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Araştırma (Research)

The sugar composition of hawthorn germplasm grown in Akçadağ (Malatya) region*

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Abstract

Objective: In this study was aimed to determine the sugar contents of hawthorn genetic resources grown in the Akçadağ (Malatya) region.

Materials and Methods: The study material was consisted in 15 genotypes belonging 5 different hawthorn species. In investigated hawthorn genotypes, glucose, fructose, sucrose and total sugar content were determined.

Results: A wide variation was determined between the species and genotypes studied in terms of investigated characteristics. Based on species, *Crataegus pontica* stood out in terms of glucose, fructose, and total sugar content (11.0 g 100 g^{-1}, 12.7 g 100 g^{-1}, and 26.1 g 100 g^{-1}, respectively), and *Crataegus aronia* in terms of sucrose content (3.7 g 100 g^{-1}). Depending on the genotypes, the highest glucose, fructose, and total sugar content (21.0, 23.6, and 45.0 g 100 g^{-1}, respectively) were determined in the H-1 genotype, and the highest sucrose content (3.7 g 100 g^{-1}) was determined in the H-15 genotype. According to the principal component analysis results, the first two components explained 99.8% of the total variation. While the first component was related to glucose, fructose, and total sugar contents, the second component was related to sucrose.

Conclusion: It is thought that the examined hawthorn genetic resources have significant potential in terms of sugar content and can be used as genetic material in breeding studies.

Keywords: Hawthorn, genetic resource, fructose, glucose, sucrose

Akçadağ (Malatya) Yöresinde Yetişen Alıç Genetik Kaynaklarının Şeker İçerikleri

Öz

Amaç: Bu çalışmada Akçadağ (Malatya) yöresinde yetişen alıç genetik kaynaklarının şeker içeriklerinin belirlenmesi amaçlanmıştır.

Materyal ve Yöntem: Çalışmada 5 alıç türüne ait 15 genotip incelenmiştir. İncelenen genotiplerde glikoz, fruktoz, sukroz ve toplam şeker içerikleri belirlenmiştir.

Araştırma Bulguları: İncelenen özellikler bakımından çalışılan türler ve genotipler arasında geniş bir varyasyon belirlenmiştir. Türler bazında, *Crataegus pontica* glikoz, fruktoz ve toplam şeker içerikleri (sırasıyla, 11.0 g 100 g^{-1}, 12.7 g 100 g^{-1} ve 26.1 g 100 g^{-1}), *Crataegus aronia* ise sukroz içeriği (3.7 g 100 g^{-1}) bakımından öne çıkmıştır. Genotiplere bağlı olarak, en yüksek glikoz, fruktoz ve toplam şeker içerikleri (sırasıyla, 21.0, 23.6 ve 45.0 g 100 g^{-1}) H-1 genotipinde, en yüksek sukroz içeriği (3.7 g 100 g^{-1}) ise H-15 genotipinde belirlenmiştir. Temel bileşen analiz sonuçlarına göre, oluşan ilk iki bileşen toplam varyasyonun %99.8'ini açıklamıştır. 1. bileşen glikoz, fruktoz ve toplam şeker içerikleri ile ilişkili iken, 2. bileşen ise sukroz içeriği ile ilişkili bulunmuştur.

Sonuç: İncelenen alıç genetik kaynaklarının şeker içerikleri bakımından önemli bir potansiyele sahip olduğu ve bu yönüyle ıslah çalışmalarında genetik materyal olarak kullanılabileceği düşünülmektedir.

Anahtar Kelimler: Alıç, genetik kaynak, fruktoz, glikoz, sukroz

Introduction

There has been intense interest in edible wild fruits in recent years. Hawthorn, one of them, is an important fruit type that is beneficial to human health with its rich nutritional content (Tadic et al., 2008). Hawthorn spreads in a vast geography, including Northern Europe, temperate regions of Asia, Africa, and North America. It is reported that hawthorn species spread over wide geography through birds and other animals as well as humans. Of the 165-200 hawthorn species grown globally, about 17 naturally spread in Türkiye. Among these species, *Crataegus monogyna, C. orientalis, C. curvisephala, C. pentagyna, C. oxycantha, C. azaralus* and *C. prunitifolia* have a wide distribution area in Türkiye (Ercisli, 2004; Muradoğlu et al., 2021). Although some hawthorn species are cultivated in different regions in the world, hawthorns generally show natural distribution (Payne and Krewer, 1990). In Türkiye, hawthorn grows naturally in mountainous areas, including bushes and rocks (Gökbunar, 2007). Hawthorn is also known as Akdiken, Yemişen, Yemşen, Yumuşan, Yemişgen, Geyikdikeni, Halıç, Haluç, Aluş, Eloş, Kuş yemişi, Yaban gülü, Haziran and Ekşi muşmula (Karadeniz, 2004).

Hawthorn is a fruit type in the form of a thorny bush or tree, deciduous in winter (Yılmaz et al., 2010). The ripe fruits are red, black, orange, and yellow, depending on the species. Its fruits and flowers are rich in antioxidants and positively affect human health. Hawthorn fruits are used in making marmalade, jam, vinegar, syrup, and canned food besides their fresh consumption (Chang et al., 2002; 2006).

It is reported that hawthorn fruit has many beneficial effects on human health and is used in folk medicine. Hawthorn berries, leaves and flowers are traditionally used as diuretic, astringent, hypotensive and cardiotonic agents (Leung and Foster, 1996). In addition, it is used in the treatment of various diseases such as heart diseases, hypertension, scurvy, constipation, and abdominal pain (Zhang et al., 2002; Barceloux, 2008; Arrieta et al., 2010). Hawthorn fruit has a rich content of antioxidants, flavonoids, fruit acids, sugars, vitamin C, glycoside, saponin and tannic acid (Ljubuncic et al., 2005; Liu, 2012). Sugars, which are an essential component of hawthorn fruit, contribute to the sweetness of the fruit and play an important role in the effects of the fruit on human health (Liu et al., 2010). In hawthorn fruit, the primary sugar is fructose. Glucose and sucrose are other important sugar components. Different researchers have reported fructose content is between 0.93 to 21.82 g 100 g^{-1}, glucose content between 0.87 to 14.74 g 100 g^{-1}, and sucrose content between 0.005 to 13.86 g 100 g^{-1} in some hawthorn species and genotypes (Bignami et al., 2003; Balta et al., 2006; Muradoğlu et al., 2019; Bostan and Mazı, 2021).

Studies have reported qualitative and quantitative differences in sugar content between different species and genotypes of hawthorn (Liu et al., 2010; Yang et al., 2012). Although there are studies to determine the sugar content of hawthorn genetic resources in Türkiye, these studies were primarily based on species or genotypes. It is seen that the number of studies in which sugar contents are determined based on both species and genotypes is limited (Balta et al., 2006; Muradoğlu et al., 2019). This research was carried out to determine the sugar content of different hawthorn species and genotypes growing naturally in Akçadağ (Malatya) region, which is rich in hawthorn genetic resources.

Materials and Methods

Plant materials

The material of the study consisted of 15 genotypes of five different hawthorn species (H-1, H-2, H-3 genotypes of *Crataegus pontica*; H-4, H-5, H-6, H-7, H-8 genotypes of *Crataegus orientalis*; H-9, H-10, H-11, H-12, H-13 genotypes of *Crataegus tanacetifolia*; H-14 genotype of *Crataegus meyeri*; H-14 genotype of *Crataegus aronia*) selected through selection breeding from the naturally grown hawthorn population in Akçadağ district of Malatya province. Approximately 250 g of fruit samples were harvested from each hawthorn genotype in the study. Care has been taken to ensure that the harvested fruits are not contaminated with diseases and pests.

Sample preparation

Sugar contents of the examined hawthorn genotypes were determined in fruit juice. The juices of the fruit samples taken from each genotype were extracted, diluted with distilled water (1:4), and homogenized with a hand blender. The obtained sample was filtered so that no residue remained. Glucose, fructose, sucrose, and total sugar contents were determined as sugar contents in the prepared fruit juice.

Glucose content

After the prepared juice was diluted with distilled water (1:100), the test strip (Cat.No. 116720, Reflectoquant, Glucose test, Merck, Germany) was immersed in this solution for 2 seconds, and the excess liquid remaining on it was removed. After waiting for 1 minute, the test strip was placed in the strip adapter of the reflectometer (RQflex plus 10, Merck, Germany), and the measurement was performed. The reading was multiplied by the dilution coefficient and expressed as g 100 g^{-1} (Balta et al., 2021).

Fructose content

Fructose content was calculated according to the formula specified in the total sugar package insert (Anonymous, 2022) and expressed in g 100 g^{-1}.

Fructose = Total sugar – glucose

Sucrose content

The prepared juice is diluted with distilled water (1:100). 1 mL of the obtained solution was taken, and 10 mL of distilled water and five drops of Sa-1 reagent were added. Then, the test strip (Cat.No. 116141, Reflectoquant, Sucrose test, Merck, Germany) was immersed in the prepared solution for 2 seconds, and the excess liquid on it was removed. After waiting for 5 minutes, the test strip was placed in the strip adapter of the reflectometer (RQflex plus 10, Merck, Germany), and the measurement was performed. The reading was multiplied by the dilution coefficient and expressed as g 100 g^{-1} (Balta et al., 2021).

Total sugar content

The prepared fruit juice was diluted with distilled water to determine the total sugar content. (1:100) 1 mL of the prepared solution was taken, and 10 mL of distilled water and five drops of TS-1 reagent were added. Then, the test strip (Cat.No. 116136, Reflectoquant, Total sugar test, Merck, Germany) was immersed in the prepared solution for 2 seconds, and the excess liquid on it was removed. After waiting for 10 minutes, the test strip was placed in the strip adapter of the reflectometer (RQflex plus 10, Merck, Germany), and the measurement was performed. The reading was multiplied by the dilution coefficient and expressed as g 100 g^{-1} (Balta et al., 2021).

Statistical analysis

JMP 14.0 (trial) statistical package program was used to evaluate the data. Principal component and biplot analyzes were performed using the sugar content of the examined hawthorn species and genotypes.

Results and Discussion

The content and composition of sugars, sugar alcohols and acids are essential quality factors that directly affect the taste and acceptability of fruits (Tang et al., 2001). The high variation in sugar content and sugar/acid ratio variation indicates significant differences in sensory properties between fruit species and cultivars. Sugars, which are an essential component of hawthorn fruit, contribute to the sweetness of the fruit and play an important role in the effects of the fruit on human health (Liu et al., 2010).

Glucose content in hawthorn species varied between 3.3 (*Crataegus meyeri*) and 11.0 g 100 g^{-1} (*Crataegus pontica*). In hawthorn genotypes, the highest glucose content was determined in H-1 (21.0 g 100 g^{-1}), while the lowest was determined in H-14 (3.3 g 100 g^{-1}). The H-1 genotype with the highest glucose content was followed by the H-10 (14.5 g 100 g^{-1}), H-5 (14.0 g 100 g^{-1}) and H-13 (9.8 g 100 g^{-1}) genotypes, respectively (Table 1). The glucose content was determined as 3.04 to 6.73 g 100 g^{-1} in genotypes of *Crataegus azarolus* species grown in Italy by Bignami et al. (2003); 1.63 to 5.22 g 100 g^{-1} in genotypes of different hawthorn species grown in Darende (Malatya) by Balta et al. (2006); 6.67 to 13.89 g 100 g^{-1} in different hawthorn species grown in the Erzincan region by Gundogdu et al. (2014); 0.87 to 2.81 g and 100 g^{-1} in hawthorn genotypes grown in Niksar (Tokat) by Bostan and Mazı (2021). Except for the H-1 genotype, the glucose content of other hawthorn genotypes was among the reference values reported by the researchers for the hawthorn genotypes they examined. The difference seen is thought to be due to genetic structure, ecological conditions, and the ripeness of the fruit.

Among the examined hawthorn species, the highest fructose content was found in *Crataegus pontica* (12.7 g 100 g^{-1}) and the lowest in *Crataegus meyeri* (4.7 g 100 g^{-1}). Among the examined genotypes, the highest fructose content was determined in the H-1 genotype (23.6 g 100 g^{-1}). The lowest was detected in the H-14 (4.7 g 100 g^{-1}) genotype. In terms of fructose content, the H-1 genotype was followed by H-5 (15.4 g 100 g^{-1}), H-10 (15.4 g 100 g^{-1}) and H-9 (11.9 g 100 g^{-1}) genotypes, respectively (Table 1). Many researchers have reported that fructose is the major sugar in hawthorn fruit (Balta et al., 2006; Gündogdu et al., 2014; Muradoğlu et al., 2019). Similarly, fructose was the principal sugar in all hawthorn genotypes examined in the present study.

In different studies, the fructose content was reported from 2.30 to 7.90 g 100 g^{-1} in Darende (Malatya) (Balta et al., 2006); 9.59 to 18.37 g 100 g^{-1} in Erzincan (Gündogdu et al., 2014); 6.51 to 15.92 g 100 g^{-1} in Şemdinli (Hakkari) (Yaviç et al., 2016); 6.05 to 21.82 g 100 g^{-1} in Bahçesaray (Van) (Muradoğlu et al., 2019). While the fructose content of the examined hawthorn genotypes was higher than the findings of Balta et al. (2006), it was found to be compatible with the values reported by other researchers.

Table 1. Sugar composition of hawthorn species and genotypes investigated

Species	Genotypes	Glucose (g 100 g^{-1})	Fructose (g 100 g^{-1})	Sucrose (g 100 g^{-1})	Total sugar (g 100 g^{-1})
Crataegus pontica	H-1	21.0±1.58	23.6±0.89	0.4±0.05	45.0±2.46
	H-2	8.0±0.89	9.2±0.60	3.6±0.07	20.8±1.44
	H-3	4.0±1.18	5.4±0.65	3.1±0.08	12.5±1.80
	Mean	**11.0±7.77**	**12.7±8.33**	**2.3±1.49**	**26.1±14.71**
Crataegus orientalis	H-4	4.0±1.26	5.1±0.35	2.9±0.10	12.0±1.68
	H-5	14.0±1.68	15.4±0.70	1.2±0.06	30.7±2.35
	H-6	8.3±1.37	9.8±0.56	2.4±0.11	20.5±1.85
	H-7	3.5±1.23	4.6±0.61	0.9±0.09	9.0±1.90
	H-8	5.5±1.04	7.5±0.52	2.9±0.10	15.9±1.60
	Mean	**7.1±4.14**	**8.5±4.10**	**2.1±0.87**	**17.6±8.00**
Crataegus tanacetifolia	H-9	5.8±1.31	8.9±0.66	3.5±0.08	18.2±1.95
	H-10	14.5±1.45	15.4±0.75	1.8±0.09	31.7±2.16
	H-11	3.8±1.14	5.6±0.58	1.5±0.11	10.9±1.62
	H-12	5.0±0.78	6.7±0.30	1.9±0.10	13.6±1.11
	H-13	9.8±1.06	11.9±0.58	2.6±0.08	24.2±1.62
	Mean	**7.8±4.18**	**9.7±3.73**	**2.3±0.75**	**19.7±7.89**
Crataegus meyeri	H-14	3.3±0.62	4.7±0.38	0.9±0.06	8.8±1.01
	Mean	**3.3±0.62**	**4.7±0.38**	**0.9±0.06**	**8.8±1.01**
Crataegus aronia	H-15	5.0±0.94	8.2±0.57	3.7±0.10	16.9±1.50
	Mean	**5.0± AB**	**8.2±0.57**	**3.7±0.10**	**16.9±1.50**

Crataegus aronia species (3.7 g 100 g^{-1}) had the highest sucrose content, while *Crataegus meyeri* species (0.9 g 100 g^{-1}) had the lowest. In the genotypes examined, the highest values in terms of sucrose content were determined in the H-15 (3.7 g 100 g^{-1}), H-2 (3.6 g 100 g^{-1}), and H-9 (3.5 g 100 g^{-1}) genotypes, while the lowest values were determined in the H-1 (0.4 g 100 g^{-1}) genotype (Table 1). The sucrose content was determined as 0.03 to 6.24 g 100 g^{-1} in genotypes of the *Crataegus azarolus* species grown in Italy by Bignami et al. (2003); 0.81 to 2.78 g 100 g^{-1} in genotypes of different hawthorn species grown in Darende (Malatya) by Balta et al. (2006); 0.005 to 5.27 g 100 g^{-1} in different hawthorn species grown in Bahçesaray (Van) region by Muradoğlu et al. (2019); 0.068 to 5.50 g 100 g^{-1} in hawthorn genotypes grown in Niksar (Tokat) by Bostan and Mazı (2021). In contrast, Yaviç et al. (2016) determined the sucrose content of hawthorn genotypes grown in Şemdinli region between 4.09 and 13.86 g 100 g^{-1}. While the sucrose content findings are generally similar to the researchers' results, Yaviç et al. (2016) found it to be lower than the findings. The observed differences are thought to be due to the genotype, climate, and soil structure.

Total sugar content in the examined hawthorn species ranged from 8.8 (*Crataegus meyeri*) to 26.1 g 100 g^{-1} (*Crataegus pontica*). In hawthorn genotypes, the highest total sugar content was determined in H-1 (45.0 g 100 g^{-1}), while the lowest was determined in H-14 (8.8 g 100 g^{-1}). The H-1 genotype with the highest total sugar content was followed by the H-10 (31.7 g 100 g^{-1}), H-5 (30.7 g 100 g^{-1}) and H-13 (24.2 g 100 g^{-1}) genotypes (Table 1). Balta et al. (2006) reported the total sugar content is from 5.81 to 13.54 g 100 g^{-1} in different hawthorn species and genotypes grown in Darende, while Bostan and Mazı (2021) reported between 3.68 and 8.11 g 100 g^{-1} in hawthorn genotypes grown in Niksar. It was determined that the total sugar content of the examined hawthorn genotypes was higher than the researchers' findings. The differences in total sugar content are thought to be due to the ripeness of the fruit, especially the genetic structure and ecological conditions, and the analysis method.

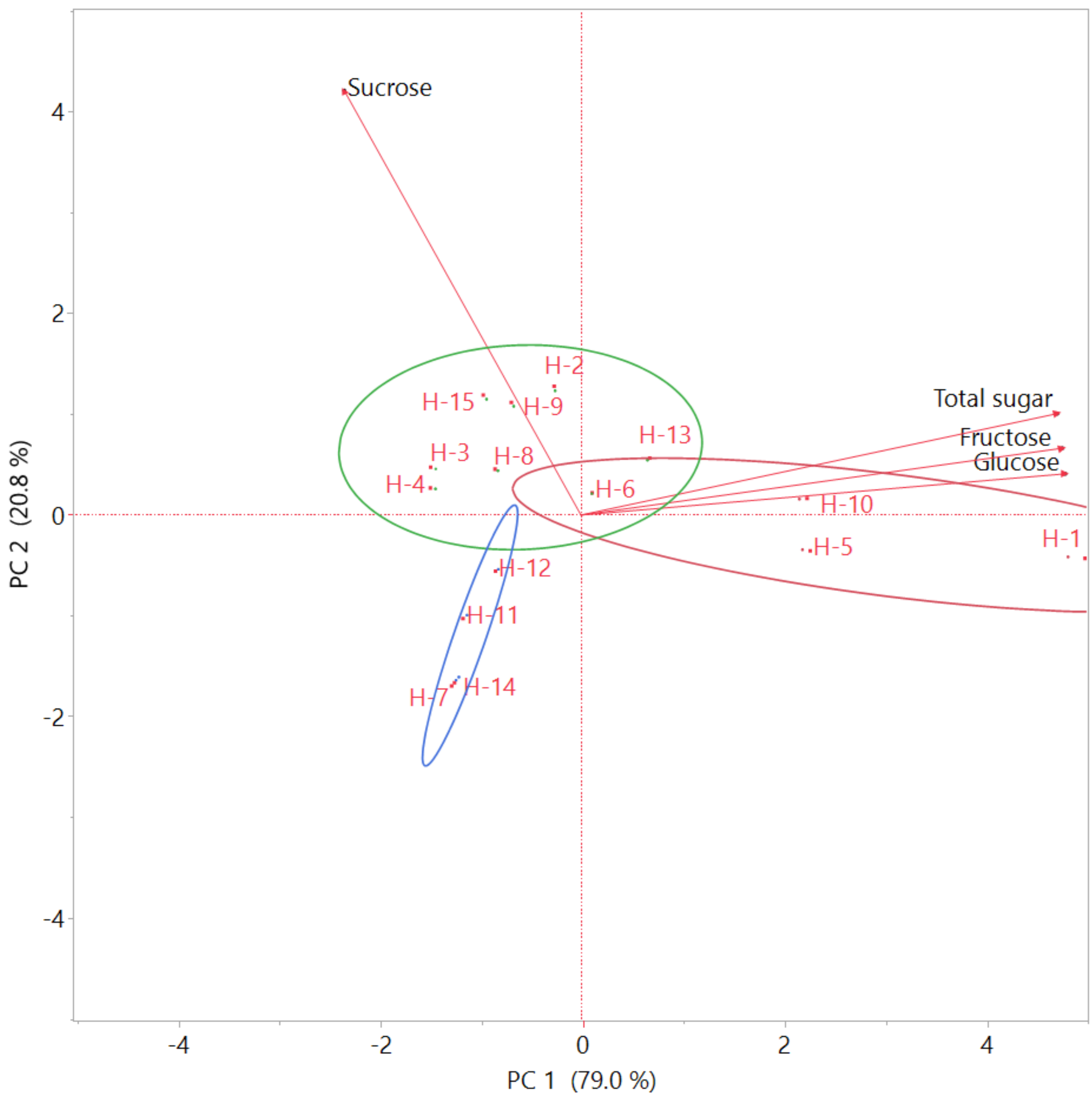

Figure 1. Biplot of the first two principal components (PCI and PC2) in the hawthorn genotypes based on sugar composition

According to the principal component analysis results, the first two components (PC1 and PC2) explained 99.8% of the total variation. PC1, which variation explains 79.0%, is related to glucose, fructose, and total sugar contents. PC2 explained 20.8% of the variation and was associated with sucrose content (Figure 1).

Two main groups (A and B) were formed in the dendrogram created depending on the sugar content of the examined hawthorn genotypes. The first main group (A) is consisted of H-1, H-5 and H-10 genotypes. The second main group (B) is divided into two sub-groups (B-1 and B-2). The first sub-group included (B-1) eight genotypes (H-2, H-3, H-4, H-6, H-8, H-9, H-13 and H-15). In the second sub-group (B-2) consisted of four genotypes (H-7, H-11, H-12 and H-14) (Figure 2). While the genotypes in the first main group were remarkable in terms of glucose, fructose and total sugar contents, the genotypes in the second main group stand out in terms of sucrose content (Figure 1).

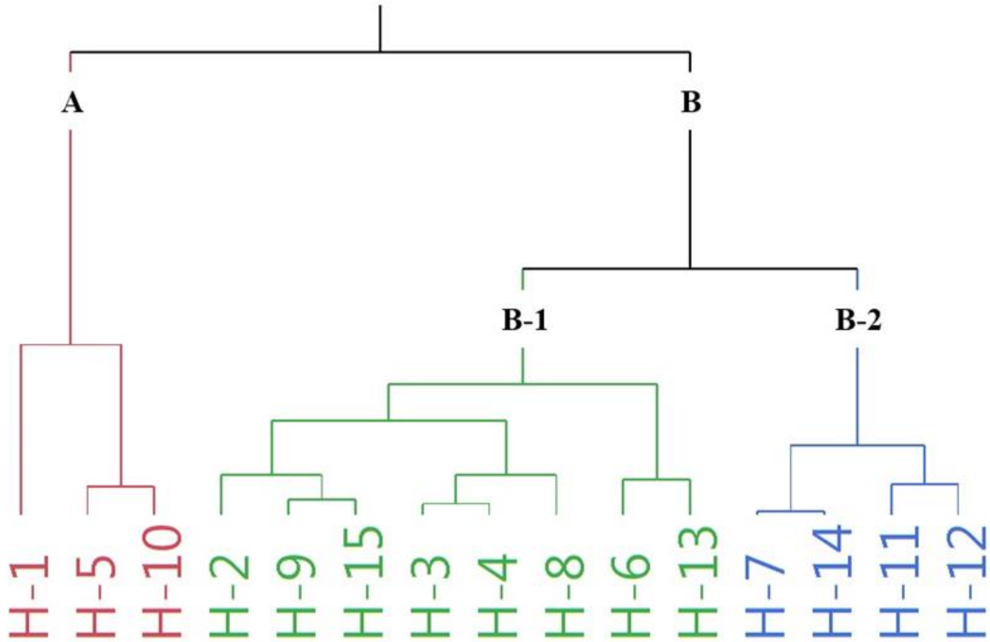

Figure 2. Dendogram of hawthorn genotypes based on sugar composition

Conclusion

In the study in which the glucose, fructose, sucrose and total sugar contents of different hawthorn species and genotypes were examined, significant differences were determined among the species and genotypes examined in terms of these characteristics. Based on species, *Crataegus pontica* was remarkable in terms of glucose, fructose, and total sugar content, and *Crataegus aronia* in terms of sucrose content. H-1 genotype in *Crataegus pontica* species had higher values than other genotypes in glucose, fructose, and total sugar content. As a result, the findings showed that the hawthorn species and genotypes examined in terms of sugars that contribute to the sweetness of the fruit and play an important role in the effects of the fruit on human health have significant potential. In addition, it is recommended to carry out more detailed studies to demonstrate the benefits of these species and genotypes to human health.

Conflicts of Interest

The authors declare no conflict interest.

Authorship contribution statement

MFB: Contributed to the planning of the research, the methodology, the evaluation of the data and the writing of the article.

OK: Contributed to the statistical analysis, the laboratory analyzes and the writing of the article.

TY: Contributed to the planning of the research, the evaluation of the data.

FB: Contributed to the planning of the research, the methodology, the evaluation of the data.

SU: Contributed to the laboratory analyzes and the writing of the article.

Kaynaklar

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