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Wild Sweet Cherry (*Prunus avium* L.) Genotypes: Morphological, Biochemical, and Antioxidant Diversity

Yabani Kiraz (*Prunus avium* L.) Genotipleri: Morfolojik, Biyokimyasal ve Antioksidan Çeşitlilik

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ABSTRACT

Türkiye is in the homeland of the sweet cherries, and especially the northeastern Anatolia region is very rich in terms of wild sweet cherry genotypes. There are numerous wild sweet cherry trees with different morphological characteristics in the region and contribute significantly to biological diversity. In this study, a total of 12 wild sweet cherry genotypes found in the Bağbaşı district of Erzurum province in Northeastern Türkiye were investigated in terms of some important fruit and tree characteristics. In morphological characterization, trees and fruits of the 12 genotypes were used for tree (tree vigor, tree habit, branching habit), fruit (taste, fruit skin color, fruit weight, soluble solid content, vitamin C, total phenolic, total flavonoid, total anthocyanin content), and antioxidant capacity (2,2-diphenyl-1-picryl-hydrazyl-hydrate and ferric reducing antioxidant powerassays). Results indicated high differences among genotypes for most of the tree, fruit, and antioxidant characteristics. In general, genotypes had medium tree vigor and semi-upright growth habit. Blackish, dark red, red, light red, and yellow fruit skin color are evident. The genotypes showed fruit weight between 1.19 and 2.06 g, soluble solid content between 19.23% and 22.10%, and total phenolic content between 135 and 249 mg gallic acid equivalent/100 g fresh weight base. Total anthocyanin and vitamin C content were found between 3.10 and 113.81 mg/100 g and 15.86 and 20.67 mg/100 g fresh weight base. Results showed that wild sweet cherry genotypes evaluated in this study have shown to be potential sources of bioactive compounds. Fruits have the potential to be explored in the scientific and technological scope, due to their high amounts of phenolic compounds and antioxidant activity.

Keywords: Biodiversity, fruit composition, genotype, morphology, sweet cherry

ÖZ

Türkiye, kirazın anavatanı konumunda ve özellikle Kuzeydoğu Anadolu Bölgesi yabani kiraz genotipleri açısından oldukça zengindir. Bölgede farklı morfolojik özelliklere sahip çok sayıda yabani kiraz ağacı bulunmakta olup biyolojik çeşitliliğe önemli ölçüde katkı sağlamaktadır. Bu çalışmada, Türkiye'nin Kuzeydoğusunda Erzurum ilinin Bağbaşı ilçesinde bulunan toplam 12 yabani kiraz genotipinin bazı önemli meyve ve ağaç özellikleri açısından incelenmiştir. Morfolojik karakterizasyon çalışmalarında, 12 genotipe ait ağaç (gelişme kuvveti, taç yapısı, dal yapısı), meyve (tat, meyve kabuğu rengi, meyve ağırlığı, suda çözünür katı madde, C vitamini, toplam fenolik, toplam flavonoid, toplam antosiyanin içeriği) ve antioksidan kapasitesi (DPPH ve FRAP testleri) incelenmiştir. Sonuçlar, ağaç, meyve ve antioksidan özelliklerinin çoğunda genotipler arasında yüksek farklılıklar olduğunu göstermiştir. Genel olarak genotipler orta gelişme kuvvetine ve yarı dik taç yapısına sahiptir. Siyahımsı, koyu kırmızı, kırmızı, açık kırmızı ve sarı meyve kabuğu renkleri gözlenmiştir. Genotipler 1.19-2.06 g arasında meyve ağırlığı, %19.23-22.10 arasında suda çözünebilir katı madde içeriği (SÇKM), 135-249 mg gallik asit/100 g taze ağırlık bazında toplam fenolik madde içeriği göstermiştir. Toplam antosiyanin ve C vitamini içeriği 3.10-113.81 mg/100 g ve 15.86-20.67 mg/100 g taze ağırlık arasında bulunmuştur. Sonuçlar, bu çalışmada değerlendirilen yabani kiraz genotiplerinin potansiyel biyoaktif bileşik kaynakları olduğunu göstermiştir. Meyveler, yüksek miktarda fenolik bileşik ve antioksidan aktivitesi nedeniyle bilimsel ve endüstriyel alanda keşfedilme potansiyeline sahiptir.

Anahtar Kelimeler: Biyoçeşitlilik, meyve bileşimi, genotip, morfoloji, kiraz

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Introduction

Horticulture crops, including fruits, are nutrients that make up the edible parts of plants, and most of their content is water. A diet rich in fruits is very important for human health. It meets the energy, protein, and fat needs very little, and because they contain fiber, folic acid, beta-carotene, which is the precursor of vitamin A, vitamins E, C, B2, and calcium, potassium, magnesium, and iron in terms of minerals, they have a lot of benefits for the human body. At the same time, they are rich sources of electrolytes, phytochemicals, and antioxidants that prevent free radicals (del Rio-Celestino & Font, 2020; Wang et al., 2021).

Fruits are very rich in bioactive phytochemicals that can reduce the risk of developing chronic diseases. Phytochemicals are plant compounds found in fruits, vegetables, and whole grains that have a reducing effect on the risk of major chronic diseases. Since these bioactive compounds are complementary to each other in terms of their mechanisms, various consumptions should be preferred in daily nutrition to provide the best benefit. At the same time, the phenolic compounds they contain may play a role in reducing the risks of chronic diseases such as heart disease, cancer, and diabetes. The flavonoid content of fruits is very important in preventing chronic diseases such as heart disease, stroke, cataract, Alzheimer's disease, and age-related decline (Cosme, 2022, Jaglan et al., 2022; Olas, 2018; Ullah et al., 2020).

The homeland of sweet cherry is the Giresun province in the Black Sea region of Türkiye. For this reason, it is mentioned by some historians that it took its name from the Greek words Kerasus or Keresea, which means sweet cherry. In B.C. 74, the Roman commander Lucullus saw the unknown wild cherry trees in the west during his expedition to the Eastern Black Sea region and took cherry saplings on his way back to Rome. Thus, the cherry spread all over the world from here. The city of Sagae, the sweet cherry production center of Japan, declared Giresun a sister city in 1989, since Giresun is the homeland of sweet cherry (Demir et al., 2011; Ercişli, 2004; Eroğul, 2018; Türkoğlu et al., 2012; Ünsal et al., 2019; Yaman, 2003).

Sweet cherries are an important fruit in Turkey with high economic value. Turkey exports sweet cherries to many European Union countries, and Turkish sweet cherries are preferred in these markets due to their high-quality fruits.

The Northeast Anatolian region is rich in wild edible fruit species. Cherry species in the region are represented by a great wealth of forms. In the region, especially wild sweet cherries, sour cherries, and cherry laurels are abundant. Wild sweet cherry is protected by the European Forest Genetic Resources Programme; however, its conservation has been neglected in Türkiye (Eken et al., 2022). Local people use wild cherry fruits by consuming them fresh, as well as processing them into many local products. These traditions also have very important contributions to the natural landscape of the region (Karlıdağ et al., 2009). However, most of the wild edible cherries are still underexploited and that represent economic importance with a potential to contribute to the food, pharmaceutical, and agribusiness fields (Ercişli et al., 2011). In the Northeast Anatolian region, the Çoruh valley is of special emphasis for plant biodiversity due to its unique geological, geomorphological, and climatic characteristics. The valley is located in Caucasian ecological area, which is determined by the World Wildlife Fund as among the 200 most important ecological areas of the worlds for plant biodiversity (Anonim, 2013).

The aim of this study is to determine morphological and biochemical potential of 12 native wild-grown sweet cherry genotypes grown in the northeastern part of Türkiye to encourage new research and postharvest processes.

Methods

Plant Material

During an expedition to the Çoruh valley, 12 wild-grown native sweet cherry genotypes were found on the same fields and were marked. The fruit samples were obtained during the harvest period. The genotypes were found in the Bağbaşı district of Erzurum province in Çoruh valley. The study was conducted in 2021.

Morphological Traits

A total of 40 fruits from different directions of trees with 3 replications were used. Fruit weight was measured by using 0.01 sensitivity electronic balances. Fruit external color and fruit taste were determined on those samples. Some important tree characteristics of genotypes were also determined.

Biochemical Traits

The biochemical analysis was conducted from four replicates on fresh sweet cherry fruits. About 100 g of fruit samples for each genotype were frozen at –20°C. At the time of analysis, fruits were thawed and homogenized in a standard food blender. Slurries were used to determine biochemical [soluble solid content (SSC), vitamin C, total flavonoid, total phenolic, total anthocyanin] and antioxidant capacity [ferric reducing antioxidant power (FRAP) and 2,2-diphenyl-1-picryl-hydrazyl-hydrate (DPPH) assays]. Soluble solid content was determined by a refractometer (Model RA-250HE, Kyoto Electronics Manufacturing Co. Ltd., Japan). Vitamin C of samples was quantified with the reflectometer set of Merck Co (Merck RQflex) and expressed as mg/100 g fresh weight.

Total Phenolic Content

Total phenolic content of wild sweet cherries fruits was measured with the rapid Folin-Ciocalteu method (Magalhães et al., 2010). Total phenolic content was expressed as milligrams gallic acid equivalent per 100 g pitted fresh wild sweet cherry fruit (mg GAE/100 g).

Total Anthocyanin Content

Total anthocyanin content was measured spectrophotometrically (Krawczyk & Petri, 1992). Total anthocyanin content was calculated as cyanidin-3-glucoside equivalent per 100 g of fresh wild sweet cherry fruit.

Total Flavonoids

Total flavonoids were measured according to the method reported by Meda et al. (2005). As the standard, quercetin was used. The results were expressed in mg quercetin equivalents (QE)/100 g fresh weight base.

Antioxidant Capacity (Ferric Reducing Antioxidant Power and 2.2-Diphenyl-1-Picryl-Hydrazyl-Hydrate Assays)

Ferric reducing antioxidant power) (Benzie & Strain, 1996) and DPPH (Blois, 1958) assays were used for antioxidant capacity analysis. The results were expressed as μmol Trolox Equivalent (TE)/g fresh weight in both assays.

Statistical Analysis

For each parameters four replicates were used. For analysis of variance, the obtained data were used for mean calculation. Duncan multiple range tests were performed at the significant level of $p < .05$. Statistical Package for the Social Sciences version 26.0 (IBM SPSS Corp., Armonk, NY, USA) program was used for statistical analysis.

Results

Morphological Traits

Tree vigor, tree growth habit, branching habit, fruit skin color, fruit taste, and fruit weight of 12 wild-grown sweet cherry genotypes are given in Table 1. There were statistically significant differences among genotypes on fruit weight at $p < .05$ (Table 1).

The majority of genotypes had medium tree vigor (nine genotypes), and the rest of the three genotypes had strong tree vigor. For tree growth habit, seven genotypes had semi-upright and four genotypes had upright, and only one genotype had strong tree growth habit. A total of seven genotypes had medium branching habit, and five genotypes had strong branching habit. For skin color characteristics, four genotypes had blackish fruit skin color, three genotypes had red, two genotypes had yellow, two genotypes had dark red, and one genotype had light red fruit skin color (Table 1). These results indicate high biodiversity in tree characteristics of genotypes.

Fruit weight of wild sweet cherry genotypes was in the range of 1.19 g (BA-4)–2.06 (BA-8). For fruit taste, the majority had a bitter taste (six genotypes), followed by slightly bitter (four genotypes) and sweet (two genotypes). Karlıdağ et al. (2009) used six wild-grown sweet cherry genotypes and reported that the majority of genotypes had medium tree vigor, semi-upright growth habit, medium branching habit, blackish fruit skin color, and bitter fruit taste. They also indicated that fruit weight was between 0.76 and 2.11 g. Mratinić et al. (2012) used 10 wild-grown sweet cherry in Serbia and reported fruit weight of 0.78–1.39 g. All of the earlier results were consistent with our results. In sweet cherry, the fruit quality characteristics such as fruit color, size, firmness, taste, and flavor are the main factors that determine consumer preference (Esti et al., 2002). Sweet cherry fruit external color varies from yellow to mahogany or almost black, depending on the anthocyanin content profile of cultivars, genotypes, accessions, etc. (Calle et al., 2021; Jin et al., 2016). Mratinić et al. (2012) used 10 wild-grown sweet cherry in Serbia and indicated that fruit skin color varied from yellow (genotypes 3 and 5) to light red (genotype 4), brown red (genotype 2), and blackish (genotypes 1, 6, 7, 8, 9, and 10).

The most important features of wild edible fruit species compared to related cultivars are smaller fruits and a bitter or sour taste (Rymbai et al., 2023). Although this situation limits their consumption as fresh, it still ensures that they are consumed fresh with high aroma and exotic tastes. What makes these fruits important is their high phytochemical content in terms of human health. Tree vigor, growth habit, and branching habit are genetically controlled by cherries (in particular in un-grafted trees), but in particular rootstocks also influence those traits (Hrotkó et al., 2023).

Biochemical Traits

Soluble solid content, vitamin C, total anthocyanin, total flavonoid content, and total phenolic content in the fruit of the wild sweet cherry genotypes are presented in Table 2. All of the earlier biochemical traits in the fruits of wild-grown sweet cherry genotypes significantly differed from each other at the 0.05 statistical level except for vitamin C (Table 2).

Fruits of wild-grown sweet cherry genotypes had SSC content between 19.23% (BA-2) and 22.10% (BA-10). However, most of the genotypes were placed in the same statistical group. There was a lack of information in the literature on wild sweet cherry fruits' biochemical traits including SSC. Studies are abundant worldwide on standard or local sweet cherry cultivars. Previously, Karlıdağ et al. (2009) used six wild-grown sweet cherry in Türkiye and found SSC in the range from 19.35% to 23.98%, which correlates with our results. The literature indicated that sweet cherry fruits had a moderate amount of sugars, especially simple sugars (e.g., glucose, fructose, sucrose, and sorbitol). These components are responsible for sweetness, while sourness is primarily due to the presence of organic acids (e.g., malic, citric, succinic, lactic, and oxalic acids) (Serradilla et al., 2011). Gjamovski et al. (2016) reported that SSC content in sweet cherry fruits is cultivar dependent and ranged from 14.0% to 16.7%, indicating lower values than ours. However, in Serbia and Chile, it was reported as 19.8% and 18.86% (Basile et al., 2021; Kalajdžić et al., 2019), which is close to our results. Mratinić et al. (2012) used 10 wild-grown

Table 1.
Morphological Tree and Fruit Characteristics of Wild Sweet Cherry Genotypes

Genotypes	Tree Vigor	Tree Growth Habit	Branching Habit	Fruit Skin Color	Fruit Taste	Fruit Weight (g)
BA-1	Medium	Semi-upright	Medium	Blackish	Bitter	1.88ab
BA-2	Strong	Upright	Medium	Yellow	Slightly bitter	1.28b
BA-3	Medium	Strong	Strong	Yellow	Bitter	1.90ab
BA-4	Medium	Semi-upright	Medium	Blackish	Bitter	1.19ab
BA-5	Strong	Upright	Medium	Red	Sweet	1.33ab
BA-6	Medium	Semi-upright	Medium	Light red	Slightly bitter	1.44ab
BA-7	Medium	Semi-upright	Strong	Dark red	Bitter	1.50ab
BA-8	Medium	Semi-upright	Medium	Red	Sweet	2.06a
BA-9	Strong	Upright	Strong	Dark red	Slightly bitter	1.86ab
BA-10	Medium	Semi-upright	Strong	Blackish	Bitter	1.76ab
BA-11	Medium	Upright	Strong	Red	Bitter	1.55ab
BA-12	Medium	Semi-upright	Medium	Blackish	Slightly bitter	2.02ab

Note: Means within a column followed by the same letter are not significantly different at $p < .05$

Table 2.
Biochemical Characteristics in Fruits of Wild Sweet Cherry Genotypes

Genotypes	SSC (%)	Vitamin C (mg/100 g)	Total Anthocyanin Content (mg cy-3-glu/100 g)	Total Flavonoid Content (mg QE/100 g)	Total Phenolic Content (mg GAE/100 g)
BA-1	21.17ab	18.33^{NS}	110.45ab	177ab	240ab
BA-2	19.23c	19.20	4.00e	83ef	135f
BA-3	19.55bc	15.86	3.10e	94e	142f
BA-4	20.88abc	17.10	102.00b	142c	214c
BA-5	19.68bc	16.06	88.40cd	130cd	196cd
BA-6	19.40bc	17.40	81.10d	112d	172de
BA-7	20.40b	16.80	96.23bc	150bc	220b
BA-8	20.07bc	19.60	85.54cd	123cd	180de
BA-9	21.04ab	16.63	90.36cd	135cd	208cd
BA-10	22.10a	19.10	113.81a	185a	249a
BA-11	20.26abc	19.35	91.68c	122cd	184d
BA-12	20.48abc	20.67	107.44ab	166b	232ab

Note: Means within a column followed by the same letter are not significantly different at $p < .05$.
NS = Nonsignificant.

sweet cherry in Serbia and found that SSC changed between 17.95% and 28.65%. From our results, we can be concluded that wild-growing sweet cherries had much higher SSC than commercially grown sweet cherry cultivars. Soluble solid content and acidity are two important internal factors that affect the quality and strongly influence the taste and market value of sweet cherry fruits, and the SSC content of fruit is affected by many factors, including genotype, soil, climate conditions, and sampling periods (Ercişli et al., 2012).

Results on vitamin C content in fruits of wild-grown sweet cherry genotypes indicated non-significant differences at $p < .05$ level (Table 2) which were between 15.86% (BA-3) and 20.67% (BA-12). Karlıdağ et al. (2009) found vitamin C in fruits of blackish, dark red, red, and yellow skin-colored wild sweet cherry fruits ranged from 19 to 27 mg/100 mL, which were in agreement with our results. Sweet cherries had moderate vitamin C content of wild sweet cherry genotypes, suggesting that non-vitamin C phytochemicals, such as polyphenolics seems to play a significant role in the antioxidant value or health benefits of wild sweet cherry fruits. The difference among studies could be effects of environmental conditions, plant genotypes, etc. A serving of sweet cherries has 18% of the recommended daily value of vitamin C. Previously, Gündoğdu and Bilge (2012) found for standard Turkish sweet cherry cultivars that vitamin C content ranged between 6.01 and -11.44 mg/100 g, indicating lower values of cultivars than wild materials.

Total phenolic content of wild-grown sweet cherry genotypes is shown in Table 2. The highest total phenolic content was obtained from BA-10 genotype as 249 mg GAE/100 g FW and followed by BA-2 (240 mg GAE/100 g FW) and BA-12 (232 mg GAE/100 g FW), while the lowest total phenolic content was obtained from BA-2 genotype as 135 mg GAE/100 g FW (Table 2). Karlıdağ et al. (2009) found that the average total phenolic content in fruits of blackish, dark red, red, and yellow skin colored wild sweet cherry fruits ranged from 148 to 321 mg GAE/100 g FW. The results clearly indicate the importance of color on total phenolic content. The lowest values were obtained from yellow skin colored genotypes and the highest total phenolic content was seen in blackish fruit skin colored genotypes (Table 2). Ağlar et al. (2019) previously reported total flavonoid content between 196 and 256 mg GAE per 100 g among sweet cherry samples. Sirbu et al. (2018) indicated that sweet cherry cultivars had variable total phenolic content. Mikulic-Petkovsek et al. (2012) used 10 wild-grown sweet cherry in Serbia and found that total phenolics were between 106.3 mg GAE/100 g FW (yellow fruit skin color) and 154.4 mg GAE/100 g FW (brown-red fruit skin color). Total phenolic compounds contribute to fruit quality and nutritional value in terms of modifying color, taste, aroma, and flavor and also in providing health-beneficial effects (Gündoğdu & Bilge, 2012).

Wild sweet cherry genotypes had quite variable total anthocyanin content, which ranged from 3.10 to 113.91 mg cy-3-glu per 100 g FW. The anthocyanin amount was strongly affected by the color of fruits, and yellow ones were found to be the poorest and blackish ones were found to be the richest source of anthocyanins. Sweet cherry fruits are well known for their anthocyanin-rich fruit. Karlıdağ et al. (2009) reported anthocyanin content between 5 mg (yellow colored) and 102 mg (blackish colored) cy-3-glu/100 g. Kim et al. (2005) used a large number of different colored sweet cherries and presented 1–432 mg/100 g anthocyanin in sweet cherry fruits. These differences in total anthocyanin content showed that the genotypes used, growing region, and the harvest period might have an impact on plant growth and metabolite concentration (Premier, 2002).

Wild sweet cherry genotypes had total flavonoid content between 94 and 177 mg QE per 100 g fresh weight base. It is clear that genotypes differed from each other in terms of total flavonoid content. Ağlar et al. (2019) previously reported total flavonoid content between 65 and 115 mg QE per 100 g among sweet cherry samples, which indicate similarities with our result. Flavonoids are phytochemical compounds present in many plants, fruits, vegetables, and leaves, with potential applications in medicinal chemistry. Flavonoids possess a number of medicinal benefits, including anticancer, antioxidant, anti-inflammatory, and antiviral properties (Al-Khayri et al., 2022; Ullah et al., 2020).

Total antioxidant capacity of wild-grown 12 sweet cherry genotypes is given in Table 3. The genotypes in general showed similar trends for antioxidant capacity determined by FRAP and DPPH

Table 3.
Antioxidant Capacity in Fruits of Wild Sweet Cherry Genotypes

Genotypes	FRAP (µmol TE/g FW)	DPPH (µmol TE/g FW)
BA-1	14.42ab	2.05ab
BA-2	8.11f	1.67d
BA-3	8.32f	1.72cd
BA-4	13.68bc	1.96b
BA-5	12.60cd	1.85bc
BA-6	9.89e	1.82c
BA-7	12.88c	1.94abc
BA-8	10.90d	1.76cd
BA-9	13.40bc	1.90abc
BA-10	15.03a	2.09a
BA-11	12.10cd	1.72cd
BA-12	14.01b	2.02ab

Note: Means within a column followed by the same letter are not significantly different at $p < .05$.
DPPH = 2.2-Diphenyl-1-picryl-hydrazyl-hydrate; FRAP = Ferric reducing antioxidant power.

assays. The 12 wild-grown sweet cherry genotypes had average antioxidant capacity determined by FRAP and DPPH methods between 8.11 and 15.03 µmol TE/g FW and 1.67 and 2.09 µmol TE/g FW, respectively. The genotype BA-10 showed the highest antioxidant capacity in both assays used, while overall BA-2 had the lowest activity determined by both antioxidant methods.

The results showed that there were positive relationships between antioxidant activity and phenolic compounds, flavonoids, and anthocyanins. In other words, the fruits belonging to genotypes, which have high total flavonoids, total anthocyanin, and total phenolic content, have also higher antioxidant activity. With increasing fruit color intensity, increases in antioxidant activity were observed. Therefore, it can be said that these compounds contribute to the antioxidant capacity of wild sweet cherry fruits. These compounds also play a therapeutic and restorative role in human health in addition to the effect on the quality, taste, aroma, and flavor of fruit (Mikulic-Petkovsek et al., 2012).

Conclusion and Recommendations

Although there are many studies on the morphological, biochemical, and antioxidant properties of cultivated sweet cherry cultivars, there are very few studies on wild sweet cherries. This study makes an important contribution to the literature in this sense. As a result of the study, it was determined that wild sweet cherry genotypes were richer, especially in terms of human health-promoting content, compared to cultivars, and their antioxidant capacity values were also quite high. On the other hand, it was determined that biological activity increased from yellow fruit color to dark blackish fruit color.

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