.68 ± 0.12 f	12.21 ± 0.30 fg	13.29 ± 0.27 f	14.50 ± 0.40 c	12.60 ± 0.10 c
81KYN9	1.31 ± 0.04 g	12.19 ± 0.22 g	12.74 ± 0.14 g	12.60 ± 0.60 c	9.60 ± 0.00 c
81KYN10	1.77 ± 0.21 a	13.55 ± 0.40 ab	14.26 ± 0.51 ab	14.30 ± 0.90 ab	11.80 ± 1.40 ab
81KYN11	1.21 ± 0.10 ab	11.75 ± 0.31 ab	12.39 ± 0.19 bc	7.25 ± 0.15 bc	6.45 ± 0.05 bc
81KYN12	1.24 ± 0.11 ab	11.56 ± 0.49 ab	11.94 ± 0.23 cd	14.50 ± 0.40 bc	12.70 ± 0.00 bc
81KYN13	1.08 ± 0.05 b	10.96 ± 0.23 ab	12.06 ± 0.15 cd	13.65 ± 0.05 bc	11.70 ± 0.10 bc

*: The difference between the means indicated by the same letter in the same column is insignificant ($P < 0.05$).

Differences between genotypes in terms of fruit width and fruit length were found to be statistically significant ($p \leq 0.001$). When genotypes were examined, the highest fruit width (13.55 mm) was determined in 81KYN10 genotype, and the lowest fruit width (9.05 mm) was determined in 81KYN2 genotype. 81KYN10 (13.55 mm), 81KYN8 (12.21 mm), 81KYN9 (12.19 mm) genotypes stand out with high fruit width, respectively. When genotypes were examined, the highest fruit length (14.26 mm) was found in 81KYN10 genotype, and the lowest fruit length (11.09 mm) was determined in 81KYN2 genotype. 81KYN10 (14.26 mm), 81KYN8 (13.29 mm), 81KYN9 (12.74 mm) genotypes stand out with high fruit length, respectively (Table 1). Yilmaz et al. (2009) reported the highest fruit width value as 19.8 mm in blackberry variety named 'Chester'. The same researchers determined the maximum fruit length value of 26.4 mm in fruit of another blackberry variety named 'Bursa 1'. Duan et al. (2023) reported the maximum fruit width value as 25.59 mm and the maximum fruit length value as 31.41 mm in the blackberry fruit they studied. Huang et al. (2022) stated the maximum fruit width value as 23.22 mm and the maximum fruit length value as 27.35 mm in blackberry fruit of 'Chester' variety. Memete et al. (2023) reported the maximum fruit width value as 7.20 mm and the maximum fruit length value as 2.77 mm in blackberry fruit with 'THRNFR' variety. According to the data of this study related to fruit width and length, the data of the above sample literature studies were significantly higher. It is thought that this difference between studies may be caused by genotype/variety. Differences between genotypes in terms of leaf width and leaf length were found to be statistically significant (p≤0.001). The highest leaf length (15.60 mm) was found in 81KYN7 genotype, while the lowest leaf length (7.25 mm) was determined in 81KYN11 genotype. 81KYN7 (15.60 mm), 81KYN8 (14.50 mm), and 81KYN12 (14.50 mm), 81KYN10 (14.30 mm) genotypes were in the foreground, respectively. The highest leaf width (12.70 mm) was detected in 81KYN12 genotype, while the lowest leaf width (6.45 mm) in 81KYN11 genotype. 81KYN12 (12.70 mm), 81KYN8 (12.60 mm), 81KYN7 (12.15 mm) genotypes are dominant with high leaf width, respectively (Table 1).

The differences between genotypes in terms of middle leaf length were found to be statistically significant (p≤0.001). The highest middle leaf length (7.65 mm) was found in 81KYN7 genotype, while the lowest middle leaf length (3.50 mm) was determined in 81KYN11 genotype. The 81KYN7 (7.65 mm), 81KYN10 (7.55 mm), 81KYN8 (7.25 mm), 81KYN12 (7.20 mm) genotypes were in the foreground, respectively (Table 2).

Table 2. Middle leaf length, petiole length, soluble solids content (SSC), pH and titratable acidity (TA) values from morphological and physicochemical characteristics of blackberry genotypes

Genotypes	Middle Leaf Length (mm)	Petiole Length (mm)	SSC (%)	pH	TA (%)
81KYN1	4.35 ± 0.15 a*	3.10 ± 0.40 a	16.70 ± 0.40 a	3.88 ± 0.00 a	0.44 ± 0.37 a
81KYN2	4.55 ± 0.05 de	4.15 ± 0.05 abc	15.15 ± 0.05 bcd	3.85 ± 0.01 cde	0.38 ± 0.04 ab
81KYN3	4.95 ± 0.15 def	4.50 ± 0.40 abc	15.65 ± 0.25 cd	3.90 ± 0.02 def	0.41 ± 0.17 bc
81KYN4	4.25 ± 0.05 efg	3.80 ± 0.10 bcd	15.40 ± 0.10 cd	3.88 ± 0.00 def	0.41 ± 0.04 bc
81KYN5	5.05 ± 0.15 efg	4.35 ± 0.15 cd	16.20 ± 0.20 cd	4.57 ± 0.02 ef	0.19 ± 0.04 bc
81KYN6	6.90 ± 0.10 efg	5.50 ± 0.10 cd	15.10 ± 0.10 cd	3.95 ± 0.01 f	0.3 ± 0.25 bc
81KYN7	7.65 ± 0.45 fg	5.65 ± 0.05 cd	11.80 ± 0.20 cd	3.51 ± 0.02 f	0.52 ± 0.77 bc
81KYN8	7.25 ± 0.05 g	5.25 ± 0.25 d	15.30 ± 0.10 cd	4.24 ± 0.02 f	0.30 ± 0.67 bc
81KYN9	5.30 ± 0.10 h	5.30 ± 0.40 d	15.00 ± 0.10 d	4.07 ± 0.03 g	0.32 ± 0.42 c
81KYN10	7.55 ± 0.05 b	4.80 ± 0.30 ab	13.80 ± 0.10 a	3.91 ± 0.01 ab	0.32 ± 0.02 ab
81KYN11	3.50 ± 0.20 b	2.75 ± 0.05 ab	12.55 ± 0.25 ab	3.88 ± 0.03 bc	0.35 ± 0.17 ab
81KYN12	7.20 ± 0.00 c	5.25 ± 0.25 abc	15.30 ± 0.10 bc	4.24 ± 0.02 cd	0.30 ± 0.67 ab
81KYN13	6.10 ± 0.00 d	5.10 ± 0.00 abc	12.95 ± 0.05 bcd	3.82 ± 0.02 cd	0.51 ± 0.38 ab

*: The difference between the means indicated by the same letter in the same column is insignificant (P < 0.05).

The differences between genotypes in terms of petiole length were found to be statistically significant (p≤0.001). The highest petiole length (5.65 mm) was found in 81KYN7 genotype, while the lowest petiole length (2.75 mm) was determined in 81KYN11 genotype. The 81KYN7 (5.65 mm), 81KYN6 (5.50 mm), 81KYN9 (5.30 mm), 81KYN8 (5.25 mm), and 81KYN12 (5.25 mm) genotypes were in the foreground, respectively (Table 2). No sample studies have been found in the literature regarding leaf width, leaf length, middle leaf length and petiole length, and it is thought that the data obtained in this study regarding these parameters may be useful for various researches.

When the data were evaluated in terms of SSC rate, the differences between genotypes were found to be statistically significant (p≤0.001). The highest rate of SSC (16.70%) was found in the 81KYN1 genotype, while the lowest rate of SSC (11.80%) was found in the 81KYN7 genotype. The 81KYN1 (16.70%), 81KYN5 (16.20%), 81KYN3 (15.65%), 81KYN4 (15.40%) genotypes were in the foreground in terms of high SSC, respectively (Table 2). Yilmaz et al. (2009) determined the highest SSC rate of 14.1% in blackberry fruit named 'Navaho'. Makus (2011) stated that the highest SSC rate in blackberry fruit named 'White Plastic' was 11.5%. Duan et al. (2023) reported the highest SSC rate of 10.43% in the blackberry fruit they studied. Meyers et al. (2017) examined the highest SSC rate of 15.1% in blackberry fruit with the 'Navaho' variety. Milosevic et al. (2012) recorded the highest SSC rate of 13.50% in blackberry fruit with the 'Navaho' variety. The results of the above-mentioned literature regarding SSC and the results of the SSC obtained in this study were similar to each other.

When the data were analyzed in terms of fruit juice pH, statistically significant differences were found between the pH amounts of fruit juices belonging to blackberry genotypes (p≤0.001). Among the genotypes, the highest pH value (4.57) was found in the 81KYN5 genotype. In addition, pH values observed in all genotypes in the study were found to be close to each other (between 3.51 and 4.57) (Table 2). Mikulic-Petkovsek et al. (2021) determined the highest fruit pH as 3.08 and the lowest fruit pH as 2.71 in blackberry fruit of named 'Cacanska Bestrna'. Yilmaz et al. (2009) found the highest pH value of 3.6 in the blackberry fruit with named 'Bursa 3'. Makus (2011) stated the highest pH value of 3.43 in blackberry fruit with named 'White Plastic'. Milosevic et al. (2012) recorded the highest pH value as 3.12 in blackberry fruit with 'Dirksen Thornless' variety. Memete et al. (2023) reported the highest pH value as 4.066 in blackberry fruit with 'OCHIT' variety. In terms of pH value, the results of the sample literature study given above and the pH value results in this study showed parallelism with each other.

When TA values of fruit juices belonging to genotypes of blackberry were examined, statistically significant differences were found (p≤0.001). Among the genotypes, 81KYN7 genotype has the highest TA value (0.52%). This genotype was

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followed by the 81KYN13 genotype with a TA value of 0.51%. The lowest TA value (0.19%) was recorded in the 81KYN5 genotype (Table 2). Yilmaz et al. (2009) determined the highest TA value in fruit of the blackberry variety named 'Bursa 2' as 1.4%. Makus (2011) stated the highest TA value as 1.29% in fruit of two blackberry varieties named 'None' and 'Dewitt'. Duan et al. (2023) reported the highest TA value as 1.91% in blackberry fruit they studied. Garazhian et al. (2020) investigated the highest TA value of 0.83% in blackberry fruit of the 'Namak Abrud 2' variety in Iran. Milosevic et al. (2012) recorded the highest TA value of 2.36% in blackberry fruit with 'Chester Thornless' variety. When the above sample literature results determined in terms of TA values in blackberry fruit were compared with the results of this study, it was seen that the studies were parallel to each other.

When the data were examined in terms of fruit skin color, statistically significant differences were found in terms of L* value ($p \leq 0.001$). According to the measurements, the lightest fruit color among the genotypes was detected in the 81KYN7 genotype with a L* value of 13.88. This genotype was followed by 81KYN6 (13.67) and 81KYN5 (13.20) genotypes, respectively. The 81KYN9 genotype had the darkest fruit color with an L* value of 11.73 (Table 3). Differences in a* values in color measurements of blackberry genotypes were found to be statistically significant ($p \leq 0.05$). According to fruit color measurements, +a value indicates red color, -a value indicates green color. Among blackberry genotypes, 81KYN4 genotype had the highest a* value with 1.34, while this genotype was followed by 81KYN3 genotype with 1.04 a* value. In addition, the 81KYN5 genotype had the lowest a* value of 0.54 (Table 3). Differences in b* value in color measurements of blackberry genotypes were found to be statistically significant ($p \leq 0.05$). While determining the fruit color, the +b value indicates that the color is yellow in the fruits and the –b value indicates that the color is blue. In the measurement of the samples taken, the 81KYN4 genotype with 1.12 had the highest b* value, while the 81KYN6 genotype with 0.24 had the lowest b* value. 81KYN4 genotype was followed by 81KYN1 genotype with a b* value of 0.85 (Table 3). Chroma refers to the intensity (saturation) of the color. Differences in chroma values of blackberry genotypes in color value measurements were found to be statistically significant ($p \leq 0.05$). In color measurements, 81KYN4 genotype has the highest (1.77) chroma value, while 81KYN5 genotype has the lowest (0.67) chroma value. The 81KYN4 genotype was followed by the 81KYN1 genotype with a chroma value of 1.29 (Table 3). The hue° angle value, which indicates the intensity of the color, is the distance from the vertical axis of the point in the color space. Differences of blackberry genotypes in terms of hue° angle value in color measurements were found to be statistically significant ($p \leq 0.01$). In the color measurements of the samples, the highest hue° angle value (40.63) was determined in 81KYN1 genotype, and the lowest hue° angle value (20.03) was determined in 81KYN6 genotype. 81KYN1 genotype was followed by 81KYN5 (36.27) and 81KYN4 (36.16) genotypes, respectively (Table 3). Duan et al. (2023) reported the highest L* value as 17.72 in the blackberry fruit they studied. Escuredo et al. (2019) stated the highest L* value in blackberry fruit as 73.46. When the results of the literature were compared with the results of this study in terms of color parameters, it was seen that other data showed parallelism with each other, except for the L* and b* values determined by Escuredo et al. (2019). On the other hand, it is thought that this partial difference in studies may be caused by genotype.

Table 3. Fruit color values of blackberry genotypes

Genotypes	L*	a*	b*	Chroma	Hue°
81KYN1	12.31 ± 0.31 a*	0.98 ± 0.03 a	0.85 ± 0.08 a	1.29 ± 0.07 a	40.63 ± 2.05 a
81KYN2	11.77 ± 0.36 bc	0.98 ± 0.10 bc	0.54 ± 0.06 cd	1.15 ± 0.10 bc	25.67 ± 2.12 a
81KYN3	12.03 ± 0.07 c	1.04 ± 0.15 bc	0.57 ± 0.15 cd	1.19 ± 0.20 cd	26.50 ± 3.51 b
81KYN4	12.30 ± 0.27 d	1.34 ± 0.25 bcd	1.12 ± 0.40 cd	1.77 ± 0.43 cde	36.16 ± 7.05 b
81KYN5	13.20 ± 0.45 de	0.54 ± 0.02 bcd	0.39 ± 0.02 cde	0.67 ± 0.01 cde	36.27 ± 2.95 bc
81KYN6	13.67 ± 0.33 ef	0.65 ± 0.04 bcd	0.24 ± 0.05 de	0.70 ± 0.03 def	20.03 ± 4.19 cd
81KYN7	13.88 ± 0.16 f	0.84 ± 0.30 cde	0.42 ± 0.14 def	0.93 ± 0.33 efg	27.02 ± 0.97 d
81KYN8	12.34 ± 0.22 f	0.98 ± 0.08 de	0.64 ± 0.02 ef	1.18 ± 0.07 fg	32.56 ± 1.07 d
81KYN9	11.73 ± 0.23 g	0.80 ± 0.12 e	0.51 ± 0.07 f	0.95 ± 0.13 g	32.54 ± 2.14 d
81KYN10	12.51 ± 0.35 ab	0.76 ± 0.15 a	0.57 ± 0.17 b	0.96 ± 0.22 b	34.46 ± 1.67 a
81KYN11	12.52 ± 0.11 ab	0.69 ± 0.04 b	0.29 ± 0.04 bc	0.75 ± 0.04 b	22.89 ± 3.03 a
81KYN12	12.34 ± 0.22 b	0.98 ± 0.08 b	0.64 ± 0.02 cd	1.18 ± 0.07 bc	32.56 ± 1.07 a
81KYN13	12.51 ± 0.16 b	0.75 ± 0.07 bc	0.38 ± 0.04 cd	0.84 ± 0.07 bc	27.49 ± 2.84 a

*: The difference between the means indicated by the same letter in the same column is insignificant ($P < 0.05$).

3.2. Total Phenolic, Total Antioxidant and Total Protein

Table 4 shows the total phenolic, total antioxidant and total protein amounts of blackberry genotypes. There were statistically significant differences at $p \leq 0.001$ level between genotypes in terms of parameters. The highest total phenolic content (52.16 mg GAE/g) was found in 81KYN7 genotype, while the lowest total phenolic content (34.70 mg GAE/g) was found in 81KYN1 genotype. The 81KYN7 (52.16 mg GAE/g), 81KYN6 (47.55 mg GAE/g), 81KYN13 (46.31 mg GAE/g), 81KYN2 (45.77 mg GAE/g) genotypes stand out in terms of high phenolic content, respectively (Table 4).

Paczkowska-Walendowska et al. (2021) reported the highest total phenolic content as 71.29 mg GAE/g in blackberry fruit of the variety named 'Loch Tay'. Garazhian et al. (2020) determined the highest total phenolic content as 129.3 in blackberry fruit with 'Jade Haraz' variety in Iran. Gündoğdu et al. (2016) recorded the highest total phenolic content in blackberry fruit in Eastern Anatolia as 438.970 mg GAE/g. Milosevic et al. (2012) stated that the highest total phenolic content in blackberry fruit with the 'Black Satin' variety was 413.2. When the literature studies determined regarding the total phenolic amount were compared with the data of this study, it was seen that significantly higher total phenolic amounts were detected in the literature studies compared to this study. It is thought that this difference between the studies may be due to factors such as the differences in genotypes and varieties, the differences in cultural practices and the different geographical conditions in which the fruits are grown.

Table 4. Total phenolic content (TPC), DPPH total antioxidant capacity (TAC) and total protein content from bioactive compound contents of blackberry genotypes

Genotypes	TPC (mg GAE/g)	DPPH (%)	Total Protein Content (g/L)
81KYN1	34.70 ± 0.02 l*	29.30 ± 0.08 b	20.48 ± 0.15 bc
81KYN2	45.77 ± 0.10 d	30.57 ± 0.18 a	20.10 ± 0.06 de
81KYN3	38.68 ± 0.18 k	9.18 ± 0.16 d	20.60 ± 0.14 ab
81KYN4	39.36 ± 0.13 j	3.28 ± 0.10 k	19.79 ± 0.10 fg
81KYN5	41.82 ± 0.10 h	6.41 ± 0.23 e	20.87 ± 0.06 a
81KYN6	47.55 ± 0.08 b	3.73 ± 0.06 j	19.70 ± 0.09 fg
81KYN7	52.16 ± 0.15 a	4.14 ± 0.13 i	19.09 ± 0.08 h
81KYN8	43.80 ± 0.09 f	5.74 ± 0.07 fg	19.61 ± 0.06 g
81KYN9	40.23 ± 0.09 i	11.76 ± 0.07 c	19.90 ± 0.05 ef
81KYN10	43.13 ± 0.06 g	5.64 ± 0.12 g	20.35 ± 0.11 bcd
81KYN11	38.82 ± 0.09 k	5.12 ± 0.10 h	18.07 ± 0.06 i
81KYN12	44.19 ± 0.07 e	3.08 ± 0.07 k	20.28 ± 0.09 cd
81KYN13	46.31 ± 0.08 c	6.09 ± 0.08 ef	19.79 ± 0.07 fg

*: The difference between the means indicated by the same letter in the same column is insignificant ($P < 0.05$).

When genotypes were evaluated, the highest total antioxidant amount (30.57%) was found in 81KYN2 genotype, while the lowest total antioxidant amount (3.08%) was found in 81KYN12 genotype. The 81KYN2 (30.57%) and 81KYN1 (29.30%) genotypes stand out in terms of high antioxidant activity, respectively (Table 4). Gündoğdu et al. (2016) determined the highest total antioxidant amount as 48.900% in 'Cherokee' variety blackberries and the lowest total antioxidant amount as 30.855% in 'Jumbo' variety. Garazhian et al. (2020) reported the highest total antioxidant amount as 88.08% in blackberry fruit of the 'Yasuj (Naregah)' variety in Iran. Gündoğdu et al. (2016) recorded the highest total antioxidant amount as 48.90% in blackberry fruit in Eastern Anatolia. Huang et al. (2022) reported the highest total antioxidant amount in blackberry fruit as 11.48%. Milosevic et al. (2012) stated that the highest total antioxidant amount in blackberry fruit with the 'Black Satin' variety was 312.72%. When the literature studies related to the total antioxidant amount were compared with the data of this study, it was seen that significantly higher total antioxidant amounts were examined in the literature studies compared to this study. It is thought that this difference between the studies may be due to factors such as the differences in genotypes and varieties, the differences in cultural practices and the different geographical conditions in which the fruits are grown.

The highest total protein amount (20.87 g/L) was found in 81KYN5 genotype, while the lowest total protein amount (18.07 g/L) was found in 81KYN11 genotype. The 81KYN5 (20.87 g/L), 81KYN3 (20.60 g/L), 81KYN1 (20.48 g/L) genotypes stand out with high total protein content, respectively (Table 4). No sample study has been found in the literature regarding the total protein amount, and it is thought that the data obtained in this study regarding this parameter may be useful for various studies to be carried out.

3.3. Clustering and Heat Mapping Analysis of Some Morphological and Biochemical Features

Hatmap analysis was performed to reveal some quality criteria and biochemical characteristics of blackberry genotypes. In the Hatmap analysis, the color change towards red in the color scale shows that the level of statistical significance has increased. The genotypes examined in the hierarchical cluster analysis were divided into four different clusters in total. The 81KYN11 genotype was found to be statistically insignificant (blue) in terms of agro-morphological and bioactive properties (Figure 1).

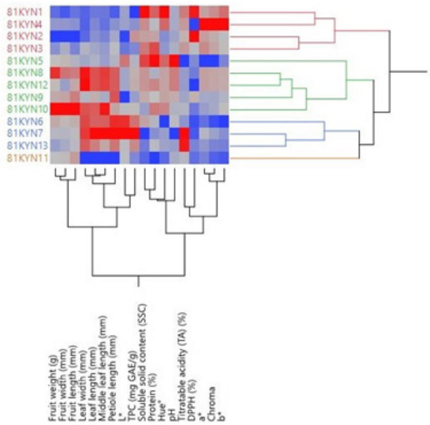

Figure 1. Clustering and heat map representation of some morphological and bioactive properties of blackberry genotypes. Blue to red color scale shows low to high values.

4. CONCLUSIONS

In this study, morphological, physicochemical and biochemical properties of 13 blackberry (*Rubus* Linnaeus) genotype fruit grown in Düzce province were investigated. In the examinations made in terms of morphological and physicochemical content, 81KYN6, 81KYN8, 81KYN9 and 81KYN10 genotypes were found to be promising in terms of fruit weight. It was determined that 81KYN8, 81KYN9 and 81KYN10 genotypes were superior in fruit width and length determined in the study.

The content of SSC ratio in fruit is one of the basic criteria that is important in determining the maturity period of a fruit and therefore can directly affect consumption. In this study, 81KYN1, 81KYN3, 81KYN4 and 81KYN5 genotypes were significantly superior to other genotypes in terms of high SSC rate, and at least 15% SSC rate was investigated in these genotypes. In the study, the values observed in all genotypes in terms of pH value were found to be close to each other (between 3.51 and 4.57). In terms of the highest TA value, 81KYN7 and 81KYN13 genotypes were more dominant.

In the study, in terms of biochemical content, 81KYN2, 81KYN6, 81KYN7 and 81KYN13 genotypes were dominant in the highest total phenolic amount, 81KYN1 and 81KYN2 genotypes in the highest total antioxidant amount, and 81KYN1, 81KYN3 and 81KYN5 genotypes in the highest total protein amount were significantly more dominant. As a result of the study, it was concluded that the genotypes that stand out in terms of morphological, physicochemical and biochemical characteristics can be evaluated in functional blackberry production.

Author Contribution Rates

Design of Study: AT(100%)

Data Acquisition: AT(100%)

Data Analysis: AT(100%)

Writing up: AT(100%)

Submission and Revision: AT(100%)

Conflict of Interest

The authors declare that there is no conflict of interest.

Ethics

This study does not require ethics committee approval.

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