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Agro-Morphological and Biochemical Characterization of Wild *Prunus spinosa* L. Subsp. *dasyphylla* (Schur) Domin Genotypes Naturally Grown in Western Black Sea Region of Turkey

Selma Kuru Berk [1], Akgul Tas [2], Erdal Orman [3], Muttalip Gundogdu [4], Tomas Necas [5,*], Ivo Ondrasek [5], Neva Karatas [6] and Sezai Ercisli [7]

1 Department of Plant and Animal Production, Mudurnu Sureyya Astarcı Vocational School, Bolu Abant Izzet Baysal University, Bolu 14300, Turkey; selmakuru61@hotmail.com
2 Department of Plant and Animal Production, Seben İzzet Baysal Vocational School, Bolu Abant Izzet Baysal University, Bolu 14300, Turkey; akgultas1438@gmail.com
3 Atatürk Horticultural Central Research Institute, Yalova 77100, Turkey; e.orman77@gmail.com
4 Department of Horticulture, Faculty of Agriculture, Bolu Abant Izzet Baysal University, Bolu 14300, Turkey; gundogdumuttalip@gmail.com
5 Department of Fruit Science, Faculty of Horticulture in Lednice, Mendel University Brno, 691 44 Lednice, Czech Republic; ivo.ondrasek@mendelu.cz
6 Department of Nutrition and Dietetics, Faculty of Health Sciences, Ataturk University, Erzurum 25240, Turkey; ngungor@atauni.edu.tr
7 Department of Horticulture, Faculty of Agriculture, Ataturk University, Erzurum 25240, Turkey; sercisli@gmail.com
* Correspondence: tomas.necas@mendelu.cz; Tel.: +420-519367244

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Abstract: In this study, agro-morphological, sensory and biochemical characteristics of 23 plum genotypes belonging to *Prunus spinosa* L. subsp. *dasyphylla* (Schur) Domin growing wild in the West Black Sea Region in Turkey were investigated. Agro-morphological, sensory and biochemical properties of genotypes were highly different from each other. Principal component analysis was performed to determine the correlation between these properties and genotypes. The variation in the study was determined to be 63.5% in agro-morphological properties, 53.8% in organic acids and 46% in phenolic compounds. In terms of fruit weight, 14BLM08 genotype (38.42 g) was determined to be superior to other genotypes. The fruit firmness value, which is important in the storage of fruits, was recorded as the highest in the 14BLM14 genotype (9.07 kg/cm^2). Chlorogenic acid was higher than the other phenolic compounds and the highest value was obtained in the 14BLM20 (11.45 mg/kg) genotype. It was recorded that the value of malic acid, which is the major organic acid of the plums, varied between 269.65–1294.64 mg/100 g. Genotypes showed diverse vitamin C content, and the highest value was found in the 14BLM18 genotype as 54.42 mg/100g. Each genotype showed superiority according to the type of traits, and thus breeders may have used these genotypes as the superior ones for specific plum breeding purposes. In addition, these genotypes could be satisfactorily used in domestication.

Keywords: plum; wild genotypes; phenolic compounds; organic acids; physicochemical properties

1. Introduction

Dependent on the continuous increase in the human population in the world, there will be difficulties in providing enough food. In this sense, fruits have an important place in both nutrition and human health [1–4].

Plums are among the major groups within the temperate climate fruit species in Turkey. Except for some very hot-dry areas of Southeast Anatolia and high plateaus of Eastern Anatolia region in Turkey, plums are grown in a wide variety of areas starting from the southeast through Anatolia, Aegean and Mediterranean regions and extending to various eco-geographical conditions. According to 2018 FAO (Food and Agriculture Organization of the United Nations) data, total plum production is 12,608,678 tons in the world. China ranks first with 6,788,107 tons of production, while Romania ranks second with 842,132 ton production amount. Turkey ranks sixth in the world with the production of 296,878 tons of plum [5]. With the high number of plum species, the origin of these species from different climatic regions has played an important role in the wide spread of this fruit species in the world. Anatolia has a very important place, as it is the gene center of some plum species and it serves as a bridge for some of them to spread to world countries [6]. *Prunus spinosa* (Blackthorn or Sloe) is native to Europe and Western Asia covering Turkey, Iran, Caucasus and locally in northwest Africa. It is a deciduous thorny shrub growing up to 4 m tall, with blackish bark and dense, stiff, spiny branches. The plants are the dwarf of a growth habit and resistant to pests, diseases and abiotic stress conditions in field. The fruit is a drupe 10–12 mm diameter, black with a pale purple-blue waxy bloom, and ripens in autumn; it is thin-fleshed, with a very strongly astringent flavor when fresh [7]. *P. spinosa* is represented by subsp. *dasyphylla* (Schur) Domin in southern and the southeastern part of the distribution range. As a variable species in its agro-morphological characters, it is well adapted to different habitats and reaches elevations of 2200 m [8]. *P. spinosa* L. subsp. *dasyphylla* does not occur in the Mediterranean region or in the drier parts of east and south-east Anatolia. It has certain ecological preferences characterized by a wet climate and grows well in humid places of the western Black Sea, Thrace, Aegean region and central Anatolia [9].

Plum fruit, whose cultural history dates back to ancient civilizations, is one of the fruits whose popularity is constantly increasing among the other fruit species and is inevitable in the industrial sector. It has been emphasized by many researchers that the fruits of plum species are important in human health and nutrition due in particular to its relatively high total phenolic content and total antioxidant capacity [10–16]. Plum is considered one of the most important fruits in the market due to the growing interest of consumers [17]. Biochemical compounds in plums have been reported to have beneficial effects on the human body [18]. Free radicals are known to be compounds that can cause many diseases and pose a threat to human health [19]. Accordingly, plum fruits are an important source of antioxidants that have the potential to neutralize free radicals [20]. Polyphenols in plums and other plant products play a role in protecting cells and cell organs by acting against chronic diseases, coronary heart disease and type 2 diabetes [21,22]. Phenolic compounds are present in almost every fruit and vegetable in large or small amounts. The demand for fruits containing anthocyanidins and anthocyanins is increasing as flavonoids have been reported as having an anticarcinogenic effect [23]. Çelik et al. [14] reported that plum fruits are rich in phenolic compounds and organic acids. Phenolic compounds are effective in creating the flavor of products, especially in the formation of a bitter taste in the mouth. Anthocyanins, one of the phenolic substances, provide the unique colors of fruits and vegetables. Phenolic compounds, which have an important effect on the fruit juice processing industry, are also effective in the clouding of beverages such as fruit juices and wine and forming residue [24]. Since the ratio of the total acid content of the fruits to the sugar content is a criterion of maturity, organic acids play an important role in the ripening of fruits, taste formation and many physiological events. In addition, since organic acids form complexes with heavy metal ions, they prevent their oxidation catalytic effects [14].

In this study, the agro-morphological, sensory and biochemical characteristics of 23 plum genotypes belonging to *Prunus spinosa* L. subsp. *dasyphylla* (Schur) Domin grown as wild forms in the Bolu (Turkey) provinces in western Turkey were investigated. It was also aimed to obtain information on

wild grown plums for developing and producing superior genotypes, as well as preventing the loss of this crucial genetic diversity of plums.

2. Materials and Methods

2.1. Plant Materials

Bolu, where the research was conducted, is a province in northwestern Turkey and many fruit species with a temperate climate are grown there. The high mountainous and dense forest structure of the area has led to the diversity of microclimate areas. Plum (*Prunus spinosa* L. subsp. *dasyphylla* (Schur) Domin) are widely wildly grown in this region. The fruit and leaf samples taken from each plum genotypes (per wild grown plant in the field represented by one genotype) from Mudurnu town belongs to Bolu province. Samples were labeled and put into boxes placed in appropriate containers and immediately transferred to the laboratory. The Mudurnu was selected as the sampling site because it has the richest *Prunus spinosa* L. subsp. *dasyphylla* (Schur) Domin populations in Bolu province. The plants were identified by Dr. Ismail Eker, Biology department of Bolu Abant Izzet Baysal University. The herbarium specimens were deposited in the Biology Department of Bolu Abant Izzet Baysal University. Fruit samples to be used for biochemical analysis were kept in the ultra-low temperature chest freezers at −80 °C until analysis. Samples were taken from trees with larger attractive fruits, higher fruit loads and free from pest and disease characteristics. The fruits were harvested at full ripening (optimal consumption maturity) stage. The genotypes were labeled from 14BLM01 to 14BLM23, indicating that 14 is the city plate number for Bolu city, with BL as the abbreviation of Bolu and M as the abbreviation of Mudurnu town. One to 23 are the genotype numbers of *Prunus spinosa* L. subsp. *dasyphylla* (Schur) Domin.

2.2. Determination of Agro-Morphological Properties of Fruits

Some agro-morphological properties of plum genotypes were investigated. Average fruit weight and stone weight of 30 fruits taken randomly from each genotype were determined with 0.1 g sensitive scales. Fruit length, fruit width, fruit thickness stone width, stone length, fruit stalk length and fruit stalk thickness were determined with a 0.01-mm sensitive digital caliper. Fruit width/fruit length ratio were used to determine fruit shape. pH was determined with a pH meter. Total soluble solid (TSS) was determined by a hand refractometer. Fruit firmness was measured by a hand penetrometer. A titration method was used to determine titratable acidity (TA).

2.3. Extraction of Organic Acids

In this study, about 300 g of each sample was fragmented and 30 g from each sample was transferred to a centrifuge tube, then diluted 1:3 with distilled water. The 25 mL of 0.009 N H_2SO_4 was added to samples and then the samples were homogenized with a crusher (Heidolph Silent Crusher M, Berlin, Germany) and mixed for an hour with a shaker (Heidolph Unimax 1010, Berlin, Germany). After centrifugation at 15000× *g* for 15 min, the supernatant was passed through coarse filter paper, twice in 0.45 µm membrane filter (Millex-HV Hydrophilic PVDF, Millipore, Taufkirchen, Germany), and last in the SEP-PAK C18 cartridge. The concentration of organic acids was determined by HPLC using an Aminex column (HPX-87H, 300 mm × 7.8 mm, Bio-Rad) fitted on an 1100 series HPLC (Agilent Technologies, Waldbronn, Germany). Organic acids were detected at both 254 nm and 280 nm wavelengths. As the mobile phase, 0.009 N H2SO4 was passed through a 0.45 µm filter membrane [25].

2.4. Extraction of Phenolics

The phenolic compounds in plum fruits were determined following the procedure described by Rodriguez-Delgado et al. [26]. About 50 g sample out of 300 g of fragmented sample for each sample was transferred to a centrifuge tube, mixed homogeneously, then diluted 1:1 with distilled water and centrifuged at 15,000× *g* for 15 min. The supernatant was passed through a 0.45 µm Millex-HV Hydrophilic PVDF membrane filter, then injected into the HPLC system (gradient). The chromatographic separation in Agilent 1100 series HPLC took place in a DAD (Photodiode array detector) detector (Agilent, Waldbronn, Germany) with 250 mm × 4.6 mm, 4m ODS column (HiChrom, New Jersey, USA). The following solvents in water with a flow rate of 1 mL/min and 20 µl injection volume were used for spectral measurements taken at both 254 nm and 280 nm: as mobile phase solvent A, methanol-acetic acid-water (10:2:88) and Solvent B, methanol-acetic acid-water (90:2:8).2.4.

2.5. Analysis of Vitamin C

Vitamin C content was detected based on modified HPLC procedure suggested by Cemeroglu [27]. Five milliliters of the fruit extracts was supplemented with 2.5% (w/v) metaphosphoric acid (Sigma, M6285, 33.5%, Taufkirchen, Germany), then centrifuged at 6500 rpm for 10 min at 4 °C. Furthermore, 0.5 mL of the mixture was brought to a final volume of 10 mL with 2.5% (w/v) metaphosphoric acid. Supernatants were filtered with 0.45 µm PTFE syringe filter (Millex-HV Hydrophilic PVDF, Millipore, Taufkirchen, Germany). C18 column (Phenomenex Luna C18, 250° 4.60 mm, 5 µ, Santa Clara, CA, USA) was used for identification of ascorbic acid at 25 °C. Ultra-distilled water with 1 mL/min flow rate and pH of 2.2 (acidified with H2SO4) was used as a mobile phase. Spectral measurements were made at 254 nm wavelength by using DAD detector. Different standards of L-ascorbic acid (Sigma A5960, Taufkirchen, Germany) (50, 100, 500, 1000, and 2000 ppm) were used for quantification of ascorbic acid readings.

2.6. Sensory Features of Fruits

A trained panel of five experts evaluated the sensory features (taste and aroma) of fruits for each genotype. The 0 to 9 bipolar hedonic scale was used to rate overall liking of taste and aroma, which was rated on a unipolar 0 to 9 intensity scale. For aroma it was indicated as 0 = not detectable, 1 = just barely detectable, 3 = slight, 5 = moderate, 7 = intense and 9 = extremely intense. The term "aromatics" was used to denote all flavor components not covered by sweetness and sourness; no specific aromas were expected to be identified. For taste, the scale indicated 0 = not detectable, 1 = extremely sour, 3 = sour, 5 = sweet-sour, 7 = sweet and 9 = extremely sweet.

2.7. Statistical Analysis

Descriptive statistics, normal distribution tests, correlation analysis, and one-way variance analysis were performed with the SAS program (Statistical Analysis System). The Duncan test was used as a multiple comparison test to express the differences between the averages. In R software, the principal component analysis was used for all variables with the ggplot2 and factor extra packages [28].

3. Results and Discussion

3.1. Agro-Morphological Properties

In this study, fruit and leaf characteristics of 23 wild plum genotypes growing in nature were examined (Tables 1 and 2). It was observed that there was statistically a wide variation among genotypes in terms of fruit and leaf characteristics ($p \leq 0.05$). The highest average fruit weight was obtained from 14BLM08 genotypes as 38.42 g, while the lowest value was observed in genotype 14BL14 as 1.79 g (Table 1). The highest fruit firmness value was determined as 9.07 kg/cm^2 in 14BLM14 genotypes, while it was not detected in 14BLM02 genotypes due to the very soft fruit texture. Stone weight was

found between 0.28–1.32 g (Table 2). The highest total soluble solid was obtained from 14BLM21 genotypes as 23.33%, while the lowest value was observed in genotype 14BL14 as 9.33%. Total acidity and pH values were determined between 0.86–4.26% and 3.17–4.13, respectively. In the present study, the wild grown *Prunus spinosa* L. subsp. *dasyphylla* (Schur) Domin genotypes were readily separated from each other for taste and aroma characteristics. It has been determined that genotypes vary in fruit taste from extremely sour (9 genotypes), sour (6 genotypes), sweet-sour (4 genotypes) and sweet (4 genotypes). Among 23 genotypes, nine genotypes had medium aroma, six had high aroma and eight had very high aroma features (Table 3). Fruit breeders need a simple and inexpensive assay to identify the taste and aroma traits in breeding populations. We found a great diversity on taste and aroma characteristics on *Prunus spinosa* L. subsp. *dasyphylla* (Schur) Domin genotypes and this indicates a richness of germplasm to select better ones for special plum breeding studies. For example, to obtain more sour or sweeter plum fruits. In addition, the 0 to 9 bipolar hedonic scale was found to be useful and provided a fast and simple approach for discriminating of individuals of *Prunus spinosa* L. subsp. *dasyphylla* (Schur) Domin to detect taste and aroma variations.

In the study, it was observed that the fruit flesh of 13 genotypes was easily separated from the stone (Table 3). In the PCA (Principal Component Analysis) conducted to determine the relationship between genotypes according to agro-morphological features, the variation was found to be 63.5%. Among the genotypes, the 14BLM02 was found to be negatively differentiated from other genotypes in terms of agro-morphological characteristics (Figure 1). It was determined that 14BL08, 14BL12 and 14BL09 genotypes were generally superior in the agro-morphological characteristics such as fruit size and were located in the second area on the PCA plot. In this research, it was seen that the genotypes that stand out especially in terms of leaf characteristics were located in the fourth area on the PCA plot. Crisosto et al. [29] reported that the weight of Black Amber fruits harvested at different dates were 109.2 g, 118.0 g, 121.4 g, and 122.3 g, respectively. The same researchers reported that fruit weight is an important quantitative hereditary factor determining yield, fruit quality and consumer acceptability. In another study, it was reported that the fruit weight of plum cultivars varied from 9.81 g to 69.96 g [30]. In a study conducted in the İnegöl region in western Turkey, soluble solid ratio of plums was 11.2%, the total acidity ratio was 0.56% and the pH value was 3.65 [31]. Abaci et al. [32] reported that the soluble solid, pH and acidity contents of plum genotypes varied between 11–13.9%, 3–4 and 0.98–2.06%, respectively. In another study, the agro-morphological properties of 79 plum genotypes were examined and it was reported that fruit weight ranged from 4.97 to 42.19 g [33]. In this study, it was observed that fruit weights and sizes of plum genotypes were quite small compared to standard varieties. It is thought that the reason for this is the wild growing nature of genotypes, where no cultivation practices such as irrigation, fertilization, pruning, etc. were applied. It is expected that the genotypes that had bigger fruits such as 14BLM08 and 14BLM12 may have given bigger fruits if they were brought to cultivation conditions. It has been reported that fruits contain essential nutrients for a healthy diet, and fruit size and dry matter are important characteristics determining fruit quality [33,34]. Some researchers have reported that larger fruit quenches thirst more effectively and provides fewer calories. It has been emphasized that smaller fruits are typically sweeter and more suitable for processing, especially to produce dried fruit such as prunes [33,35].

Table 1. Some agro-morphological fruit properties of plum genotypes.

Genotypes	Coordinates	Altitude (a.s.l)	Fruit Weight (g)	Fruit Width (mm)	Fruit Length (mm)	Fruit Thickness (mm)	Fruit Firmness (kg/cm^2)	Fruit Shape Index	Fruit Stalk Length (mm)
14BLM01	40°.47′58.76′′N; 31° 21′48.34′′E	855 m	11.58 ± 0.78 fg *	25.30 ± 0.16 j	35.22 ± 0.14 c	25.70 ± 0.20 h	1.47 ± 0.09 fgh	0.72 ± 0.00 k	12.38 ± 0.43 d-h
14BLM02	40°.49′37.45′′N; 31°.22′.53.30′′E	863 m	1.79 ± 0.05 k	13.60 ± 0.05 o	14.69 ± 0.36 m	13.70 ± 0.13 o	N.D.	0.93 ± 0.02 f	4.49 ± 0.33 k
14BLM03	40°.50′27.47′′N; 31°.24′36.22′′E	875 m	14.92 ± 0.39 de	29.44 ± 0.45 ef	27.68 ± 0.31 h	29.64 ± 0.68 def	0.87 ± 0.07 h	1.06 ± 0.00 ab	9.78 ± 0.78 ij
14BLM04	40°.49′19.77′′N; 31°.30′55.38′′E	860 m	9.14 ± 0.30 hi	26.19 ± 0.30 j	24.46 ± 0.26 j	26.20 ± 0.25 h	3.23 ± 0.32 bc	1.07 ± 0.02 a	15.13 ± 0.57 bc
14BLM05	40°.73′27.36′′N; 31°.58′45.13′E	910 m	19.02 ± 0.48 c	29.17 ± 0.08 efg	35.76 ± 0.63 c	29.86 ± 1.08 de	3.33 ± 0.29 bc	0.82 ± 0.02 hi	18.66 ± 1.24 a
14BLM06	40°.49′55.89′′N; 31°.22′17.68′′E	863 m	8.82 ± 0.07 hi	22.60 ± 0.23 l	27.37 ± 0.31 h	22.75 ± 0.35 k	2.93 ± 0.18 cd	0.83 ± 0.01 hi	12.68 ± 0.27 d–g
14BLM07	40°.48′19.55′′N; 31°.30′62.84′′E	878 m	15.06 ± 0.89 de	27.33 ± 0.20 i	29.50 ± 0.19 g	28.48 ± 0.10 fg	1.07 ± 0.18 h	0.93 ± 0.01 ef	14.07 ± 0.95 cd
14BLM08	40°.38′60.81′′N; 31°.20′49.73′E	1040 m	38.42 ± 1.28 a	37.51 ± 0.11 a	37.44 ± 0.26 b	40.13 ± 0.14 a	1.73 ± 0.29 e–h	1.00 ± 0.01 cd	12.97 ± 0.75 def
14BLM09	40°.39′38.51′′N; 31°.09′80.58′′E	1008 m	13.37 ± 0.99 ef	27.96 ± 0.14 hi	26.34 ± 0.55 hi	28.91 ± 0.22 d–g	3.97 ± 0.26 b	1.06 ± 0.02 ab	13.83 ± 0.23 cde
14BLM10	40°.56′61.55′′N; 31°.32′22.46′E	880 m	16.14 ± 0.43 d	28.66 ± 0.35 fgh	29.28 ± 0.23 g	29.97 ± 0.25 d	2.30 ± 0.17 def	0.98 ± 0.01 cde	11.66 ± 0.17 fgh
14BLM11	40°.54′78.13′′N; 31°.23′50.67′E	903 m	9.34 ± 0.28 hi	24.16 ± 0.26 k	27.05 ± 0.45 hi	24.32 ± 0.35 ij	2.20 ± 0.12 d–g	0.90 ± 0.02 fg	12.66 ± 0.69 d–g
14BLM12	40°.50′0918′′N; 31°.18′39.56′E	920 m	26.41 ± 0.53 b	31.80 ± 0.10 c	39.87 ± 0.44 a	32.91 ± 0.32 c	0.97 ± 0.12 h	0.80 ± 0.01 ij	20.14 ± 0.99 a
14BLM13	40°.38′45.49′′N; 31°.33′60.45′E	1020 m	4.65 ± 0.10 j	17.92 ± 0.44 n	20.74 ± 0.31 l	18.17 ± 0.64 n	2.73 ± 0.15 cd	0.86 ± 0.01 gh	8.71 ± 0.39 j
14BLM14	40°.38′07.34′′N; 31°.21′18.35′E	1007 m	13.24 ± 0.44 ef	27.52 ± 0.21 i	27.01 ± 0.28 hi	29.07 ± 0.11 d–g	9.07 ± 0.87 a	1.02 ± 0.02 bc	10.51 ± 0.38 hij
14BLM15	40°.45′09.76′′N; 31°.29′72.09′E	845 m	19.41 ± 0.89 c	33.18 ± 0.18 b	31.14 ± 0.82 f	34.48 ± 0.20 b	3.97 ± 0.15 b	1.06 ± 0.02 ab	12.59 ± 0.34 d–g
14BLM16	40°.45′51.62′′N; 31°.19′63.68′E	861 m	13.42 ± 0.44 ef	25.42 ± 0.33 j	33.61 ± 0.35 d	25.26 ± 0.37 hi	2.33 ± 0.18 def	0.76 ± 0.00 jk	10.96 ± 0.17 ghi
14BLM17	40°.45′09.41′′N; 31°.20′19.41′E	857 m	12.96 ± 0.57 f	27.79 ± 0.35 hi	26.15 ± 0.13 hi	27.94 ± 0.33 g	3.87 ± 0.29 b	1.06 ± 0.01 ab	13.10 ± 0.32 def
14BLM18	40°.53′30.70′′N; 31°.35′36.37′E	1105 m	15.09 ± 0.61 de	30.58 ± 0.25 d	32.84 ± 0.52 de	28.59 ± 0.35 efg	2.33 ± 0.24 def	0.93 ± 0.01 ef	9.12 ± 0.67 ij
14BLM19	40°.52′03.16′′N; 31°.20′86.23′E	853 m	5.38 ± 0.31 j	19.50 ± 0.31 m	21.39 ± 0.27 kl	19.66 ± 0.17 m	2.07 ± 0.18 d–g	0.91 ± 0.00 f	9.36 ± 0.42 ij
14BLM20	40°.50′45.23′′N; 31°.10′19.12′E	850 m	19.01 ± 1.11 c	28.32 ± 0.20 ghi	35.76 ± 1.09 c	28.27 ± 0.53 g	2.50 ± 0.21 cde	0.80 ± 0.03 ij	16.58 ± 0.48 b

Table 1. *Cont.*

Genotypes	Coordinates	Altitude (a.s.l)	Fruit Weight (g)	Fruit Width (mm)	Fruit Length (mm)	Fruit Thickness (mm)	Fruit Firmness (kg/cm^2)	Fruit Shape Index	Fruit Stalk Length (mm)
14BLM21	40°.52′34.23′′N; 31°.23′60.15′′E	865 m	10.13 ± 0.05 gh	23.69 ± 0.33 k	25.62 ± 0.64 ij	23.79 ± 0.41 jk	1.20 ± 0.23 h	0.93 ± 0.03 f	14.15 ± 0.32 cd
14BLM22	40°.45′08.03′′N; 31°.25′56.34′′E	835 m	7.49 ± 0.43 i	22.54 ± 0.65 l	22.67 ± 1.22 k	21.18 ± 0.30 l	1.33 ± 0.18 gh	1.00 ± 0.02 cd	11.98 ± 1.01 e–h
14BLM23	40°.51′70.91′′N; 31°.17′56.19′′E	840 m	16.74 ± 0.59 d	29.77 ± 0.76 de	31.49 ± 0.34 ef	28.49 ± 0.56 fg	2.20 ± 0.15 d–g	0.95 ± 0.02 def	9.07 ± 0.34 ij

*: Different letters in columns indicate significantly different values at $p \leq 0.05$. N.D: Not detected.

Table 2. Stone and leaf characteristics of plum genotypes.

Genotypes	Stone Weight (g)	Stone Length (mm)	Stone Width (mm)	Leaf Width (cm)	Leaf Length (cm)	Leaf Stalk Length (mm)	Leaf Stalk Thickness (mm)
14 BLM 01	0.77 ± 0.06 fgh *	17.44 ± 0.03 de	9.96 ± 0.12 ef	4.03 ± 0.24 c	6.65 ± 0.25 d	16.55 ± 0.59 c–f	1.12 ± 0.06 bcd
14 BLM 02	0.28 ± 0.00 l	9.14 ± 0.20 l	7.35 ± 0.39 h	1.27 ± 0.07 h	3.20 ± 0.10 k	5.75 ± 0.33 l	0.60 ± 0.03 k
14 BLM 03	0.67 ± 0.02 g–j	12.46 ± 0.41 ijk	10.74 ± 0.13 de	2.67 ± 0.09 fg	5.08 ± 0.12 f–i	10.71 ± 0.98 jk	0.88 ± 0.02 fgh
14 BLM 04	0.59 ± 0.03 h–k	12.38 ± 0.30 ijk	10.02 ± 0.04 ef	3.20 ± 0.25 ef	4.63 ± 0.04 hij	14.77 ± 1.17 e–h	0.72 ± 0.07 h–k
14 BLM 05	1.28 ± 0.09 b	23.96 ± 0.32 b	12.86 ± 0.33 b	4.85 ± 0.34 a	9.10 ± 0.28 a	17.84 ± 1.04 bcd	1.23 ± 0.11 bc
14 BLM 06	0.80 ± 0.03 efg	18.04 ± 0.26 de	10.43 ± 0.07 de	3.90 ± 0.15 c	5.73 ± 0.11 ef	16.79 ± 0.58 b-f	1.06 ± 0.02 cde
14 BLM 07	1.15 ± 0.03 bc	18.79 ± 0.33 d	12.18 ± 0.22 b	4.30 ± 0.25 bc	7.47 ± 0.35 bc	13.20 ± 1.29 g–j	0.83 ± 0.09 f–j
14 BLM 08	0.80 ± 0.06 efg	14.97 ± 0.99 fg	10.27 ± 0.75 de	2.52 ± 0.19 g	4.73 ± 0.36 g–j	12.58 ± 0.73 h–k	0.65 ± 0.04 jk
14 BLM 09	0.63 ± 0.09 g–j	12.12 ± 0.25 jk	10.64 ± 0.55 de	3.77 ± 0.09 cd	6.83 ± 0.37 cd	17.66 ± 1.04 b-e	1.24 ± 0.03 b
14 BLM 10	0.73 ± 0.09 f–j	13.56 ± 0.53 g–j	11.20 ± 0.16 cd	2.58 ± 0.09 g	4.75 ± 0.09 g–j	12.76 ± 0.86 h–k	0.83 ± 0.02 f–j
14 BLM 11	0.54 ± 0.04 jk	15.33 ± 0.61 f	10.87 ± 0.26 de	2.85 ± 0.09 efg	4.63 ± 0.09 hij	16.18 ± 1.46 def	0.65 ± 0.02 jk
14 BLM 12	1.70 ± 0.02 a	25.86 ± 0.44 a	14.80 ± 0.33 a	3.33 ± 0.16 de	6.20 ± 0.38 de	17.85 ± 0.28 bcd	0.87 ± 0.03 f–i
14 BLM 13	0.44 ± 0.03 kl	13.18 ± 0.21 h–k	9.05 ± 0.11 fg	2.58 ± 0.21 g	4.22 ± 0.25 j	9.82 ± 0.88 k	0.69 ± 0.05 ijk
14 BLM 14	0.74 ± 0.02 f–i	14.88 ± 0.12 fg	11.07 ± 0.47 d	2.42 ± 0.25 g	4.13 ± 0.29 j	13.92 ± 0.87 f–i	0.69 ± 0.05 ijk
14 BLM 15	0.69 ± 0.02 f–j	14.35 ± 0.02 fgh	12.43 ± 0.21 b	2.58 ± 0.11 g	4.18 ± 0.06 j	12.29 ± 0.41 h–k	0.80 ± 0.02 g–j
14 BLM 16	1.03 ± 0.09 cd	21.78 ± 0.31 c	11.19 ± 0.20 cd	4.03 ± 0.04 c	6.08 ± 0.34 de	21.10 ± 0.36 a	0.78 ± 0.01 g-k
14 BLM 17	0.97 ± 0.15 cde	16.79 ± 0.34 e	12.45 ± 0.10 b	2.97 ± 0.16 efg	4.47 ± 0.23 ij	17.58 ± 1.43 b-e	0.65 ± 0.01 jk
14 BLM 18	0.88 ± 0.02 def	17.49 ± 0.43 de	12.12 ± 0.15 bc	2.87 ± 0.12 efg	4.83 ± 0.27 g–j	18.25 ± 1.00 a-d	0.96 ± 0.02 d–g
14 BLM 19	0.56 ± 0.02 ijk	13.69 ± 0.49 ghi	9.97 ± 0.07 ef	2.98 ± 0.15 efg	5.42 ± 0.18 e–h	12.08 ± 0.64 h–k	0.74 ± 0.04 h–k
14 BLM 20	1.32 ± 0.05 b	25.30 ± 0.22 a	14.03 ± 0.31 a	4.63 ± 0.12 ab	7.97 ± 0.45 b	19.83 ± 1.05 ab	1.52 ± 0.09 a
14 BLM 21	1.01 ± 0.02 cd	18.88 ± 0.30 d	12.91 ± 0.15 b	2.88 ± 0.12 efg	5.18 ± 0.06 f–i	11.72 ± 0.62 ijk	0.93 ± 0.06 efg
14 BLM 22	0.31 ± 0.00 l	11.95 ± 0.33 k	8.45 ± 0.21 g	4.20 ± 0.26 bc	4.90 ± 0.31 g–j	15.97 ± 1.49 d–g	0.99 ± 0.08 def
14 BLM 23	0.89 ± 0.10 def	17.21 ± 1.22 e	12.35 ± 0.60 b	2.77 ± 0.20 efg	5.53 ± 0.09 efg	19.40 ± 0.50 abc	1.10 ± 0.11 b-e

*: Different letters in columns indicate significantly different values at $p \leq 0.05$.

Table 3. Biochemical and sensory properties of plum fruits.

	TSS (%)	pH	Total Acidity (%)	Taste	Aroma	Stone Separation from Flesh
14 BLM 01	17.47 ± 0.35 def *	3.93 ± 0.03 bc	1.11 ± 0.06 jk	5.7± 0.2 c	7.1± 0.4 b	Very difficult
14 BLM 02	19.00 ± 1.10 bcd	3.47 ± 0.07 gh	3.01 ± 0.37 b	3.3± 0.2 d	5.2± 0.3 bc	Difficult
14 BLM 03	16.40 ± 0.31 fgh	3.47 ± 0.03 gh	2.06 ± 0.04 efg	3.5± 0.3 d	8.9± 0.5 a	Easy
14 BLM 04	11.40 ± 0.60 j	4.13 ± 0.07 a	1.90 ± 0.04 fgh	3.2± 0.1 d	8.8± 0.5 a	Difficult
14 BLM 05	19.13 ± 1.16 bcd	4.07 ± 0.03 ab	1.77 ± 0.03 f–i	5.1± 0.4 c	6.9± 0.3 bc	Easy
14 BLM 06	18.00 ± 0.23 def	4.07 ± 0.07 ab	1.69 ± 0.09 ghi	5.0± 0.3 c	6.9± 0.3 bc	Easy
14 BLM 07	18.53 ± 0.29 cde	3.67 ± 0.13 ef	1.08 ± 0.04 jk	5.9± 0.2 c	8.8± 0.6 a	Easy
14 BLM 08	15.60 ± 0.31 gh	3.43 ± 0.03 gh	1.02 ± 0.04 jk	5.6± 0.1 c	5.2± 0.4 bc	Difficult
14 BLM 09	13.27 ± 0.41 i	3.77 ± 0.03 de	1.10 ± 0.05 jk	5.4± 0.4 c	5.3± 0.2 bc	Very easy
14 BLM 10	16.33 ± 0.24 fgh	3.37 ± 0.03 h	2.17 ± 0.08 def	3.5± 0.3 d	8.7± 0.5 a	Easy
14 BLM 11	15.47 ± 0.29 h	3.57 ± 0.03 fg	1.57 ± 0.09 hi	5.0± 0.2 c	8.8± 0.3 a	Very easy
14 BLM 12	19.93 ± 0.58 bc	4.13 ± 0.07 a	0.87 ± 0.04 k	9.0± 0.7 a	5.4± 0.2 bc	Easy
14 BLM 13	13.47 ± 0.29 i	3.40 ± 0.00 gh	2.47 ± 0.18 cde	3.2± 0.2 d	5.0± 0.2 c	Easy
14 BLM 14	9.33 ± 0.18 k	3.33 ± 0.03 h	2.06 ± 0.08 efg	3.1± 0.1 d	9.0± 0.6 a	Easy
14 BLM 15	13.07 ± 0.18 i	3.33 ± 0.03 h	2.88 ± 0.09 bc	3.1± 0.1 d	5.3± 0.2 bc	Middle
14 BLM 16	18.40 ± 0.31 cde	3.83 ± 0.03 cd	0.89 ± 0.09 k	8.8± 0.2 a	8.7± 0.4 a	Very easy
14 BLM 17	13.67 ± 0.24 i	3.17 ± 0.03 i	4.26 ± 0.47 a	3.0± 0.2 d	5.5± 0.1 bc	Easy
14 BLM 18	20.33 ± 0.48 b	3.87 ± 0.03 cd	1.44 ± 0.03 ij	6.9± 0.4 b	8.8± 0.3 a	Very easy
14 BLM 19	17.20 ± 0.46 efg	3.57 ± 0.09 fg	2.10 ± 0.06 efg	3.7± 0.2 d	5.2± 0.2 bc	Difficult
14 BLM 20	18.40 ± 0.31 cde	3.93 ± 0.03 bc	0.86 ± 0.03 k	8.9± 0.6 a	7.7± 0.3 b	Easy
14 BLM 21	23.33 ± 0.29 a	3.53 ± 0.03 fg	2.57 ± 0.11 cd	5.0± 0.2 c	7.3± 0.3 b	Easy
14 BLM 22	12.47 ± 0.29 ij	3.57 ± 0.03 fg	2.05 ± 0.07 efg	3.3± 0.1 d	7.4± 0.3 b	Easy
14 BLM 23	24.33 ± 1.35 a	3.93 ± 0.03 bc	1.09 ± 0.04 jk	8.9± 0.5 a	5.3± 0.2 bc	Easy

*: Different letters in columns indicate significantly different values at $p \leq 0.05$.

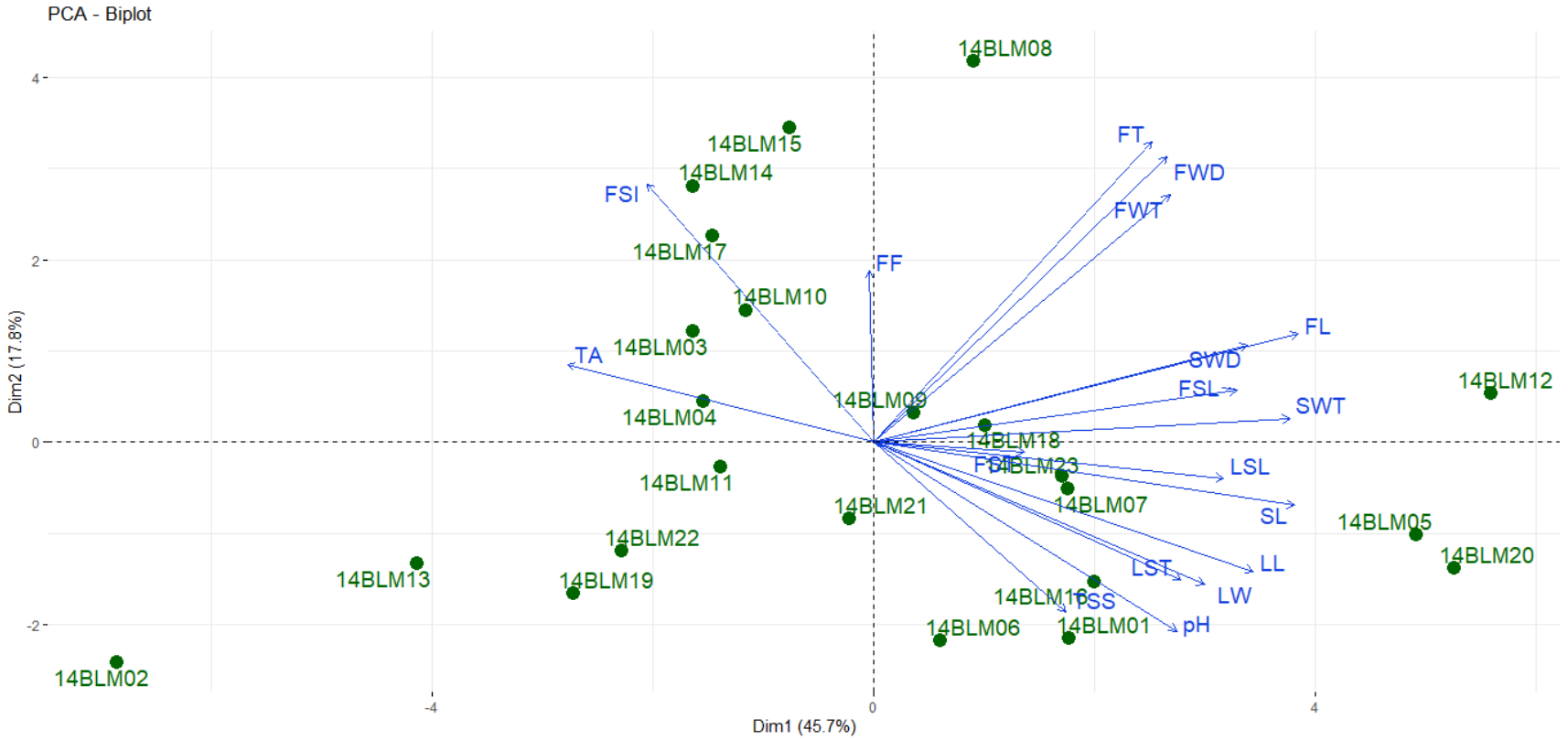

Figure 1. Distribution of genotypes according to agro-morphological characteristics. FWT: Fruit weight; FWD: Fruit width; FL: Fruit length; FT: Fruit thickness; FF: Fruit firmness; FSI: Fruit shape index; FSL: Fruit stalk length; FST: Fruit stalk thickness; SW: Stone weight; SL: Stone length; SW: Stone width; LW: Leaf width; LL: Leaf length; LSL: Leaf stalk length; LST: Leaf stalk thickness; TSS: Total soluble solid; TA: Total acidity.

3.2. Phenolic Compounds

Phenolic compounds play a role in many physiological events such as color and taste formation in plants. Among these compounds that affect fruit quality, gallic, protocatechuic, catechin, chlorogenic, rutin, phloridzin, ferulic, o-coumaric, p-coumaric, vanillic, caffeic and syringic acid compounds were determined. It has been observed that phenolic compounds show a wide variation based on wild plum genotypes. The differences between plum genotypes in terms of phenolic compound contents were statistically significant at the $p \leq 0.05$ level (Tables 4 and 5). In this study, it was determined that the chlorogenic acid content of the examined genotypes was generally higher than the other phenolics. The highest chlorogenic acid content was obtained from 14BLM20 as 11.45 mg/kg, while the lowest chlorogenic acid content was determined in the 14BLM16 genotype as 1.18 mg/kg. Gallic acid, protocatechuic acid and catechin contents ranged from 0.49 mg/kg (14BLM09) to 3.10 mg/kg (14BLM12), 0.45 mg/kg (14BLM12) to 5.27 mg/kg (14BLM22) and 0.57 mg/kg (14BLM11) to 6.78 mg/kg (14BLM15), respectively. The variation was determined as 46% by the principal component analysis performed to determine the relationship between phenolic compounds and genotypes. When looking at the PCA plot, it was seen that most of the genotypes were concentrated in the first and third areas (Figure 2). It was observed that the distribution of phenolic compounds was concentrated in the second and fourth areas. Coumaric acid (*p*, *o*) group showed parallelism among themselves, and there was a negative correlation between them and vanillic acid. We found a parallel relationship between catechin, chlorogenic acid, rutin and phloridzin. It was determined that ferulic acid was close to the middle of the PCA plot and has a value close to the average of all phenolics. Lombardi-Boccia et al. [36] reported that protocatechuic, caffeic, ferulic and chlorogenic acid in plum fruits were 0.6 mg kg^{-1}, 22.6 mg kg^{-1}, acid 9.3 mg kg^{-1} and 37.5 mg kg^{-1}, respectively. Treutter et al. [37] reported that the rutine, chlorogenic acid, *p*-coumaric acid and catechin content of the fruits of the Jojo plum variety found 66.1 mg 100 g^{-1}, 17.4 mg 100 g^{-1}, 3.8 mg 100 g^{-1} and 0.2 mg 100 g^{-1}, respectively. In the study conducted by Gündüz and Onur [38], they emphasized that the total phenolic content of the Papaz plum variety was 294.2 mg GAE/kg fresh weight base. Mikulic-Petkovsek et al. [39] conducted a study to determine the phenolic compound of different plums and they reported that the catechin and *p*-coumaric acid were found as 6.33 mg/kg and 7.72 mg/kg, respectively. It has been demonstrated in other studies that plum fruits are rich in phenolic compounds and are important in terms of health [14,40]. Results obtained in this study were generally in agreement with previous findings of researchers. It is thought that the biochemical differences are affected by several factors such as environmental conditions, namely temperature, humidity, atmosphere, altitude, etc. Those have a major impact on the appearance, texture, composition and eating quality of fruits. Genetic factors of genotypes, in particular heritable traits, also strongly affects biochemical content in fruits [41–46]. Flavanol licosides, which are phenolic substances, are slightly yellow in color and are found in almost every plant. Light is required for the synthesis of these compounds, which are found more heavily in the peel of fruits [47]. Fruit breeding programs have mostly concentrated on yield improvement, resistance to diseases, tolerance to biotic and abiotic stresses, longer shelf life, early or late production and varietal diversification. However, consumers are increasingly becoming aware of the potential benefits resulting from diets rich in fruits for maintaining a good health and preventing diseases. Fruits represent a major source of phenolic acids, which are powerful antioxidants characterized by an organic carboxylic acid function and which present multiple properties beneficial for human health. In consequence, developing new varieties with enhanced content in phenolic acids is an increasingly important breeding objective. Results showed that *Prunus spinosa* L. subsp. *dasyphylla* (Schur) Domin genotypes, in particular 14BLM05, 14BLM07, 14BLM11, 14BLM12, 14BLM13, 14BLM15, 14BLM16, 14BLM20 and 14BLM22, exhibited higher phenolic content than the other genotypes. This finding is important because those genotypes are ready materials to use in plum breeding to increase fruit bioactive phenolic acids.

Table 4. Phenolic compounds of plum fruits (mg/kg).

Genotypes	Gallic Acid	Protocatechuic Acid	Catechin	Chlorogenic Acid	Rutin	Phloridzin
14 BLM 01	1.63 ± 0.06 e *	0.59 ± 0.01 j	1.97 ± 0.05 h	4.18 ± 0.08 j	0.69 ± 0.09 ijk	0.73 ± 0.03 fgh
14 BLM 02	0.61 ± 0.03 jk	0.48 ± 0.04 j	0.95 ± 0.03 l	7.69 ± 0.03 e	0.95 ± 0.03 g	0.74 ± 0.03 fgh
14 BLM 03	0.65 ± 0.04 ij	1.45 ± 0.02 fg	2.52 ± 0.06 f	2.21 ± 0.06 k	0.44 ± 0.03 m	0.59 ± 0.04 jkl
14 BLM 04	0.82 ± 0.08 h	0.65 ± 0.04 ij	1.11 ± 0.08 k	2.07 ± 0.04 kl	0.45 ± 0.04 m	0.47 ± 0.03 mn
14 BLM 05	2.67 ± 0.06 b	0.95 ± 0.01 hi	1.12 ± 0.04 k	9.91 ± 0.03 b	1.66 ± 0.03 cd	1.20 ± 0.05 cd
14 BLM 06	0.77 ± 0.04 hi	1.24 ± 0.08 gh	2.21 ± 0.05 g	1.62 ± 0.07 mn	0.74 ± 0.04 ij	0.36 ± 0.03 o
14 BLM 07	1.46 ± 0.02 f	1.32 ± 0.03 g	0.71 ± 0.03 mn	8.27 ± 0.18 d	0.55 ± 0.01 klm	0.76 ± 0.03 efg
14 BLM 08	1.02 ± 0.08 g	0.75 ± 0.04 ij	2.57 ± 0.10 f	4.32 ± 0.04 j	1.75 ± 0.01 c	0.38 ± 0.03 no
14 BLM 09	0.49 ± 0.04 k	0.72 ± 0.03 ij	1.93 ± 0.04 h	6.22 ± 0.04 h	0.82 ± 0.06 hi	0.68 ± 0.02 g–j
14 BLM 10	0.81 ± 0.03 h	0.63 ± 0.02 ij	5.45 ± 0.06 b	5.32 ± 0.06 i	2.65 ± 0.04 a	0.81 ± 0.02 ef
14 BLM 11	1.92 ± 0.02 d	3.95 ± 0.05 c	0.57 ± 0.02 n	6.84 ± 0.01 g	1.65 ± 0.04 cd	1.52 ± 0.05 a
14 BLM 12	3.10 ± 0.04 a	0.45 ± 0.01 j	3.51 ± 0.08 d	1.48 ± 0.07 no	1.45 ± 0.03 e	0.84 ± 0.05 e
14 BLM 13	2.75 ± 0.07 b	0.73 ± 0.01 ij	3.68 ± 0.03 c	9.78 ± 0.27 b	1.49 ± 0.01 e	0.53 ± 0.02 klm
14 BLM 14	1.05 ± 0.04 g	0.56 ± 0.05 j	0.66 ± 0.04 n	1.84 ± 0.06 lm	1.53 ± 0.05 de	1.24 ± 0.01 c
14 BLM 15	0.52 ± 0.02 jk	4.46 ± 0.06 b	6.78 ± 0.10 a	7.22 ± 0.04 f	2.12 ± 0.04 b	1.42 ± 0.04 b
14 BLM 16	2.29 ± 0.01 c	3.47 ± 0.43 d	1.41 ± 0.05 j	1.18 ± 0.08 o	1.17 ± 0.03 f	0.53 ± 0.02 klm
14 BLM 17	1.65 ± 0.04 e	2.09 ± 0.08 e	3.23 ± 0.04 e	4.06 ± 0.05 j	1.29 ± 0.03 f	1.12 ± 0.03 d
14 BLM 18	1.13 ± 0.03 g	0.70 ± 0.03 ij	0.85 ± 0.01 lm	8.76 ± 0.06 c	0.88 ± 0.02 gh	0.70 ± 0.04 ghi
14 BLM 19	1.93 ± 0.04 d	1.65 ± 0.05 f	0.64 ± 0.03 n	6.61 ± 0.04 g	0.81 ± 0.06 hi	0.64 ± 0.03 hij
14 BLM 20	1.76 ± 0.05 e	4.20 ± 0.09 bc	1.64 ± 0.04 i	11.45 ± 0.31 a	1.16 ± 0.06 f	0.45 ± 0.03 mno
14 BLM 21	1.99 ± 0.08 d	0.53 ± 0.01 j	1.15 ± 0.05 k	1.21 ± 0.06 o	0.53 ± 0.03 lm	0.72 ± 0.01 fgh
14 BLM 22	2.16 ± 0.03 c	5.27 ± 0.06 a	1.19 ± 0.09 k	6.23 ± 0.10 h	0.60 ± 0.10 jkl	0.61 ± 0.02 ijk
14 BLM 23	1.02 ± 0.07 g	0.78 ± 0.06 ij	0.86 ± 0.04 lm	5.37 ± 0.04 i	0.66 ± 0.03 jkl	0.50 ± 0.05 lm
Genotypes	**Ferulic Acid**	***O*-Coumaric Acid**	**Vanillic Acid**	**Caffeic Acid**	**Syringic Acid**	***p*-Coumaric Acid**
14 BLM 01	1.38 ± 0.05 d *	0.39 ± 0.01 c	0.32 ± 0.02 ghi	0.74 ± 0.04 k	3.68 ± 0.07 a	0.92 ± 0.04 j
14 BLM 02	0.21 ± 0.02 n	0.07 ± 0.00 j-m	0.23 ± 0.01 ijk	1.39 ± 0.05 f–i	0.69 ± 0.03 efg	1.25 ± 0.02 f
14 BLM 03	0.29 ± 0.02 mn	0.32 ± 0.02 def	0.15 ± 0.02 kl	2.51 ± 0.10 d	0.80 ± 0.05 efg	1.23 ± 0.06 f
14 BLM 04	0.25 ± 0.04 mn	0.19 ± 0.01 gh	0.19 ± 0.04 jkl	1.25 ± 0.06 g–j	0.89 ± 0.05 ef	1.21 ± 0.04 fg
14 BLM 05	1.04 ± 0.05 e	0.35 ± 0.02 cd	0.13 ± 0.01 l	1.49 ± 0.04 fg	3.61 ± 0.06 ab	0.98 ± 0.06 ij
14 BLM 06	0.76 ± 0.04 fg	0.45 ± 0.03 b	0.35 ± 0.02 fgh	1.13 ± 0.04 g–j	0.90 ± 0.03 ef	1.13 ± 0.03 fgh
14 BLM 07	0.45 ± 0.03 ijk	0.28 ± 0.03 f	0.17 ± 0.01 jkl	1.05 ± 0.02 ijk	1.48 ± 0.07 d	0.86 ± 0.02 jk
14 BLM 08	0.54 ± 0.03 hi	0.30 ± 0.03 ef	0.18 ± 0.01 jkl	1.18 ± 0.05 g–j	0.96 ± 0.03 ef	1.06 ± 0.05 hi
14 BLM 09	0.34 ± 0.04 j–n	0.05 ± 0.00 lm	0.27 ± 0.03 hij	1.08 ± 0.06 ijk	1.60 ± 0.04 d	1.53 ± 0.04 e
14 BLM 10	0.84 ± 0.03 f	0.11 ± 0.01 ijk	0.71 ± 0.06 b	1.31 ± 0.04 g–j	1.00 ± 0.03 e	1.17 ± 0.04 fgh

Table 4. *Cont.*

Genotypes	Ferulic Acid	*O*-Coumaric Acid	Vanillic Acid	Caffeic Acid	Syringic Acid	*p*-Coumaric Acid
14 BLM 11	1.95 ± 0.07 b	0.44 ± 0.01 b	0.20 ± 0.02 jkl	3.14 ± 0.07 c	3.47 ± 0.06 ab	1.20 ± 0.06 fg
14 BLM 12	1.70 ± 0.03 c	0.33 ± 0.03 de	0.20 ± 0.01 jkl	1.05 ± 0.11 ijk	3.46 ± 0.30 ab	1.66 ± 0.03 d
14 BLM 13	0.64 ± 0.05 gh	0.07 ± 0.00 j-m	0.61 ± 0.04 c	1.46 ± 0.04 fgh	1.94 ± 0.03 c	1.09 ± 0.05 ghi
14 BLM 14	0.34 ± 0.04 j–n	0.03 ± 0.00 m	0.92 ± 0.05 a	0.95 ± 0.04 jk	0.74 ± 0.04 efg	1.59 ± 0.04 de
14 BLM 15	2.25 ± 0.12 a	0.12 ± 0.01 ij	0.62 ± 0.04 c	2.24 ± 0.12 de	0.69 ± 0.05 efg	0.94 ± 0.03 j
14 BLM 16	0.64 ± 0.02 gh	0.74 ± 0.02 a	0.24 ± 0.03 ijk	4.80 ± 0.03 b	0.63 ± 0.03 fg	2.76 ± 0.04 a
14 BLM 17	0.36 ± 0.02 j-m	0.15 ± 0.01 hi	0.93 ± 0.06 a	1.70 ± 0.01 f	0.55 ± 0.04 g	0.94 ± 0.03 j
14 BLM 18	0.33 ± 0.01 k-n	0.06 ± 0.00 klm	0.16 ± 0.01 kl	1.50 ± 0.08 fg	1.29 ± 0.18 d	2.33 ± 0.01 c
14 BLM 19	0.29 ± 0.02 lmn	0.08 ± 0.00 jkl	0.26 ± 0.02 hij	1.50 ± 0.09 fg	0.53 ± 0.01 g	0.57 ± 0.02 l
14 BLM 20	0.43 ± 0.04 i–l	0.09 ± 0.01 jkl	0.44 ± 0.04 def	2.08 ± 0.10 e	2.07 ± 0.07 c	1.08 ± 0.05 hi
14 BLM 21	0.45 ± 0.05 ijk	0.19 ± 0.02 gh	0.45 ± 0.03 de	1.16 ± 0.07 g–j	0.53 ± 0.03 g	0.57 ± 0.02 l
14 BLM 22	1.35 ± 0.06 d	0.10 ± 0.01 jk	0.36 ± 0.03 efg	6.01 ± 0.45 a	1.39 ± 0.06 d	2.60 ± 0.04 b
14 BLM 23	0.47 ± 0.03 ij	0.21 ± 0.02 g	0.53 ± 0.03 cd	1.08 ± 0.03 h–k	3.33 ± 0.26 b	0.77 ± 0.01 k

*: Different letters in columns indicate significantly different values at $p \leq 0.05$.

Table 5. Organic acid and vitamin C contents of plum fruits (mg/100 g).

Genotypes	Citric Acid	Tartaric Acid	Malic Acid	Oxalic Acid	Succinic acid	Fumaric Acid	Vitamin C
14 BLM 01	74.62 ± 1.40 c *	10.07 ± 0.31 gh	686.09 ± 9.14 i	3.75 ± 0.00 ijk	59.47 ± 0.96 b	3.08 ± 0.04 h	32.96 ± 0.29 f
14 BLM 02	22.74 ± 0.21 k	30.09 ± 0.08 a	1071.62 ± 7.87 d	10.84 ± 0.34 d	52.79 ± 0.57 cd	0.88 ± 0.02 op	47.40 ± 0.49 b
14 BLM 03	11.32 ± 0.72 m	6.41 ± 0.07 l	867.33 ± 7.05 g	3.50 ± 0.25 ijk	20.80 ± 0.07 k	3.34 ± 0.05 g	29.39 ± 0.33 g
14 BLM 04	23.57 ± 0.36 k	12.59 ± 1.01 e	610.50 ± 6.29 j	3.38 ± 0.13 ijk	31.40 ± 1.59 i	2.09 ± 0.01 j	28.14 ± 1.03 gh
14 BLM 05	21.08 ± 0.42 k	10.50 ± 0.07 fg	455.42 ± 4.81 n	2.51 ± 0.04 k	54.96 ± 0.12 c	4.84 ± 0.04 c	39.12 ± 0.19 d
14 BLM 06	15.91 ± 0.49 l	7.72 ± 0.17 i–l	928.48 ± 5.39 f	3.38 ± 0.13 ijk	21.53 ± 0.08 k	0.80 ± 0.04 pr	35.86 ± 0.14 e
14 BLM 07	85.45 ± 0.89 a	7.84 ± 0.10 ijk	562.01 ± 7.15 l	4.38 ± 0.13 hi	54.45 ± 0.68 cd	3.60 ± 0.07 f	43.65 ± 1.49 c
14 BLM 08	22.78 ± 1.67 k	11.08 ± 0.52 efg	1149.29 ± 2.66 b	7.63 ± 0.63 e	27.99 ± 1.17 j	0.72 ± 0.03 r	29.30 ± 0.26 g
14 BLM 09	13.94 ± 0.04 klm	6.65 ± 0.14 kl	440.68 ± 6.50 no	5.75 ± 0.75 fgh	85.79 ± 1.61 a	4.10 ± 0.06 e	33.43 ± 0.24 f
14 BLM 10	79.89 ± 1.58 b	16.56 ± 0.11 d	1294.64 ± 0.89 a	6.25 ± 0.50 efg	27.48 ± 0.53 j	4.71 ± 0.03 d	53.74 ± 1.36 a
14 BLM 11	57.54 ± 1.86 g	8.93 ± 0.49 hi	546.40 ± 3.02 lm	5.75 ± 0.25 fgh	34.74 ± 0.26 h	3.68 ± 0.06 f	31.92 ±1.26 f
14 BLM 12	15.33 ± 0.19 kl	8.37 ± 0.24 ij	386.68 ± 5.73 p	6.17 ± 0.06 efg	46.17 ± 0.13 f	1.72 ± 0.05 k	22.73 ± 0.03 j
14 BLM 13	61.07 ± 1.65 f	11.77 ± 0.21 def	1132.28 ± 6.72 c	12.27 ± 0.66 c	49.03 ± 0.15 ef	2.57 ± 0.07 i	42.57 ± 0.41 c
14 BLM 14	12.28 ± 0.27 lm	16.22 ± 0.65 d	613.77 ± 4.73 j	2.50 ± 0.25 k	21.35 ± 0.23 k	2.48 ± 0.01 i	37.08 ± 0.10 de
14 BLM 15	52.83 ± 1.25 h	22.33 ± 1.04 b	1008.32 ± 8.36 e	16.09 ± 0.73 a	32.93 ± 1.96 hi	2.10 ± 0.03 j	48.86 ± 1.27 b
14 BLM 16	42.57 ± 1.19 j	7.70 ± 0.44 i–l	606.99 ± 4.75 j	4.13 ± 0.13 ij	39.92 ± 0.10 g	1.25 ± 0.01 m	26.69 ± 0.88 hi
14 BLM 17	54.58 ± 1.15 gh	19.02 ± 0.57 c	1279.28 ± 7.22 a	13.72 ± 0.72 b	39.13 ± 0.74 g	1.05 ± 0.04 n	25.84 ± 0.74 i
14 BLM 18	14.14 ± 0.17 klm	11.84 ± 0.06 de	428.17 ± 4.03 o	4.88 ± 0.13 ghi	51.66 ± 1.40 de	1.59 ± 0.04 l	54.42 ± 0.75 a
14 BLM 19	46.97 ± 1.21 i	7.19 ± 0.07 jkl	531.73 ± 7.37 m	6.25 ± 0.50 efg	61.89 ± 0.01 b	0.95 ± 0.02 no	35.99 ± 0.57 e
14 BLM 20	70.64 ± 1.73 d	9.92 ± 0.10 gh	269.65 ± 2.07 r	10.38 ± 0.38 d	23.83 ± 2.48 k	9.13 ± 0.01 a	22.62 ± 0.52 j
14 BLM 21	53.93 ± 0.97 h	10.31 ± 0.20 g	791.95 ± 2.14 h	6.50 ± 0.75 ef	16.80 ± 0.67 l	5.11 ± 0.05 b	20.32 ± 0.66 k
14 BLM 22	64.66 ± 1.70 e	7.14 ± 0.01 jkl	586.85 ± 4.30 k	2.75 ± 0.25 jk	31.67 ± 0.82 hi	0.86 ± 0.01 op	27.26 ± 0.19 ghi
14 BLM 23	48.39 ± 0.94 i	12.08 ± 0.37 de	431.56 ± 3.76 o	10.67 ± 0.82 d	21.81 ± 1.19 k	1.02 ± 0.00 n	22.37 ± 0.19 jk

*: Different letters in columns indicate significantly different values at $p \leq 0.05$.

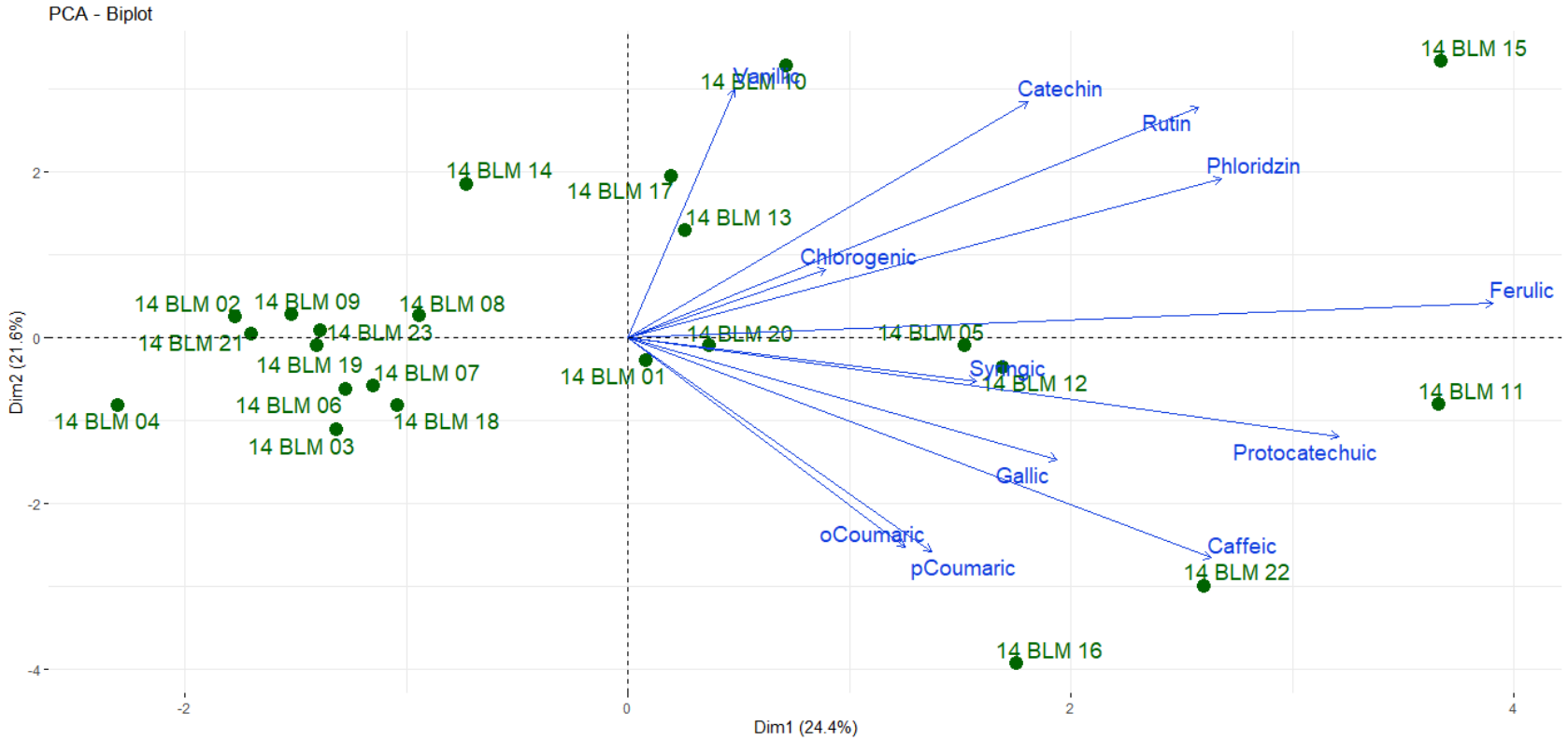

Figure 2. Distribution of plum genotypes according to phenolic compounds.

3.3. Organic Acid and Vitamin C Contents

The ratio of organic acids is among the important quality parameters that affect the taste formation in fruits. In this study, organic acid and vitamin C contents of plum genotypes grown in wild form were determined. It was observed that organic acids and vitamin C contents showed variation based on genotypes, and statistically significant differences were found at the level of $p \leq 0.05$ (Table 5). Malic acid was recorded as higher than other organic acids, followed by succinic and citric acid. Looking at the organic acid content of the genotypes, malic, succinic and citric ranged from 269.65 mg/100 g (14BLM20) to 1294.64 mg/100 g (14BLM10), 16.80 mg/100 g (14BLM21) to 85.79 mg/100 g (14BLM09) and 11.32 mg/100 g (14BLM03) to 85.45 mg/100 g (14BLM07), respectively. The highest vitamin C content was obtained from 14BLM18 genotype as 54.42 mg/100 g, while the lowest was determined in the 14BLM21 genotype as 20.32 mg/100 g, indicating 2.5-fold differences among those two genotypes. The genotypes 14BLM02, 14BLM10, 14BLM15 and 14BLM18 showed higher vitamin C content. Genotyping diversity of vitamin C is important for the development of new plum cultivars with high vitamin C contents. We found relatively higher variation in vitamin C among 23 plum genotypes. Vitamin C (ascorbic acid and dehydroascorbic acid) is a water-soluble antioxidant; though only present at a low-to-moderate level in plums, high consumption of plums and their products means they make a significant contribution to dietary vitamin C intake. A main step in breeding is to gain better knowledge about genetic resources that are suitable in breeding programs, and this will also help to conserve biological diversity. Thus, the genotypes that had high vitamin C could be important for future plum breeding activities.

In the study, it was seen that the variation between organic acids and vitamin C was found as 53.8% by PCA (Principal Component Analysis)(Figure 3). It was observed that there was a negative relationship between citric and succinic acid and a similar relationship was found between vitamin C and fumaric acid. A parallel relationship was found between malic, tartaric and oxalic acid. It was observed that genotypes were concentrated in the first and third areas on the PCA plane. Usenik et al. [48] examined the change of organic acids during the maturation period. The same researchers reported that malic acid, shikimic acid and fumaric acid contents of Jojo cultivar were determined as 9.0–21.8 g kg^{-1}, 55.1–64.0 mg kg^{-1} and 1.2–6.7 mg kg^{-1}, respectively. Lombardi-Boccia et al. [36] recorded that the citric acid, malic acid and ascorbic acid content of organically grown plum fruits were as 25.7 mg 100 mg^{-1}, 1.98 g 100 g^{-1} and 1.60 mg 100 g^{-1}, respectively. It has been known that many factors such as climate, cultural practices and genetic characteristics of the species affect organic acid and vitamin C contents [41–46]. It should not be forgotten that although the loss of organic acids was minimized during fruit harvest, preservation and analysis processes, this situation cannot be prevented completely. Therefore, changes and reactions in the physiology of fruits also affect the organic acid content [49–51].

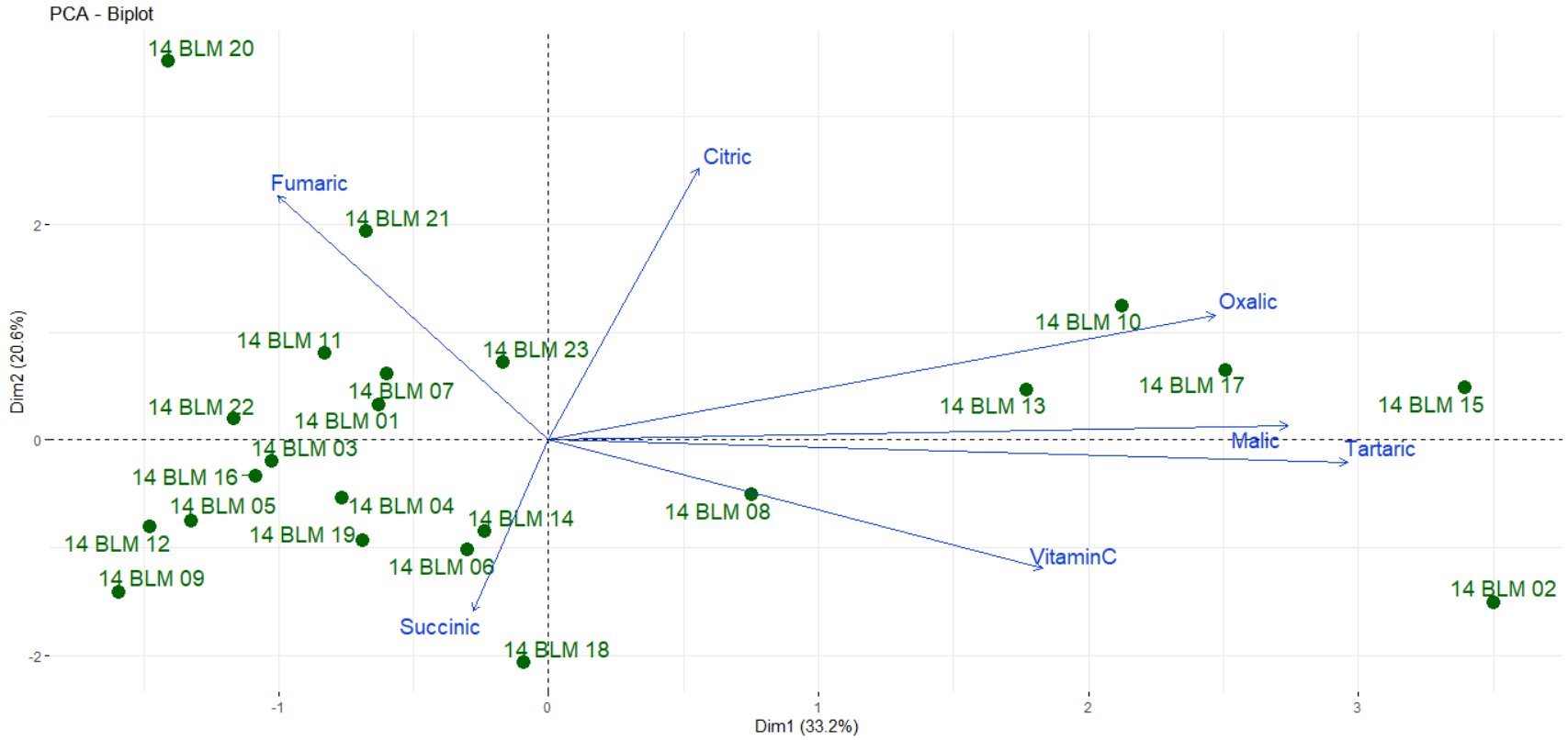

Figure 3. Distribution of plum genotypes according to organic acids and vitamin C contents.

4. Conclusions

In this study, the 14BLM08 genotype was found to be promising in terms of important agro-morphological characteristics such as fruit weight and size among plum genotypes growing in wild form. It was determined that the 14BLM14 genotype was superior to other genotypes in terms of flesh firmness, which is among the important parameters affecting the preservation and transportation of fruits to the market. In the study, the 14BLM18 genotype was found promising in terms of vitamin C content, and the 14BLM10 genotype was found promising in terms of malic acid content. It had been observed that the chlorogenic acid was higher than other phenolics and that the 14BLM20 genotype was promising in terms of this compound. It was determined that fruits belonging to these genotypes have properties that can be used in fresh consumption and in the industry (fruit juice, jam, marmalade, etc.). As a result, the examined plum genotypes could be important plant genetic resources in terms of conservation of genetic resources. Therefore, it is important to reproduce and preserve these genetic resources in plum breeding studies.

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Conflicts of Interest: The authors declare that they have no conflict of interest.

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