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Phenotypic Diversity of Pomegranate Cultivars: Discriminating Power of Some Morphological and Fruit Chemical Characteristics

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Abstract: In modern agricultural production, where a small number of commercial cultivars dominate, the collection, evaluation, and preservation of germplasm are important tasks to reduce the erosion of genes and preserve biodiversity. The aim of this study is to characterize the morphological and fruit chemical properties of the pomegranate germplasm grown on the East Adriatic coast, including the commercial cultivars 'Hicaznar', 'Granada', and 'Wonderful', and to highlight the characteristics with the greatest discriminating power. The characterization of the tree, leaf, flower, arils, seed, and juice was carried out using the UPOV descriptor. The colors of the peel, arils, and juice were analyzed according to the CIEL*a*b* method, total soluble solids were measured using refractometers, and total acidity was determined by titration with 0.1 M NaOH. The research results showed significant diversity between the cultivars, which were grouped into several clusters using an unsupervised analysis technique. Factors such as plant vigor, plant growth habit, predominant number of leaves per node on young shoots, crown type, fruit shape, fruit shape in cross-section, peel weight, total aril weight, aril weight, number of arils per fruit, seed length and width, seed yield, total acidity, TSS/TA ratio, and color parameters of the peel, arils, and juice showed high variability, indicating their strong discriminating power in determining the phenotypic diversity of pomegranate.

Keywords: pomegranate; germplasm; ex situ collection; qualitative and quantitative markers; color; acidity; fruit shape; crown type fruit shape in cross-section; juice yield

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1. Introduction

The pomegranate is a flavorful fruit that is native to the Mediterranean. Growing public awareness of the health benefits of pomegranate has led to an increasing demand for its cultivation and commercialization. Numerous cultivars have descended from wild populations, making the pomegranate a prime example of the domestication of a wild fruit tree [1]. Fundamental botanical knowledge, diverse morphological variation within a plant species, and an understanding of growing conditions and physiological needs are essential for germplasm identification and for growers to optimize crop production and management. More than 500 pomegranate cultivars have been identified worldwide, showing their great genetic variability, but only about 50 are cultivated for commercial purposes [2]. This selective cultivation has significantly reduced the genetic richness. Establishing repositories comprising germplasm from wild, semi-wild, and less popular cultivars in different geographical regions is crucial to maintaining the genetic basis for future breeding and improvement of pomegranate cultivars, as well as enhancing crop quality [3].

Mediterranean countries, such as Spain, Morocco, Tunisia, Greece, Turkey, and Egypt, have established local collections of pomegranate germplasm [4], which play a central role in maintaining genetic diversity and provide valuable breeding material. To avoid redundancy and effectively assess the diversity within these collections, it is essential to thoroughly characterize each cultivar, not only by its physical characteristics but also by comprehensive genetic analysis [5]. While geneticists deal with molecular diversity, agronomists focus on observable morphological variation for sustainable breeding methods, as Hawkes [6] discussed in 1991. The use of germplasm collections to study phenotypic variation not only improves our understanding of basic plant biology but also holds promise for studying the adaptive responses of long-lived woody plants to changing environmental conditions [7].

As with many other fruit species, the nomenclature of pomegranate cultivars is confusing, and numerous synonyms and homonyms further complicate their characterization. Fruit quality assessment is a multi-layered approach that takes into account external appearance, morphological characteristics, chemical composition, post-harvest characteristics, and microbiological and chemical safety. The most important parameters include the visual aspects of the fruit, such as size, shape, and color, as well as chemical characteristics such as acidity, sweetness, and antioxidant activity. All these factors together influence the commercial value of pomegranate products, market perception, and consumer preferences [8].

Ex situ germplasm collections of pomegranate cultivars grown on the East Adriatic coast exist in Croatia, but the lack of morphological and molecular studies prevents a comprehensive assessment of the preserved genetic diversity, indicating the need for further investigations aimed at qualitative use in breeding and/or breeding programs.

The main objectives of this research were to evaluate the morphological and some fruit chemical characteristics of native and introduced pomegranate cultivars grown on the eastern coast of the Adriatic Sea. In addition, based on the obtained results, the aim was to determine which of the characteristics assessed have the greatest discriminating power in determining the diversity of pomegranate cultivars. The detailed characterization, evaluation, and documentation of the studied germplasm are invaluable for the further development of pomegranate production, genetic conservation, and for facilitating future breeding programs aimed at sustainable improvement; this underscores the crucial role of living collections for the conservation of genetic diversity.

2. Materials and Methods

2.1. Site Characteristics, Environmental, Conditions and Plant Material

The evaluation was carried out on fruit samples from nineteen cultivars, consisting of sixteen native pomegranate cultivars traditionally grown on the eastern Adriatic coast ('Barski slatki', 'Bokežan', 'Dividiš', 'Domaći kiseli', 'Dubrovački kasni', 'Glavaš', 'Konjski zub', 'Kristal', 'Medunac', 'Mojdiški sitnozrni', 'Pastun', 'Sladun', 'Slatki crveni', 'Slatki tankokorac', 'Šerbetaš', and 'Zamorac') and three introduced cultivars ('Granada', 'Hicaznar', and 'Wonderful'). The native cultivars were collected along the eastern Adriatic coast, propagated by cuttings, and planted in 2011 in the Gene Bank of Mediterranean Fruit Species located at the Institute for Adriatic Crops and Karst Reclamation, Split, Croatia (43°30′22″ N; 16°29′47″ E; 60 m a.s.l.). The trees were healthy and bush-shaped with three to four main trunks, planted 4.5 × 3 m apart. The orchard was drip-irrigated and the usual cultivation practices were applied (pruning, fertilization, and plant protection).

The collection was grown in a Mediterranean climate, defined as a Csa climate type according to the Koppen–Geiger climate classification [9]. The average annual temperature was 17.5 °C, with mild winters (absolute minimum 2 °C in January) and hot summers (absolute maximum 33.2 °C in August). The annual precipitation at this location was 754 mm during vegetation (April to October, 50% of annual precipitation). The average duration of sunshine was 2742 h (Croatian Meteorological and Hydrological Service).

2.2. Sampling

Twenty-three qualitative and fifty-eight quantitative characteristics of the tree, leaf, flower, fruit, aril, juice, and seed were evaluated on three trees per cultivar in four consecutive years (2017–2020). In all years studied, samples of 30 mature leaves and 25 bell-shaped flowers (fertile flowers) per tree were randomly collected in the canopy. The leaves were taken from the outer part of the tree at the end of August. The flowers were collected at the time of full bloom during the second half of May. A total of 36 fruits (3 fruits per tree × 3 trees × 4 years), which had developed from the flowers in the first part of flowering were collected randomly around the canopies for each cultivar. The fruits were harvested when they were ripe according to local practices (fruit size and external color) between 15–30 October (depending on the year and cultivar). The samples were taken to the Pomology Laboratory of the Institute for Adriatic Crops and Karst Reclamation, Split, Croatia, where the morphological characterization and chemical analyses of the juice were performed.

2.3. Morphological Characteristics

The morphological characteristics were assessed according to the UPOV (International Union for the Protection of New Varieties of Plants) descriptors for pomegranates [10].

2.3.1. Qualitative Characteristics

Tree characteristics were described in terms of the vigor of the tree, the growth habit, the intensity of the gray color on the main branches, the number of one-year-old shoots ending in thorns, and the predominant number of leaves per node on young shoots. The shape of the leaf blade (except for the apex), the anthocyanin coloration of the petiole, the intensity of the green coloration of the leaf blade, the calyx color, the color of the corolla, the surface of the petals, the predominant number of flowers on the one-year-old shoot, the predominant type of arrangement of the flowers, the fruit shape, the shape of the fruit base, the shape of the fruit apex, the shape in cross-section, the crown type, the fruit overcolor, the extent of the aril, the aril color, the juice color, and the hardness of the seed were described on a scale from 1 to 9 according to the UPOV descriptor. The evaluation was conducted by a five-member panel with extensive experience in the morphological characterization of fruit species, specializing in pomegranates.

2.3.2. Quantitative Characteristics

Leaves and flowers were scanned using an Epson Perfection V700 photo scanner; the leaf blade length and width, leaf blade length and width ratio, leaf area, the petiole length, the calyx length, the calyx width, the ratio of the calyx length and width, the petal length, the petal width, the petal length and width ratio, petal form coefficient, the petal area, and the petal perimeter were measured using WinFOLIA Pro 2014a software (Regent Instruments Inc., Quebec, QC, Canada). The number of sepals and petals was determined by counting.

The weight of the individual fruits, peel, aril, and seed weight, as well as the total aril weight, were measured using an electronic scale ±0.01 g (Shimadzu, Kyoto, Japan). Fruit length without crown, fruit diameter, crown length, crown diameter, and peel thickness were determined using digital micrometers. For the fruit and crown diameter, two perpendicular measurements were taken around the equatorial plane, while for peel thickness, two measurements were taken from opposite sides of the fruit. The fruit form index (percentage ratio of equatorial fruit diameter/fruit length excluding crown), fruit crown index (percentage ratio of crown length/total fruit length), and fruit peel thickness index (percentage ratio of peel thickness/fruit diameter) were calculated. The aril yield was calculated as the ratio between aril weight and fruit weight multiplied by 100. The number of arils per fruit was estimated by counting the number of arils in a 100 g sample and extrapolating the number of arils based on the total weight of arils per fruit. Aril length, aril width, seed length, and seed width were measured on 30 arils per year for each cultivar using the Epson Perfection V700 photo scanner and WinSEEDLE Pro 2019a analysis software (Regent

Instruments Inc., Quebec, QC, Canada). Seed yield was determined as the ratio of seed weight per 50 g of arils, multiplied by 100.

The color parameters of the fruit peel were measured in the middle part of the fruit, twice at different points of each fruit. After measuring the peel color, the fruits were opened and the arils were removed. Thirty arils were randomly taken from each cultivar for the measurements. Moreover, 200 g of the arils from three fruits per tree were pressed through four layers of gauze cloth and used to measure the juice color. The Chroma meter CR-400 (Konica Minolta, Osaka, Japan) was used to measure the color of the peel, arils, and juice (CIE L*a*b* method) of the pomegranate, expressed in the parameters L*, a*, b*, C*, and h°. The color parameter L* indicates the lightness of the peel, arils, or juice, and ranges from 0 (opaque) to 100 (completely transparent). Value a* stands for redness and ranges from negative values for green to positive values for red. Value b* denotes 'yellowing' and ranges from negative values for blue to positive values for yellow [11]. Chroma (C*) and hue angle (h°) denote the visual color appearances. The hue angle represents the visual experience according to which the color is evaluated with the following values: 0–90°: red–violet, 90–180°: yellow, 180–270°: blue–green, and 270–360°: blue. The C* value stands for the color intensity. These parameters are calculated using the following equation:

$$(180 - h^{\circ})/(L^* + C^*)$$

to obtain what we call the 'color index' [12].

2.4. Juice Yield, Total Soluble Solids, and Total Acidity Content

Fruit juice content was obtained by extracting 50 g of arils per fruit by squeezing through four layers of gauze cloth. The juice yield was determined as the ratio of milliliters of juice per 50 g of arils sampled, multiplied by 100. Total soluble solid (TSS) and total acidity (TA) were analyzed to classify cultivars into sweet, sweet–sour or sour groups. Total soluble solid (TSS) and total acidity (TA) analyses were performed. TSS was determined using a digital refractometer (Mettler Toledo, Greifensee, Switzerland, calibrated with distilled water) at 21 °C and TA was determined by titrating to pH 8.1 with a 0.1 M NaOH solution, expressed as g citric acid per 100 g juice [13].

2.5. Statistical Analysis

The approach used in this study (to detect the associated characteristics and distribution of samples in 19 pomegranate cultivar datasets) included univariate and multivariate statistical algorithms. For the generated dataset, descriptive statistics were generated for morphological parameters of trees, leaves, flowers, fruit, and arils, as well as color parameters of fruits, arils, juice, and fruit chemical traits. To determine the differences between cultivars, significant differences at the 5% level between means were determined using a non-parametric test (Kruskal–Wallis) for qualitative morphological traits and a one-way ANOVA analysis test for other traits, followed by Tukey's honest significant difference (HSD) test. The minimum, maximum, mean, standard deviation (SD), and coefficient of variation (CV) were calculated and used as indicators of variability.

An unsupervised analysis technique, utilizing a heatmap created through clustering using the Ward method, was employed to analyze data, facilitating the identification of patterns, and enhancing the understanding of interrelationships or similarities. This analysis focused on studied pomegranate cultivars (19), which were clustered based on 44 traits specifically chosen for their coefficient of variation exceeding 15%. The Pearson correlation coefficient analysis was performed to examine and quantify the relationships between the analyzed morphological and chemical characteristics, thereby elucidating the extent and nature of their interdependencies within the dataset. The correlation was considered significant at a value of $p \leq 0.05$.

The analyses were performed with Statistica 14.0.0.15 (Tibco Software Inc., Palo Alto, CA, USA, 2020), whereas RStudio was applied for Heatmap (RStudio 2023.09.1, Posit Software, PBC 2009–2023).

3. Results

3.1. Morphological Characteristics

Qualitative characteristics of the studied pomegranate cultivars are shown in Table 1 while the distribution frequency for these qualitative characteristics is shown in Table 2. For 10 characteristics, significant differences were found between cultivars (e.g., plant growth habit and fruit shape ($p < 0.001$), as well as the predominant number of leaves per node, shape of the fruit apex, fruit extent of overcolor, fruit shape in cross-section, seed hardness, petal surface, flower arrangement, and petiole anthocyanin coloration, which were predominant ($p \leq 0.05$).

3.1.1. Tree

Seven tree characteristics were part of the first group of characteristics used to evaluate the cultivars (Tables 1 and 2). Plant vigor, plant growth habit, and the predominant number of leaves per node on young shoots showed high variability. The vigor of the cultivars studied was generally medium (53%) and strong (42%), except for 'Konjski zub', which was weak. The growth habit predominantly spread (63%), while 37% of the cultivars exhibited an upright growth habit. In this study, 47% of cultivars had a medium-intensity gray color on the main branches, while all cultivars had some annual shoots ending in thorns. Cultivars were divided into three groups based on the predominant number of leaves per node on young shoots: 52% had more than three leaves per node ('Bokežan', 'Dividiš', 'Domaći kiseli', 'Dubrovački kasni', 'Glavaš', 'Medunac', 'Sladun', 'Slatki crveni', 'Zamorac', and 'Hicaznar'), 32% with two leaves ('Barski slatki', "Konjski zub', 'Kristal', 'Mojdiški sitnozrni', 'Slatki tankokorac', and 'Granada'), and 16% ('Pastun', 'Šerbetaš', and 'Wonderful') with three leaves per node. In 63% of the cultivars, the flowers were arranged in an inflorescence, while the cultivars 'Dividiš' 'Dubrovački kasni', 'Konjski zub', 'Medunac', 'Mojdiški sitnozrni', 'Šerbetaš', 'and 'Zamorac' had a solitary flower arrangement.

3.1.2. Leaf and Flower

Leaf characteristics were part of the second group of characteristics used for the study. The mean values between the studied cultivars for all evaluated characteristics differed significantly ($p \leq 0.05$) and the coefficient of variation was between 6.65% and 10.97% (Table 3).

Leaf blade length ranged from 4.44 cm ('Mojdiški sitnozrni') to 5.58 cm ('Domaći kiseli'), the leaf width varied from 1.56 cm ('Wonderful') to 1.97 cm ('Slatki crveni'), while the LL/LW ratio ranged from 2.45 ('Mojdiški sitnozrni') to 3.18 ('Domaći kiseli'). In addition, petiole length ranged from 0.42 cm ('Hicaznar') to 0.60 cm ('Pastun'), with anthocyanin coloration ranging from medium (42%) to strong intensity (58%), depending on the cultivar. The shape of the leaf blade—specifically, the shape of the apex excluding the tip—was predominantly moderately obtuse (53%), followed by a right angle (37%), and moderately acute (10%) (Table 2).

The variability in the flower characteristics of the studied cultivars is shown in Table 4. The calyx length ranged from 3.30 cm ('Konjski zub') to 4.28 cm ('Medunac'); the calyx width was from 1.36 cm ('Domaći kiseli') to 1.98 cm ('Glavaš'); the petal length was from 2.49 cm to 2.99 cm, and the petal width was from 1.51 cm to 2.42 cm. The form coefficient of the petals ranged between 0.81 and 0.89, while the cultivars were divided into three groups based on the flower surface, with moderately wrinkled petal surfaces predominating (68%). The predominant color of the calyx was medium red in 74% of the studied cultivars and the color of the corolla was orange–red in 79% of cases (Table 2).

Table 1. Qualitative characteristics of the studied pomegranate cultivars according to UPOV (2013).

	Cultivar	**Barski slatki**	**Bokežan**	**Dividiš**	**Domaći kiseli**	**Dubrovački kasni**	**Glavaš**	**Konjski zub**	**Kristal**	**Medunac**	**Mojdiški sitnozrni**	**Pastun**	**Sladun**	**Slatki crveni**	**Slatki tankokorac**	**Šerbetaš**	**Zamorac**	**Hicaznar**	**Granada**	**Wonderful**
Tree	Plant vigor (PV)	5	7	7	7	5	7	3	5	5	5	5	7	7	5	5	7	7	5	5
	Plant growth habit (PGH)	3	3	3	3	3	3	1	1	1	3	3	1	1	3	3	3	3	3	3
	Intensity of the gray color of the main branches (IGC)	2	1	2	2	2	3	3	3	2	1	1	3	2	3	2	2	3	3	2
	Number of one-year-old shoots ending in thorns	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
	Predominant number of leaves per node on young shoots (DNL)	1	3	3	3	3	3	1	1	3	1	2	3	3	1	2	3	3	1	2
	Predominant number of flowers per node (F/Node)	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	Arrangement of flowers (predominant type) (AF)	2	2	1	2	1	2	1	2	1	1	2	2	2	2	1	1	2	2	2
Leaf	Leaf blade: shape of apex, excluding the tip (LBS)	4	3	4	3	4	2	4	4	4	3	3	3	3	4	4	3	4	4	2
	Leaf blade: intensity of the green color (IGC)	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	3	5
	Petiole: anthocyanin coloration (PAC)	7	5	7	5	7	7	5	5	7	7	7	7	7	7	7	5	5	5	5
Flower	Calix color (CC)	3	3	2	3	3	3	2	1	3	2	3	2	3	3	3	3	3	3	3
	Corolla color (CoC)	5	5	5	5	5	3	5	4	5	5	5	3	6	5	5	5	5	5	5
	Petal surface (PS)	3	3	3	3	3	5	3	3	3	1	3	3	5	3	5	1	3	5	3
Fruit	Fruit shape (FS)	4	4	4	1	1	4	4	1	4	4	4	4	4	4	1	4	1	4	4
	Shape of the base (SFB)	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
	Shape of the fruit apex (FSA)	2	3	3	2	2	3	2	2	2	2	2	3	3	2	2	3	2	2	3
	Crown type (CT)	2	2	1	2	3	1	2	2	3	3	2	1	3	1	2	3	2	3	2
	Fruit overcolor (FOC)	4	6	5	6	4	5	4	3	3	3	6	5	3	5	5	4	6	6	6
	Fruit extent of overcolor (FEOC)	7	7	5	7	1	7	5	1	1	1	7	7	7	7	5	7	7	7	7
	Shape in cross-section (SCS)	3	1	2	1	2	2	2	2	1	1	2	1	1	3	3	2	3	1	2

Table 1. *Cont.*

	Cultivar	Barski slatki	Bokežan	Dividiš	Domaći kiseli	Dubrovački kasni	Glavaš	Konjski zub	Kristal	Medunac	Mojdiški sitnozrni	Pastun	Sladun	Slatki crveni	Slatki tankokorac	Šerbetaš	Zamorac	Hicaznar	Granada	Wonderful
Aril	Aril main color (AMC)	6	6	2	5	6	5	3	2	6	5	5	6	4	4	6	5	7	7	7
Seed	Hardness of seed (HS)	2	3	2	3	3	3	2	2	3	3	3	3	2	3	3	3	3	2	2
Juice	Juice color (JC)	5	3	1	3	3	3	2	2	3	2	3	2	4	3	5	3	5	5	5

Table 2. Distribution frequency (%) for the qualitative characteristics of the studied pomegranate cultivars.

Characteristic	Frequency (%)								
	1	2	3	4	5	6	7	8	9
Plant vigor			Weak (5)		Medium (53)		Strong (42)		
Plant growth habit	Upright (37)		Spreading (63)		Weeping (0)				
The intensity of the gray color of the main branches	Light (16)		Medium (47)		Dark (37)				
No. of one-year-old shoots ending in thorns	None or very few (0)	Few (100)	Medium (0)	Many (0)					
Predominant no. of leaves per node	Two (32)	Three (16)	More than three (52)						
Predominant no. of flowers per node	One (100)	Two (0)	Three (0)	More than three (0)					
Arrangement of flowers	Solitary (37)	Inflorescence (63)							
Leaf blade: the shape of the apex, excluding the tip	Strongly acute (0)	Moderately acute (10)	Right angle (37)	Moderately Obtuse (53)	Strongly Obtuse (0)				
Leaf blade: intensity of the green color			Light (5)		Medium (95)		Dark (0)		
Petiole: anthocyanin coloration			Weak (0)		Medium (42)		Strong (58)		
Calyx color	Orange (5)	Orange–red (21)	Medium red (74)	Dark red (0)					

Table 2. *Cont.*

Characteristic	**Frequency (%)**								
Corolla color	White (0)	Pink (0)	Light orange (11)	Medium Orange (5)	Orange Red (79)	Medium red (5)			
Petal surface	Smooth or slightly Wrinkled (11)		Moderately Wrinkled (68)		Strongly Wrinkled (21)				
Fruit shape	Spheroid (26)	Ellipsoid (0)	Ovoid (0)	Oblate (74)					
Shape of the base	Truncate (5)	Convex (95)	Angular (0)						
Shape of the fruit apex	Convex (0)	Truncate (63)	Necked (37)						
Crown type	Closed; convergent sepals (21)	Semi-opened; right sepals (47)	Opened; divergent sepals (32)	Largely opened (0)					
Fruit overcolor	Orange (0)	Orange red (0)	Pink (21)	Pink red (21)	Medium red (26)	Red purple (32)	Purple (0)	Dark purple (0)	
Fruit extent of overcolor	Very small (21)		Small (0)		Medium (16)		Large (63)		Very large (0)
Shape in cross-section	Round (37)	Round to angular (42)	Angular (21)						
Aril main color	White (0)	Light pink (10)	Medium pink (5)	Dark pink (10)	Light red (26)	Medium red (32)	Dark red (17)		
Juice color	Creamy-bright pink (5)		Pink (21)		Light red (42)	Red (5)	Dark red (26)		
Hardness of seed	Soft (0)	Medium (37)	Hard (63)						

Table 3. Leaf morphological characteristics of the studied cultivars.

Cultivar	Leaf Blade Length (LL; cm)	Leaf Blade Width (LW; cm)	LL/LW Ratio	Leaf Area (LA; cm²)	Petiole Length (PL; cm)
Barski slatki	4.57 ± 0.67 e	1.81 ± 0.25 de	2.55 ± 0.39 i	6.15 ± 1.54 de	0.46 ± 0.09 gh
Bokežan	4.76 ± 0.67 cde	1.67 ± 0.19 efg	2.87 ± 0.41 e	5.67 ± 1.17 fg	0.48 ± 0.10 efg
Dividiš	5.20 ± 0.65 b	1.69 ± 0.20 ef	3.11 ± 0.43 ab	6.28 ± 1.24 de	0.55 ± 0.11 bcd
Domaći kiseli	5.58 ± 0.87 a	1.76 ± 0.22 def	3.18 ± 0.42 a	7.02 ± 1.70 bc	0.56 ± 0.13 abc
Dubrovački kasni	4.93 ± 0.64 bcd	1.89 ± 0.24 abc	2.63 ± 0.36 hi	6.97 ± 1.54 c	0.45 ± 0.07 gh
Glavaš	4.59 ± 0.74 cde	1.64 ± 0.18 efg	2.82 ± 0.46 ef	5.46 ± 1.19 fg	0.47 ± 0.09 fgh
Konjski zub	4.97 ± 0.66 bcd	1.63 ± 0.17 efg	3.07 ± 0.38 abc	5.92 ± 1.20 ef	0.51 ± 0.08 cdefg
Kristal	4.98 ± 0.49 bc	1.72 ± 0.23 de	2.93 ± 0.41 de	6.27 ± 1.11 de	0.51 ± 0.06 def
Medunac	5.28 ± 0.78 ab	1.92 ± 0.25 ab	2.76 ± 0.34 fg	7.40 ± 1.95 abc	0.56 ± 0.10 abc
Mojdiški sitnozrni	4.44 ± 0.40 cde	1.82 ± 0.16 abcde	2.45 ± 0.27 j	6.07 ± 0.86 def	0.43 ± 0.05 fgh
Pastun	5.51 ± 0.82 a	1.93 ± 0.25 ab	2.87 ± 0.37 e	7.53 ± 1.83 a	0.60 ± 0.10 a
Sladun	5.18 ± 0.81 b	1.76 ± 0.26 de	2.97 ± 0.48 cde	6.45 ± 1.66 d	0.57 ± 0.12 ab
Slatki crveni	4.86 ± 0.77 cd	1.97 ± 0.26 a	2.48 ± 0.30 j	7.08 ± 1.97 bc	0.52 ± 0.09 cde
Slatki tankokorac	4.71 ± 0.56 cde	1.82 ± 0.25 bcd	2.62 ± 0.44 hi	6.30 ± 1.36 de	0.51 ± 0.10 def
Šerbetaš	5.23 ± 0.57 ab	1.92 ± 0.25 ab	2.76 ± 0.38 fg	7.40 ± 1.42 ab	0.55 ± 0.10 bc
Zamorac	5.19 ± 0.81 b	1.68 ± 0.28 ef	3.13 ± 0.48 a	6.31 ± 1.84 de	0.54 ± 0.10 bcd
Hicaznar	4.58 ± 0.62 de	1.72 ± 0.21 de	2.66 ± 0.27 gh	5.72 ± 1.39 f	0.42 ± 0.08 h
Granada	4.79 ± 0.74 cde	1.60 ± 0.22 fg	3.01 ± 0.38 bcd	5.53 ± 1.32 fg	0.46 ± 0.10 fgh
Wonderful	4.67 ± 0.69 cde	1.56 ± 0.21 g	3.02 ± 0.45 bcd	5.28 ± 1.22 g	0.43 ± 0.10 h
Min.	4.44	1.56	2.45	5.28	0.42
Max.	5.58	1.97	3.18	7.53	0.60
Mean	4.95	1.76	2.81	6.36	0.50
SD	0.33	0.12	0.22	0.70	0.05
CV%	6.65	6.94	7.90	10.97	10.69

Values are given as mean ± SD, n = 100. Different lower-case letters in each column indicate a significant difference between the cultivars at $p \leq 0.05$ by the Tukey's test.

3.1.3. Fruit

Fruit characteristics of the observed pomegranate cultivars are listed in Tables 1 and 5. Significant differences between cultivars were observed for all fruit characteristics ($p \leq 0.05$). The greatest variability was observed for fruit shape, crown type, and fruit shape in cross-section for qualitative characteristics, and in peel weight for quantitative characteristics.

The fruit weight differed significantly between the cultivars and ranged from 261.9 g ('Medunac') to 497.97 g ('Slatki tankokorac'). Fruit length and diameter values varied, receptively, between 68.3 mm ('Medunac') and 85.19 mm ('Pastun') and 78.05 mm ('Zamorac') and 98.63 mm ('Slatki tankokorac'), while FL/FD was 0.81–0.90. In terms of fruit shape (FL/FD ratio), 'Pastun', 'Slatki crveni', and 'Granada' were more spherical, while 'Glavaš' was more oblate, as confirmed by the Fruit Form Index (the ratio between the equatorial fruit diameter and the fruit length, excluding the crown). The IFF ranged from 109.4% ('Granada') to 123.4% ('Glavaš').

The majority of cultivars had a convex base shape (95%), while 63% of the cultivars had a truncated fruit apex and 37% had a necked apex. In the cross-section, the cultivars can be divided into three groups: round (37%), round to angular (42%), and angular (21%) (Table 2).

The crown size and crown type also differed between the cultivars. The values for the crown length ranged from 11.22 mm ('Zamorac') to 17.98 mm ('Slatki tankokorac') and the crown index (IC) ranged from 14% ('Zamorac') to 19% ('Medunac') (Table 5).

Peel weight varied between 97.82 g ('Mojdiški sitnozrni') and 259.88 g ('Dividiš'). The peel weight of 'Mojdiški sitnozrni' did not differ significantly from those of 'Dubrovački kasni', 'Kristal', 'Medunac', and 'Zamorac'. The cultivar 'Sladun' had the thickest peel (5.86 mm) but was not significantly different from the cultivars 'Kristal', 'Pastun', 'Slatki tankokorac', and 'Hicaznar'.

Table 4. Flower morphological characteristics of the cultivars studied.

Cultivar	Calyx Length (CL; cm)	Calyx Width (CW; cm)	CL/CW Ratio	Petal Length (PL; cm)	Petal Width (PW; cm)	PL/PW Ratio	Petal Area (PA; cm²)	Perimeter of Petal (PP; cm)	Petal Coefficient Form (CoP)	Number of Sepals (NS)	Number of Petals (NP)
Barski slatki	3.97 ± 0.31 abc	1.59 ± 0.18 ef	2.52 ± 0.23 b	2.81 ± 0.25 b–f	2.28 ± 0.17 bcd	1.24 ± 0.10 j	4.60 ± 0.61 b	8.01 ± 1.04 b	0.88 ± 0.05 abc	6.91 ± 0.88 bc	7.00 ± 0.93 bc
Bokežan	3.76 ± 0.47 c–g	1.56 ± 0.23 e–h	2.42 ± 0.22 b–e	2.49 ± 0.23 i	1.51 ± 0.12 j	1.65 ± 0.16 a	2.68 ± 0.35 h	6.50 ± 0.51 k	0.78 ± 0.04 k	7.74 ± 1.21 a	7.78 ± 1.67 a
Dividiš	3.84 ± 0.41 c–f	1.75 ± 0.20 c	2.22 ± 0.26 gh	2.71 ± 0.22 fg	2.13 ± 0.24 e–h	1.29 ± 0.13 ghi	4.06 ± 0.71 de	7.65 ± 0.64 fgh	0.87 ± 0.04 cde	6.90 ± 1.06 bc	6.92 ± 1.09 bc
Domaći kiseli	3.76 ± 0.31 c–g	1.36 ± 0.18 j	2.79 ± 0.35 a	2.80 ± 0.33 b–f	1.87 ± 0.22 i	1.50 ± 0.11 b	3.65 ± 0.79 fg	7.50 ± 0.91 hi	0.81 ± 0.04 j	6.82 ± 0.98 bc	6.82 ± 0.95 bcd
Dubrovački kasni	3.89 ± 0.33 b–e	1.75 ± 0.21 c	2.23 ± 0.17 gh	2.85 ± 0.25 b–e	2.20 ± 0.17 df	1.29 ± 0.09 gh	4.42 ± 0.60 bc	7.98 ± 0.61 bc	0.87 ± 0.04 bcd	7.83 ± 1.00 a	7.83 ± 1.00 a
Glavaš	3.78 ± 0.24 c–g	1.98 ± 0.35 a	1.96 ± 0.31 j	2.73 ± 0.38 ef	1.92 ± 0.19 i	1.42 ± 0.12 cd	3.59 ± 0.71 g	7.36 ± 0.88 i	0.83 ± 0.05 i	7.12 ± 1.08 b	7.12 ± 1.08 b
Konjski zub	3.30 ± 0.26 h	1.52 ± 0.11 f–i	2.18 ± 0.22 hi	2.50 ± 0.17 i	2.36 ± 0.17 ab	1.07 ± 0.10 k	4.18 ± 0.48 cde	7.81 ± 0.43 c–f	0.86 ± 0.04 d–g	6.21 ± 0.89 de	6.21 ± 0.82 f
Kristal	3.61 ± 0.37 efg	1.58 ± 0.17 efg	2.30 ± 0.27 efg	2.57 ± 0.29 hi	2.42 ± 0.31 a	1.07 ± 0.08 k	4.43 ± 0.96 bc	8.00 ± 0.85 bc	0.86 ± 0.04 d–g	6.30 ± 0.52 de	6.30 ± 0.52 ef
Medunac	4.28 ± 0.29 a	1.92 ± 0.20 ab	2.25 ± 0.22 fgh	2.77 ± 0.22 def	2.10 ± 0.20 e–h	1.33 ± 0.10 fg	4.15 ± 0.59 cde	7.75 ± 0.58 d–g	0.87 ± 0.06 b–e	8.17 ± 0.79 a	8.11 ± 0.76 a
Mojdiški sitnozrni	3.79 ± 0.20 c–g	1.65 ± 0.10 de	2.30 ± 0.26 efg	2.73 ± 0.36 ef	2.10 ± 0.20 e–h	1.30 ± 0.09 gh	4.06 ± 0.70 de	7.66 ± 0.35 fgh	0.86 ± 0.04 d–g	6.05 ± 0.56 e	6.06 ± 0.57 f
Pastun	4.02 ± 0.54 abc	1.71 ± 0.18 cd	2.37 ± 0.37 c–f	2.93 ± 0.19 ac	2.09 ± 0.17 gh	1.41 ± 0.12 d	4.19 ± 0.50 cde	7.83 ± 0.49 cde	0.86 ± 0.04 de	6.68 ± 0.87 c	6.67 ± 0.85 cde
Sladun	3.84 ± 0.25 c–f	1.64 ± 0.17 de	2.37 ± 0.25 def	2.59 ± 0.27 hi	1.92 ± 0.23 i	1.36 ± 0.11 ef	3.42 ± 0.66 g	7.06 ± 0.69 j	0.86 ± 0.05 efg	6.69 ± 0.91 c	6.72 ± 0.98 bcd
Slatki crveni	4.09 ± 0.37 ab	1.67 ± 0.21 d	2.48 ± 0.34 b	2.86 ± 0.26 bcd	2.06 ± 0.18 h	1.39 ± 0.09 de	4.15 ± 0.64 cde	7.84 ± 0.66 cde	0.84 ± 0.04 fgh	6.80 ± 1.02 bc	6.81 ± 1.03 bcd
Slatki tankokorac	3.70 ± 0.30 d–g	1.51 ± 0.16 ghi	2.47 ± 0.23 bcd	2.53 ± 0.26 i	2.09 ± 0.24 e–h	1.22 ± 0.14 j	3.71 ± 0.70 fg	7.42 ± 0.92 i	0.85 ± 0.08 fgh	6.67 ± 0.70 cd	6.69 ± 0.73 cde
Šerbetaš	3.61 ± 0.34 d–h	1.49 ± 0.15 i	2.46 ± 0.24 bc	2.60 ± 0.26 ghi	2.12 ± 0.20 e–h	1.23 ± 0.08 ij	3.96 ± 0.67 ef	7.54 ± 0.66 ghi	0.87 ± 0.04 bcd	6.68 ± 0.91 c	6.68 ± 0.91 cde
Zamorac	3.95 ± 0.34 a–d	1.89 ± 0.20 b	2.10 ± 0.19 i	2.99 ± 0.25 a	2.06 ± 0.19 h	1.46 ± 0.11 bc	4.28 ± 0.67 cd	7.95 ± 0.61 bcd	0.85 ± 0.04 efg	7.75 ± 0.91 a	7.67 ± 0.93 a
Hicaznar	3.72 ± 0.35 c–g	1.56 ± 0.21 e–i	2.40 ± 0.22 b–f	2.95 ± 0.24 abc	2.34 ± 0.22 abc	1.27 ± 0.06 g–j	5.05 ± 0.80 a	8.49 ± 0.75 a	0.88 ± 0.03 abc	6.22 ± 0.65 de	6.22 ± 0.65 ef
Granada	3.60 ± 0.33 g	1.48 ± 0.20 hi	2.45 ± 0.25 bcd	2.71 ± 0.19 e–h	2.21 ± 0.16 c–f	1.23 ± 0.08 hij	4.38 ± 0.61 bcd	7.86 ± 0.57 c–f	0.89 ± 0.03 a	6.05 ± 0.57 e	6.07 ± 0.59 f
Wonderful	3.53 ± 0.34 gh	1.71 ± 0.16 cd	2.09 ± 0.24 i	2.68 ± 0.23 fgh	2.18 ± 0.20 d–g	1.23 ± 0.08 hij	4.24 ± 0.69 b,e	7.72 ± 0.58 e–h	0.89 ± 0.03 a	6.30 ± 0.64 de	6.42 ± 0.85 def
Min.	3.30	1.36	1.96	2.49	1.51	1.07	2.68	6.50	0.80	6.05	6.06
Max.	4.28	1.98	2.79	2.99	2.42	1.65	5.05	8.49	0.89	7.83	7.83
Mean	3.79	1.65	2.34	2.73	2.10	1.31	4.06	7.68	0.86	6.84	6.85
SD	0.23	0.17	0.19	0.16	0.21	0.14	0.52	0.43	0.02	0.66	0.67
CV%	6.00	10.05	8.25	5.74	10.04	10.99	12.81	5.59	2.90	9.57	9.35

Values are given as mean ± SD, n = 100. Different lower-case letters in each column indicate a significant difference between cultivars at $p \leq 0.05$ by the Tukey's test.

Table 5. Fruit morphological characteristics of the cultivars studied.

Cultivar	Fruit Weight (FWg; g)	Fruit Length (FL; mm)	Fruit Diameter (FD; mm)	FL/FD Ratio	Fruit Form Index (IFF; %)	Crown Length (CrL; mm)	Crown Index (IC; %)	Peel Thickness (PT; mm)	Peel Thickness Index (IPT; %)	Peel Weight (PWg; g)
Barski slatki	440.50 ± 93.33 abc	84.94 ± 6.89 a	95.76 ± 6.73 ab	0.89 ± 0.07 ab	113.1 ± 8.6 cde	16.35 ± 2.95 abc	16.2 ± 2.6 bcd	4.79 ± 1.22 b	5.0 ± 1.3 bc	207.73 ± 53.42 cd
Bokežan	347.23 ± 61.06 b–f	76.26 ± 4.83 a–e	90.32 ± 5.66 abc	0.84 ± 0.03 abc	118.5 ± 4.9 b	16.62 ± 3.48 abc	17.9 ± 3.4 ab	4.31 ± 1.55 bc	4.8 ± 1.7 c	197.77 ± 47.72 c–f
Dividiš	474.86 ± 161.94 ab	83.40 ± 7.63 ab	98.19 ± 9.32 a	0.85 ± 0.05 abc	117.9 ± 6.9 b	17.31 ± 2.72 abc	17.3 ± 2.9 ab	4.45 ± 0.98 b	4.6 ± 1.0 c	259.88 ± 109.85 a
Domaći kiseli	389.44 ± 118.81 a–f	78.54 ± 8.24 a–e	90.92 ± 7.58 abc	0.86 ± 0.04 abc	116.1 ± 5.9 bcd	15.89 ± 2.27 bcd	17.0 ± 3.0 ab	4.49 ± 1.25 b	4.9 ± 1.2 bc	227.11 ± 66.58 a–d
Dubrovački kasni	262.53 ± 41.72 f	69.40 ± 5.14 e	80.28 ± 4.69 d	0.86 ± 0.05 abc	116.0 ± 6.1 bcd	16.07 ± 3.69 a–d	18.8 ± 4.1 a	3.97 ± 1.08 bc	5.0 ± 1.4 bc	126.68 ± 41.16 hi
Glavaš	392.01 ± 93.63 a–f	74.62 ± 7.14 b–e	91.84 ± 7.64 abc	0.81 ± 0.04 c	123.4 ± 6.7 a	16.20 ± 3.86 a–d	17.9 ± 34.0 ab	4.32 ± 1.25 bc	4.7 ± 1.3 c	219.17 ± 60.47 a–d
Konjski zub	404.60 ± 93.95 a–e	78.22 ± 5.94 a–e	93.38 ± 7.34 ab	0.84 ± 0.06 abc	119.6 ± 8.1 ab	15.54 ± 2.29 cd	16.6 ± 2.2 bc	4.37 ± 0.97 b	4.7 ± 1.0 c	154.05 ± 45.98 fgh
Kristal	326.66 ± 52.69 c–f	73.00 ± 4.66 cde	86.84 ± 5.71 bcd	0.84 ± 0.04 abc	119.1 ± 5.5 ab	15.43 ± 4.63 cd	17.4 ± 4.7 ab	5.05 ± 0.69 ab	5.9 ± 0.9 ab	134.18 ± 32.05 ghi
Medunac	261.90 ± 38.50 ef	68.30 ± 4.84 e	81.64 ± 4.56 cd	0.84 ± 0.03 abc	119.7 ± 4.4 ab	16.09 ± 2.66 a–d	19.0 ± 2.7 a	4.31 ± 0.91 bc	5.3 ± 1.0 abc	133.14 ± 24.47 ghi
Mojdiški sitnozrni	277.26 ± 49.72 def	69.74 ± 7.77 de	80.60 ± 9.91 cd	0.87 ± 0.03 abc	115.5 ± 4.1 bcd	12.77 ± 2.14 ef	15.6 ± 3.2 b	3.79 ± 0.98 bc	4.7 ± 0.9 c	97.82 ± 34.23 i
Pastun	491.83 ± 148.79 a	85.19 ± 9.16 a	95.04 ± 8.93 ab	0.90 ± 0.06 ab	111.9 ± 7.3 de	17.33 ± 2.63 abc	17.0 ± 2.7 ab	4.69 ± 0.45 ab	5.0 ± 0.7 bc	245.59 ± 74.21 ab
Sladun	430.67 ± 122.21 abc	81.69 ± 7.65 abc	96.74 ± 7.25 a	0.84 ± 0.04 bc	118.8 ± 6.0 b	14.40 ± 2.35 de	15.0 ± 2.0 cd	5.86 ± 1.10 a	6.1 ± 1.3 a	251.53 ± 67.14 ab
Slatki crveni	446.59 ± 76.74 abc	84.96 ± 8.22 a	94.88 ± 6.42 ab	0.90 ± 0.07 a	112.2 ± 7.8 de	17.81 ± 4.51 a	17.2 ± 3.6 ab	4.16 ± 1.31 b	4.4 ± 1.4 c	198.11 ± 50.28 de

Table 5. *Cont.*

Cultivar	Fruit Weight (FWg; g)	Fruit Length (FL; mm)	Fruit Diameter (FD; mm)	FL/FD Ratio	Fruit Form Index (IFF; %)	Crown Length (CrL; mm)	Crown Index (IC; %)	Peel Thickness (PT; mm)	Peel Thickness Index (IPT; %)	Peel Weight (PWg; g)
Slatki tankokorac	497.97 ± 175.62 a	84.54 ± 10.23 ab	98.63 ± 8.91 a	0.86 ± 0.04 abc	117.2 ± 6.0 bc	17.98 ± 1.68 ab	17.7 ± 2.1 ab	4.63 ± 1.06 ab	4.7 ± 1.0 c	215.19 ± 93.09 bcd
Šerbetaš	413.28 ± 117.93 a–d	81.62 ± 7.52 abc	92.10 ± 9.05 ab	0.89 ± 0.04 ab	112.9 ± 6.0 cde	14.33 ± 2.10 de	15.0 ± 2.0 cd	2.85 ± 1.27 c	3.1 ± 1.3 d	184.46 ± 61.71 def
Zamorac	304.50 ± 89.12 c–f	69.36 ± 7.96 de	78.05 ± 7.43 d	0.89 ± 0.05 abc	112.9 ± 6.1 cde	11.22 ± 2.52 f	14.0 ± 2.9 d	3.41 ± 0.60 bc	4.4 ± 1.1 c	112.26 ± 36.19 hi
Hicaznar	462.65 ± 101.71 abc	84.71 ± 6.21 ab	95.17 ± 7.47 ab	0.89 ± 0.06 ab	112.6 ± 7.8 cde	17.05 ± 2.01 abc	16.8 ± 2.2 ab	4.63 ± 1.54 ab	4.9 ± 1.7 bc	239.53 ± 68.93 abc
Granada	378.47 ± 91.50 a–f	79.94 ± 11.99 a–d	88.72 ± 7.25 bcd	0.90 ± 0.12 a	109.4 ± 10.2 e	16.84 ± 2.09 abc	17.1 ± 2.3 ab	4.05 ± 1.71 bc	4.6 ± 2.1 c	171.09 ± 40.88 efg
Wonderful	392.76 ± 83.05 a–f	78.56 ± 6.57 a–e	91.87 ± 7.07 ab	0.86 ± 0.04 abc	117.1 ± 6.1 bc	16.96 ± 3.14 abc	17.7 ± 2.8 ab	4.23 ± 0.97 b	4.6 ± 1.0 c	221.08 ± 64.90 a–d
Min.	261.90	68.30	78.05	0.81	109.4	11.22	14.0	2.85	3.1	97.82
Max.	497.97	85.19	98.63	0.90	123.4	17.98	19.0	5.86	6.1	259.88
Mean	389.25	78.26	90.58	0.86	116.0	15.90	16.9	4.33	4.8	189.28
SD	75.03	5.99	6.33	0.03	3.54	1.72	1.29	0.62	0.61	50.03
CV (%)	19.27	7.65	6.99	3.07	3.05	10.79	7.62	14.38	12.60	26.43

Values are given as mean ± SD, n = 36. Different lower-case letters in each column indicate significant differences between cultivars at $p \leq 0.05$ by Tukey's test.

The results of the analysis of variance showed significant differences in the chromatic values of the color parameters L*, a*, b*, C*, and h° for the peel color attributes between the cultivars (Table 6). Peel color varied significantly ($p \leq 0.05$), with the highest coefficient of variation for the values a* and h° being 32.34% and 28.56%, respectively.

The fruit color is an important characteristic, especially for consumer preference. The lightness of the peel (L*) varied between 44.06 and 66.86. The cultivars 'Konjski zub', 'Šerbetaš', 'Dividiš', 'Sladun', and 'Dubrovački kasni' had the lightest peel colors, while the peels of 'Wonderful', 'Granada', and 'Bokežan' were the darkest (Figure 1). The a* value ranges from negative values for green to positive values for red, while the b* value ranges from negative values for blue to positive values for yellow. In our study, the a* value represents the red color of the peel and ranges from 11.97 to 47.53, while b* represents the yellow color of the peel and ranges from 22.52 to 34.97. For the introduced cultivars 'Hicaznar', 'Granada', and 'Wonderful' as well as the native cultivar 'Bokežan', the red color of the peel dominates, while for the other native cultivars, the yellow color of the peel dominates. In addition, high variability in peel color within cultivars was observed in all native cultivars, except 'Bokežan', with the coefficient of variation ranging from 36.45% ('Barski slatki') to 94.42% ('Mojdiški sitnozrni'). Chroma (C*) describes the color intensity and hue angle (h°) describes the visual color impression. The cultivars with the higher red coloration had the highest C*, while the cultivars with the lighter peel had the highest h°.

Figure 1. Visual representation of the studied cultivars.

Table 6. Peel color CIE L*a*b* parameters of the studied cultivars.

Cultivar	Fruit Peel Color					Fruit Peel Color Index; FCI
	L*	a*	b*	C*	h°	
Barski slatki	54.57 ± 8.60 gh	38.04 ± 13.87 bcd	29.25 ± 3.88 cd	49.35 ± 8.36 bcd	39.79 ± 14.35 de	1.35 ± 0.15 cd
Bokežan	47.89 ± 8.01 ij	47.53 ± 6.99 a	23.99 ± 3.29 fg	53.43 ± 6.27 a	27.16 ± 5.41 f	1.51 ± 0.12 ab
Dividiš	64.78 ± 12.49 a–d	28.28 ± 17.94 ef	32.48 ± 5.11 ab	46.10 ± 7.97 def	52.52 ± 21.63 bc	1.16 ± 0.25 efg
Domaći kiseli	59.80 ± 12.57 c–g	35.22 ± 15.56 cde	29.71 ± 5.24 bcd	48.06 ± 8.55 bcd	42.91 ± 17.42 cd	1.28 ± 0.22 de
Dubrovački kasni	64.10 ± 5.16 a–d	19.01 ± 13.75 gh	34.97 ± 6.18 a	42.32 ± 3.06 fgh	61.82 ± 20.11 ab	1.12 ± 0.23 g
Glavaš	56.62 ± 8.27 e–h	35.90 ± 13.14 cde	27.95 ± 3.50 de	46.77 ± 8.13 cde	40.13 ± 14.11 de	1.36 ± 0.15 cd
Konjski zub	66.86 ± 4.49 ab	16.73 ± 8.98 gh	32.00 ± 3.98 abc	37.28 ± 2.18 ij	62.77 ± 14.87 ab	1.13 ± 0.18 g
Kristal	60.94 ± 13.81 c–f	25.66 ± 15.32 fg	26.74 ± 7.97 de	40.46 ± 4.69 ghi	48.81 ± 24.40 cd	1.33 ± 0.37 d

Table 6. *Cont.*

Cultivar	Fruit Peel Color					Fruit Peel Color Index; FCI
	L*	a*	b*	C*	h°	
Medunac	62.64 ± 9.42 a–d	28.67 ± 17.01 ef	33.81 ± 5.26 a	47.11 ± 7.08 bcd	52.50 ± 20.43 bcd	1.17 ± 0.22 efg
Mojdiški sitnozrni	61.60 ± 5.25 b–f	11.97 ± 11.30 h	31.96 ± 3.99 abc	36.02 ± 1.97 j	69.72 ± 19.20 a	1.14 ± 0.25 fg
Pastun	56.30 ± 12.70 fgh	33.49 ± 15.42 def	28.43 ± 8.21 d	46.59 ± 7.81 de	42.69 ± 19.80 cd	1.36 ± 0.31 cd
Sladun	64.32 ± 7.03 a–d	31.88 ± 14.30 def	32.21 ± 4.73 abc	47.16 ± 6.90 bcd	47.53 ± 16.65 cd	1.19 ± 0.15 ef
Slatki crveni	59.25 ± 11.33 d–g	31.85 ± 13.23 def	25.73 ± 6.47 ef	42.91 ± 6.55 efg	41.27 ± 18.47 d	1.38 ± 0.27 bcd
Slatki tankokorac	54.25 ± 11.37 gh	35.48 ± 13.76 cde	28.19 ± 4.78 de	46.94 ± 7.39 bcd	40.84 ± 16.03 de	1.39 ± 0.22 bcd
Šerbetaš	65.24 ± 5.94 abc	19.61 ± 12.60 gh	31.85 ± 5.65 abc	39.65 ± 2.84 hij	59.22 ± 19.82 b	1.16 ± 0.23 efg
Zamorac	64.30 ± 7.13 a–d	31.86 ± 13.65 cde	32.19 ± 4.52 abc	46.89 ± 7.90 cde	47.45 ± 16.57 cd	1.19 ± 0.14 ef
Hicaznar	52.12 ± 5.45 hi	42.43 ± 8.28 abc	24.48 ± 2.30 fg	49.21 ± 7.37 bcd	30.72 ± 5.80 ef	1.47 ± 0.06 bc
Granada	44.28 ± 5.45 j	45.34 ± 4.05 ab	22.80 ± 3.09 fg	50.81 ± 4.49 ab	26.66 ± 2.82 f	1.62 ± 0.14 a
Wonderful	44.06 ± 6.73 j	45.07 ± 4.16 ab	22.52 ± 3.19 g	50.49 ± 4.01 abc	26.60 ± 4.00 f	1.63 ± 0.16 a
Min.	44.06	11.97	22.52	36.02	26.60	1.12
Max.	66.86	47.53	34.97	53.43	69.72	1.63
Mean	57.76	31.79	28.84	45.59	45.20	1.31
SD	7.08	10.28	3.84	4.82	12.91	0.16
CV (%)	12.26	32.34	13.31	10.57	28.56	12.21

Values are given as mean ± SD, n = 9. Different lowercase letters in each column indicate a significant difference between cultivars at $p \leq 0.05$ by Tukey's test. Abbreviations: L*—lightness, a*—red–green color spectrum, b*—yellow–blue color spectrum, C*—Chroma, and h°—hue angle.

3.1.4. Aril

The significant differences between aril characteristics and the high variability (>20%) between cultivars for total aril weight, aril weight, number of arils per fruit, seed length, seed width, and seed yield are shown in Table 7.

The arils contain the edible part of the pomegranate fruit, which contains the juice and the seed. The total aril weight varied between 128.76 g ('Medunac') and 282.78 g ('Slatki tankokrac'). Aril yield was highest in 'Mojdiški sitnozrni' (65.49%) compared to all studied cultivars except 'Konjski zub', and 'Zamorac', while it was lowest in 'Sladun' (40.92%).

The weight of the individual aril was between 0.27 g and 0.59 g. The cultivars 'Kristal' (0.59 g), 'Dividiš' (0.58 g), and 'Konjski zub' (0.55 g) had the highest values and showed no difference to 'Slatki tankokorac' (0.52 g). In addition, 'Kristal' had the longest and widest aril (14.58 mm and 10.05 mm), while 'Wonderful' and 'Granada' had the shortest and narrowest (10.34 mm and 7.26 mm and 10.53 and 7.87 mm, respectively). The number of arils in the fruit varied between 336 and 692 in the different cultivars.

The cultivars also differed in seed characteristics with a coefficient of variation of 23.71, 23.77, and 20.27% for seed length, seed width, and seed yield, respectively. The longest seeds had 'Konjski zub' (8.16 mm) and 'Kristal' (8.10 mm) and the shortest 'Domaći kiseli' (6.58 mm) of all other cultivars except for 'Dubrovački kasni'. The widest seed was 'Dividiš' (3.86 mm) compared to all cultivars except for 'Konjski zub', while the narrowest was 'Mojdiški sitnozrni' (2.83 mm). Seed yield ranged from 4.29% to 8.47% and the heaviest seed was 'Zamorac' (0.043 g). In our study, 63% of the cultivars had hard seeds and 37% had medium seeds (Table 2).

The mean values of the aril and juice color parameters (L*, a*, b*, C*, and h°) and significant differences of studied cultivars are shown in Tables 8 and 9.

Table 7. Aril morphological characteristics of the studied cultivars.

Cultivar	Total Arils Weight (TAW; g)	Arils Yield (AY; %)	Aril Weight (AWg; g)	Aril Length (AL; mm)	Aril Width (AW; mm)	Number of Arils in the Fruit (No/AF)	Seed Length (SL; mm)	Seed Width (SW; mm)	Seed Weight (SWg; g)	Seed Yield (SY; %)
Barski slatki	232.62 ± 52.09 a–d	52.89 ± 5.32 ef	0.36 ± 0.08 c–f	11.81 ± 0.90 ef	8.34 ± 0.86 ef	653 ± 158 ab	7.56 ± 0.58 cd	3.67 ± 0.37 b	0.031 ± 0.008 c	8.06 ± 1.63 ab
Bokežan	149.46 ± 29.17 fg	43.34 ± 6.09 jk	0.31 ± 0.03 efg	10.73 ± 0.76 ij	8.14 ± 0.67 fg	482 ± 109 cde	6.89 ± 0.48 g	3.38 ± 0.29 fgh	0.027 ± 0.003 e–h	8.12 ± 1.40 ab
Dividiš	214.98 ± 70.68 a–f	46.01 ± 12.23 hij	0.58 ± 0.12 a	13.62 ± 1.33 b	9.86 ± 1.14 a	410 ± 199 def	7.73 ± 0.76 bc	3.86 ± 0.41 a	0.026 ± 0.006 f–i	4.65 ± 1.79 g
Domaći kiseli	168.99 ± 55.41 d–g	43.41 ± 9.45 jk	0.31 ± 0.06 fg	11.00 ± 0.58 hi	8.49 ± 0.56 de	518 ± 221 cd	6.58 ± 0.45 h	3.27 ± 0.31 h	0.028 ± 0.003 b–g	8.47 ± 1.58 a
Dubrovački kasni	135.85 ± 30.17 g	52.24 ± 9.56 efg	0.36 ± 0.04 c–g	11.96 ± 0.82 c–f	9.00 ± 0.90 c	383 ± 97 ef	6.87 ± 0.65 fgh	3.44 ± 0.36 d–h	0.025 ± 0.003 f–i	6.81 ± 1.11 c–f
Glavaš	172.84 ± 40.81 c–g	44.45 ± 5.51 ijk	0.37 ± 0.07 c–f	11.83 ± 0.73 ef	8.66 ± 0.84 cd	463 ± 129 c–f	7.72 ± 0.60 bc	3.61 ± 0.35 bcd	0.030 ± 0.007 bcd	7.91 ± 2.30 a–d
Konjski zub	250.55 ± 60.71 ab	62.00 ± 6.84 ab	0.55 ± 0.08 a	13.48 ± 1.53 b	9.49 ± 1.09 b	467 ± 146 cde	8.16 ± 0.83 a	3.67 ± 0.48 abc	0.026 ± 0.006 f–i	4.85 ± 1.19 g
Kristal	192.47 ± 38.39 b–f	58.98 ± 7.71 bc	0.59 ± 0.09 a	14.58 ± 1.02 a	10.05 ± 0.88 a	336 ± 93 f	8.10 ± 0.82 a	3.53 ± 0.47 c–f	0.023 ± 0.006 ij	4.29 ± 1.74 g
Medunac	128.76 ± 21.14 g	49.17 ± 4.30 fghi	0.33 ± 0.07 d–g	11.59 ± 0.90 fg	8.96 ± 0.98 c	420 ± 145 def	6.89 ± 0.65 fg	3.41 ± 0.39 fgh	0.023 ± 0.002 hij	7.52 ± 1.05 a–e
Mojdiški sitnozrni	179.44 ± 22.75 b–g	65.49 ± 6.33 a	0.32 ± 0.06 d–g	12.46 ± 0.49 c	8.94 ± 0.65 c	587 ± 123 abc	7.16 ± 0.49 ef	2.83 ± 0.56 i	0.032 ± 0.008 bc	6.36 ± 1.07 ef
Pastun	246.24 ± 79.50 abc	49.93 ± 3.62 fgh	0.39 ± 0.09 c–f	12.24 ± 1.12 cd	8.89 ± 0.97 c	665 ± 228 ab	7.74 ± 0.65 bc	3.60 ± 0.37 b–e	0.030 ± 0.005 b–e	7.88 ± 1.70 abc
Sladun	179.14 ± 75.42 efg	40.92 ± 6.73 k	0.42 ± 0.11 cd	11.30 ± 0.86 gh	8.74 ± 0.90 cd	428 ± 123 def	6.93 ± 0.41 g	3.62 ± 0.27 bc	0.027 ± 0.002 def	6.96 ± 0.85 ce
Slatki crveni	248.49 ± 49.09 ab	55.86 ± 8.35 cde	0.40 ± 0.09 cde	12.01 ± 0.89 de	8.78 ± 0.86 cd	615 ± 143 ab	7.44 ± 0.60 d	3.41 ± 0.33 fgh	0.025 ± 0.005 f–i	5.89 ± 1.03 f
Slatki tankokorac	282.78 ± 89.15 a	57.31 ± 5.24 bcd	0.52 ± 0.12 ab	13.60 ± 1.24 b	9.51 ± 0.87 b	558 ± 228 bc	7.82 ± 0.71 b	3.37 ± 0.38 gh	0.024 ± 0.003 g–j	4.81 ± 1.33 g
Šerbetaš	228.81 ± 64.82 a–e	55.61 ± 5.90 cde	0.45 ± 0.05 bc	12.06 ± 1.29 cde	8.86 ± 1.15 c	483 ± 193 cd	7.46 ± 0.52 cde	3.74 ± 0.33 ab	0.027 ± 0.003 d–g	5.99 ± 0.51 f
Zamorac	192.24 ± 67.73 a–g	62.62 ± 7.31 ab	0.35 ± 0.04 c–g	12.20 ± 1.10 cd	8.88 ± 0.95 c	579 ± 236 abc	7.43 ± 0.51 d	3.61 ± 0.34 bcd	0.043 ± 0.001 a	5.57 ± 0.79 fg
Hicaznar	223.12 ± 54.03 a–f	48.59 ± 6.86 ghi	0.35 ± 0.08 c–g	11.24 ± 0.71 gh	7.39 ± 0.71 h	659 ± 177 ab	7.56 ± 0.46 cd	3.48 ± 0.24 d–g	0.024 ± 0.004 hij	6.76 ± 1.73 ef
Granada	207.39 ± 63.62 b–f	54.28 ± 6.67 de	0.32 ± 0.12 fg	10.53 ± 0.79 jk	7.87 ± 0.71 g	692 ± 174 a	7.72 ± 0.48 bc	3.46 ± 0.33 efg	0.021 ± 0.005 j	7.20 ± 2.68 b–e
Wonderful	171.68 ± 31.47 d–g	44.41 ± 7.08 ijk	0.27 ± 0.04 g	10.34 ± 0.86 k	7.26 ± 0.79 h	641 ± 147 ab	7.17 ± 0.51 e	3.39 ± 0.32 gh	0.023 ± 0.005 ij	8.23 ± 1.92 a
Min.	128.76	40.92	0.27	10.24	7.26	336	6.58	2.83	0.021	4.29
Max.	282.78	65.49	0.59	14.58	10.05	692	8.16	3.86	0.043	8.47
Mean	200.31	51.97	0.40	12.02	8.71	528	7.42	3.49	0.03	6.65
SD	42.05	7.27	0.10	1.17	0.79	108	1.76	0.83	0	1.35
CV (%)	20.99	13.99	24.32	9.70	9.12	20.51	23.71	23.77	17.99	20.27

Values are given as mean ± SD, n = 120. Different lower-case letters in each column indicate a significant difference between the cultivars at $p \leq 0.05$ by the Tukey's test.

Table 8. CIE L*a*b* aril color parameters of the studied cultivars.

Cultivar	Aril Color					Aril Color Index; ACI
	L*	a*	b*	C*	h°	
Barski slatki	33.61 ± 2.41 abc	17.60 ± 2.36 def	6.87 ± 1.64 bc	18.91 ± 2.73 d–g	21.09 ± 2.71 bc	3.05 ± 0.34 c
Bokežan	41.88 ± 3.72 fg	14.45 ± 4.29 a–d	9.45 ± 1.94 f–i	17.50 ± 3.72 c–f	34.36 ± 9.94 ef	2.47 ± 0.29 i
Dividiš	46.68 ± 3.78 h	12.47 ± 4.50 a	10.49 ± 1.29 ij	16.60 ± 3.38 cde	41.92 ± 11.47 g	2.19 ± 0.21 l
Domaći kiseli	44.22 ± 5.01 gh	13.38 ± 4.49 ab	9.69 ± 1.70 g–j	16.83 ± 3.51 cde	37.82 ± 12.55 fg	2.35 ± 0.33 k
Dubrovački kasni	35.55 ± 2.28 cd	18.39 ± 1.47 f	7.51 ± 1.08 cd	19.88 ± 1.62 fg	22.16 ± 2.45 bcd	2.86 ± 0.20 de
Glavaš	41.25 ± 4.53 f	14.02 ± 4.28 abc	10.38 ± 2.00 hij	17.77 ± 3.23 c–g	37.97 ± 11.82 fg	2.45 ± 0.33 jk
Konjski zub	34.77 ± 2.31 bcd	18.63 ± 3.30 f	8.22 ± 1.70 c–f	20.39 ± 3.54 g	23.87 ± 3.38 bcd	3.34 ± 0.40 b
Kristal	40.08 ± 4.64 f	11.91 ± 5.09 a	9.28 ± 1.80 f–i	15.60 ± 3.61 bc	40.62 ± 15.70 fg	3.77 ± 0.30 a
Medunac	40.14 ± 2.59 f	17.71 ± 1.94 ef	7.79 ± 1.22 cde	19.38 ± 1.97 efg	23.78 ± 3.48 bcd	2.84 ± 0.21 de
Mojdiški sitnozrni	41.29 ± 3.22 fg	14.61 ± 2.99 a–e	7.46 ± 1.38 cd	16.51 ± 2.72 cd	27.61 ± 6.58 cde	2.53 ± 0.40 hij
Pastun	41.16 ± 5.05 f	14.73 ± 6.23 a–e	11.13 ± 1.60 j	18.92 ± 4.92 d–g	40.03 ± 13.74 fg	2.64 ± 0.20 fgh
Sladun	39.62 ± 3.32 ef	16.35 ± 2.69 b–f	9.00 ± 1.62 e–h	18.74 ± 2.65 d–g	29.05 ± 5.36 de	2.65 ± 0.25 fgh
Slatki crveni	37.10 ± 1.89 de	16.33 ± 3.55 b–f	8.42 ± 2.05 d–g	18.43 ± 3.85 c–g	27.42 ± 4.49 cde	2.34 ± 0.31 k
Slatki tankokorac	37.06 ± 2.55 de	18.06 ± 2.71 f	8.25 ± 1.64 c–g	19.89 ± 2.98 fg	24.46 ± 3.26 cd	2.60 ± 0.25 ghi
Šerbetaš	35.79 ± 3.23 cd	16.76 ± 2.68 c–f	7.40 ± 1.83 cd	18.37 ± 2.97 c–g	23.68 ± 4.33 bcd	2.77 ± 0.26 def
Zamorac	41.14 ± 5.07 f	14.70 ± 6.26 a–e	11.10 ± 1.63 j	18.90 ± 4.94 d–g	39.89 ± 13.70 fg	2.33 ± 0.32 k
Granada	31.32 ± 1.99 a	17.31 ± 3.40 def	5.43 ± 2.10 b	18.17 ± 3.85 c–g	16.83 ± 3.32 ab	2.75 ± 0.25 efg
Hicaznar	31.68 ± 1.45 a	13.02 ± 1.90 a	2.67 ± 0.94 a	13.30 ± 2.04 ab	11.25 ± 2.52 a	3.79 ± 0.31 a
Wonderful	32.20 ± 1.42 ab	12.34 ± 1.93 a	2.46 ± 0.93 a	12.59 ± 2.06 a	10.93 ± 2.63 a	2.92 ± 0.35 cd
Min.	31.32	11.91	2.46	12.59	10.93	2.19
Max.	46.68	18.63	11.13	20.39	41.92	3.79
Mean	38.08	15.45	7.88	17.65	27.49	2.77
SD	4.42	2.27	2.39	2.14	9.63	0.45
CV (%)	11.61	14.69	30.32	12.12	35.03	16.25

Values are given as mean ± SD, n = 30. Different lowercase letters in each column indicate a significant difference between cultivars for $p \leq 0.05$ by the Tukey's test. Abbreviations: L*—lightness, a*—red–green color spectrum, b*—yellow–blue color spectrum, C*—Chroma, and h°—hue angle.

Table 9. CIE L*a*b* juice color parameters of the studied cultivars.

Cultivar	Juice Color					Juice Color Index: JCI
	L*	a*	b*	C*	h°	
Barski slatki	20.36 ± 0.61 abc	3.47 ± 0.32 ab	3.44 ± 0.17 ghi	4.89 ± 0.20 bc	44.83 ± 3.42 hij	5.35 ± 0.08 bcd
Bokežan	22.51 ± 0.26 def	7.49 ± 0.34 hij	4.37 ± 0.05 j	8.67 ± 0.31 h	30.27 ± 0.89 def	4.80 ± 0.06 g
Dividiš	26.07 ± 0.24 h	5.90 ± 0.19 efg	1.23 ± 0.04 a	6.03 ± 0.19 cde	11.81 ± 0.08 a	5.24 ± 0.02 d
Domaći kiseli	23.47 ± 0.10 fg	7.82 ± 0.29 ij	2.75 ± 0.07 def	8.29 ± 0.29 gh	19.39 ± 0.26 abc	5.06 ± 0.04 f
Dubrovački kasni	23.24 ± 0.10 efg	6.70 ± 0.14 ghi	2.32 ± 0.11 cd	7.10 ± 0.09 efg	19.07 ± 1.16 abc	5.30 ± 0.01 cde
Glavaš	20.30 ± 0.30 abc	5.08 ± 0.31 def	3.75 ± 0.12 i	6.32 ± 0.29 de	36.49 ± 1.46 fgh	5.39 ± 0.03 bcd
Konjski zub	24.72 ± 0.61 gh	5.59 ± 0.29 d–g	1.39 ± 0.25 ab	5.77 ± 0.24 b–e	13.99 ± 2.88 ab	5.44 ± 0.09 b
Kristal	23.94 ± 0.51 fg	2.27 ± 1.01 a	1.01 ± 0.17 a	2.50 ± 0.97 a	26.15 ± 8.95 cde	5.82 ± 0.26 a
Medunac	24.33 ± 0.33 g	8.24 ± 0.80 j	1.86 ± 0.23 bc	8.45 ± 0.73 gh	12.86 ± 2.80 ab	5.10 ± 0.09 f
Mojdiški sitnozrni	21.78 ± 0.28 cde	6.39 ± 1.05 fgh	2.57 ± 0.07 de	6.89 ± 1.01 ef	22.15 ± 2.54 bcd	5.51 ± 0.05 b
Pastun	19.22 ± 1.50 a	4.33 ± 0.40 bcd	3.16 ± 0.30 fgh	5.35 ± 0.49 bcd	36.14 ± 1.13 fgh	5.86 ± 0.23 a
Sladun	21.61 ± 0.24 b–e	4.94 ± 0.49 cde	3.04 ± 0.16 efg	5.80 ± 0.49 b–e	31.73 ± 1.63 efg	5.41 ± 0.09 bcd
Slatki crveni	20.59 ± 0.38 abc	3.46 ± 0.12 ab	3.04 ± 0.47 efg	4.62 ± 0.26 b	41.17 ± 5.00 ghi	5.50 ± 0.17 b
Slatki tankokorac	23.96 ± 0.76 fg	7.38 ± 0.09 hij	2.38 ± 0.15 cd	7.75 ± 0.05 fgh	17.91 ± 1.21 abc	5.11 ± 0.09 ef
Šerbetaš	21.43 ± 0.38 bcd	4.21 ± 0.20 bcd	2.85 ± 0.24 def	5.10 ± 0.06 bcd	34.06 ± 3.50 efg	5.50 ± 0.06 bc
Zamorac	19.20 ± 1.50 a	4.23 ± 0.30 bcd	3.12 ± 0.30 fgh	5.32 ± 0.50 bcd	36.05 ± 1.15 gfh	5.87 ± 0.22 a
Granada	19.18 ± 0.09 a	2.97 ± 0.31 ab	3.68 ± 0.22 hi	4.73 ± 0.33 bc	51.09 ± 2.35 j	5.39 ± 0.10 bcd
Hicaznar	20.07 ± 0.03 ab	3.33 ± 0.07 ab	3.63 ± 0.02 ghi	4.93 ± 0.05 bc	47.49 ± 0.68 ij	5.31 ± 0.20 d
Wonderful	19.28 ± 0.74 a	3.62 ± 0.26 abc	3.81 ± 0.04 ij	5.26 ± 0.16 bcd	46.54 ± 2.15 ij	5.44 ± 0.22 bc
Min.	19.18	2.27	1.01	2.50	11.81	4.80
Max.	26.07	8.24	4.37	8.67	51.09	5.87
Mean	22.00	5.18	2.79	6.03	30.17	5.36
SD	2.11	1.84	0.96	1.60	12.84	0.25
CV (%)	9.63	35.71	34.03	26.78	42.59	5.39

Values are given as mean ± SD, n = 9. Different lowercase letters in each column indicate a significant difference between the aril color characteristics of the cultivars for $p \leq 0.05$ by Tukey's test. Abbreviations: L*—lightness, a*—red–green color spectrum, b*—yellow–blue color spectrum, C*—Chroma, and h°—hue angle.

The aril colors of 'Granada' and 'Hicaznar' were darker (the lowest L* value) compared to other studied cultivars except for 'Wonderful' and 'Barski slatki', while 'Dividiš' and

'Domaći kiseli' had the lightest aril colors. The red–green color spectra (a*) of all studied cultivars indicated the red aril colors. 'Konjski zub' had the highest red color intensity, followed by 'Dubrovački kasni', 'Slatki tankokorac', 'Barski slatki', 'Medunac', 'Sladun', 'Slatki crveni', 'Šerbetaš', and 'Granada'. No significant differences were found between these cultivars. 'Kristal', 'Dividiš', 'Wonderful', and 'Granada' had the lowest values for red. In all of the studied cultivars, the yellow–blue color spectrum (b*) was oriented toward yellow, which was the most pronounced in the cultivars 'Pastun' (11.13), 'Dividiš' (10.49), 'Glavaš' (10.38), and 'Domaći kiseli' (9.69), while 'Wonderful' and 'Hicaznar' had the lowest yellow color intensities (2.46 and 2.67, respectively). The lowest color intensity (C*) of the aril was observed in the cultivars 'Wonderful' (12.59) and 'Hicaznar' (13.30), while the C* of 'Konjski zub' was higher compared to the cultivars 'Bokežan', 'Dividiš', 'Domaći kiseli', 'Kristal', 'Mojdiški sitnozrni', 'Hicaznar', and 'Wonderful' (Table 8). According to the h° value, all cultivars belonged to the red–violet group (10.93–41.92). The h° value was the lowest for dark cultivars ('Granada', 'Hicaznar', and 'Wonderful').

In addition, statistical differences were found between the cultivars in the color parameters of the juice, along with a high degree of variability in the red–green (a*) and yellow–blue (b*) color spectra, color intensity (C*), and h° value (Table 9).

The darkest juice (L*) values were found in 'Granada', 'Zamorac', 'Pastun', and 'Wonderful', and did not differ from 'Hicaznar', 'Barski slatki', 'Glavaš', and 'Slatki crveni', while 'Dividiš' had the lightest juice color compared to the other studied cultivars except for 'Konjski zub'. The a* value varied from 2.27 to 8.24. 'Medunac' had the highest a* value but did not differ from Bokežan, Domaći kiseli, and 'Slatki tankokorac'. The C* value varied between 2.50 and 8.67, while h° was between 11.81 and 51.09. According to the value for h°, all cultivars belonged to the red–violet juice color group.

3.2. Juice Yield, Total Soluble Solids, and Total Acidity Content

The high juice yield and the quality characteristics of the juice are very important properties for producers, breeders, and the processing industry. The juice yield (JY), total soluble solid (TSS; °Brix), total acidity (TA; %), and the TSS/TA ratio of the juice of the cultivars studied are shown in Table 10.

Table 10. Juice yield, total soluble solid, total acidity, and TSS/TA ratio of the studied cultivars.

Cultivar	Juice Yield (JY; %)	Total Soluble Solid (TSS; °Brix)	Total Acidity (TA; %)	TSS/TA
Barski slatki	64.3 ± 13.5 ab	15.9 ± 1.2 ab	0.66 ± 0.06 e	24.13 ± 2.29 d
Bokežan	64.3 ± 9.1 ab	16.0 ± 1.7 ab	2.11 ± 0.71 bc	8.29 ± 2.56 e
Dividiš	69.0 ± 6.1 ab	13.8 ± 1.6 d	1.69 ± 0.28 d	8.37 ± 1.49 e
Domaći kiseli	68.5 ± 8.4 ab	16.1 ± 1.2 ab	2.10 ± 0.37 bc	7.88 ± 1.46 e
Dubrovački kasni	65.9 ± 8.2 ab	16.8 ± 1.4 ab	0.54 ± 0.07 e	31.35 ± 3.30 abc
Glavaš	67.2 ± 8.3 ab	16.0 ± 2.5 ab	2.46 ± 0.29 ab	6.60 ± 1.21 e
Konjski zub	67.1 ± 1.6 ab	15.3 ± 1.1 bcd	0.46 ± 0.08 e	34.30 ± 8.20 a
Kristal	71.8 ± 10.0 ab	15.3 ± 1.6 a–d	0.46 ± 0.07 e	33.74 ± 5.53 a
Medunac	69.3 ± 3.8 ab	15.2 ± 2.3 a–d	0.57 ± 0.17 e	27.96 ± 6.18 bcd
Mojdiški sitnozrni	66.4 ± 5.9 ab	12.8 ± 0.49 d	0.49 ± 0.06 e	26.42 ± 3.89 cd
Pastun	61.9 ± 8.9 b	14.1 ± 1.4 cd	1.81 ± 0.31 cd	8.01 ± 1.55 e
Sladun	65.8 ± 7.7 ab	18.9 ± 1.4 ab	0.66 ± 0.08 e	24.24 ± 2.51 d
Slatki crveni	68.5 ± 10.2 ab	16.6 ± 1.3 ab	0.53 ± 0.08 e	31.81 ± 3.71 ab
Slatki tankokorac	73.7 ± 5.9 a	14.1 ± 1.4 cd	0.61 ± 0.11 e	23.47 ± 4.26 d
Šerbetaš	73.4 ± 2.4 a	17.2 ± 1.3 a	0.64 ± 0.11 e	27.25 ± 3.12 cd
Zamorac	68.3 ± 2.6 ab	15.7 ± 0.8 a–d	2.17 ± 0.29 abc	7.38 ± 1.30 e
Hicaznar	67.5 ± 9.0 ab	16.8 ± 1.9 ab	2.10 ± 0.44 bc	8.33 ± 1.89 e
Granada	68.9 ± 9.9 ab	15.7 ± 2.0 abc	2.50 ± 0.51 a	6.63 ± 1.96 e
Wonderful	63.9 ± 9.5 ab	16.8 ± 1.1 ab	2.15 ± 0.34 abc	7.97 ± 1.19 e
Min.	61.9	12.8	0.46	6.60
Max.	73.7	18.9	2.50	34.30

Table 10. *Cont.*

Cultivar	Juice Yield (JY; %)	Total Soluble Solid (TSS; °Brix)	Total Acidity (TA; %)	TSS/TA
Mean	67.7	15.75	1.30	18.64
SD	3.10	1.39	0.82	11.04
CV (%)	4.59	8.80	63.08	59.21

Values are given as mean ± SD, n = 12. Different lower-case letters in each column indicate a significant difference between cultivars at $p \leq 0.05$ by the Tukey's test.

There were significant differences in the juice yield of the studied cultivars, ranging from 61.86% to 73.69%. 'Slatki tankokorac' and 'Šerbetaš' had higher juice yields than 'Pastun'. The total soluble solid content and total titratable acidity varied significantly between 12.8 °Brix ('Mojdiški sitnozrni') and 18.9 °Brix ('Sladun') and between 0.46% ('Konjski zub' and 'Kristal') and 2.50% ('Granada'). The TSS/TA ratio is also an important parameter and plays a major role in the perception of pomegranate flavor, as it creates a balance between sweetness and acidity and determines the taste. Each pomegranate cultivar requires a specific TSS/TA ratio at the time of harvest. In this study, the TSS/TA ratio varied between 6.60 ('Glavaš') and 34.30 ('Konjski zub').

3.3. Relationship between Different Pomegranate Cultivars and their Morphological and Chemical Characteristics

The use of a heat map allows visualizing complex relationships between 19 pomegranate cultivars, clustered based on 44 characters specifically selected for their coefficient of variation exceeding 15%; this approach helps in identifying patterns and understanding their interrelationships or similarities (Figure 2).

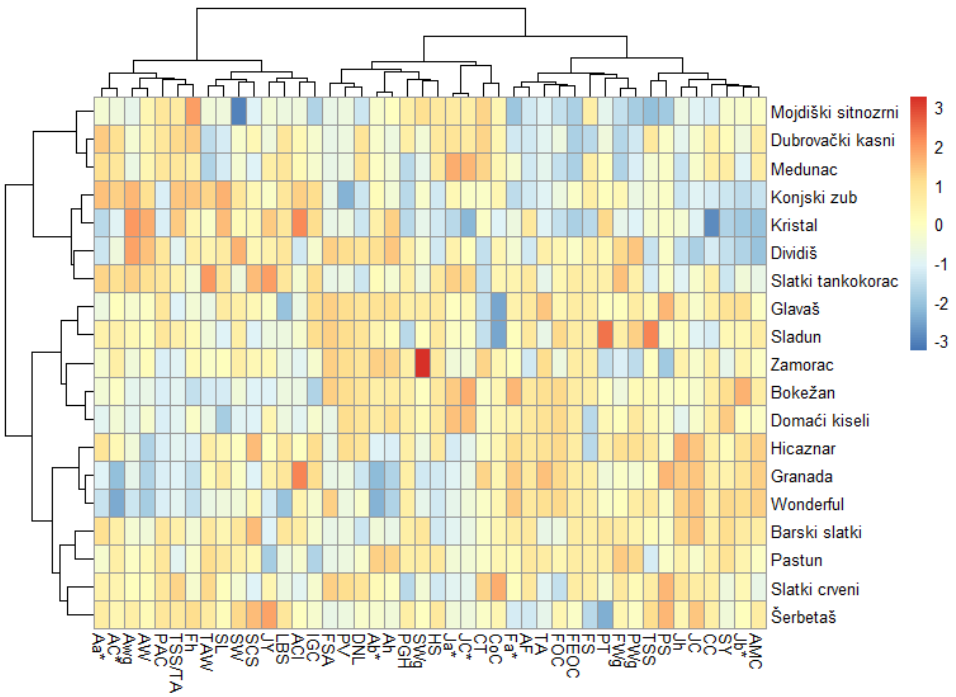

Figure 2. Clustering of pomegranate cultivars based on the morphological parameters of the tree, leaf, flower, fruit, aril, and seed, as well as the chemical parameters of the juice. The rows of the diagram represent the cultivars and the columns denote the analyzed characteristics. For the abbreviations of the analyzed traits, see Tables 1 and 3–10. In addition, the color parameters obtained from the CIE L*a*b* method are represented by the letters L*, a*, b* C*, and h° located behind the label representing the object of analysis, i.e., fruit (F), aril (A) or juice (J). The colors of the cells of the heatmap indicate low (dark blue), medium (white), and high (dark red) values of a particular trait.

The pomegranate cultivars were divided into two clusters, which were further subdivided into subgroups. The first cluster featured the fruit peel h° color value (Fh°) and lower values of the red color of fruit peel (Fa*) and juice b* (Jb*) values. Within this cluster, 'Mojdiški sitonozrni', 'Dubrovački kasni', and 'Medunac' stood out with high red juice color values (Ja*), but also had lower values for fruit and peel weight (FWg and PWg) and fruit extent of overcolor (FEOC). The second sub-cluster was characterized by high aril weight (AWg) and TSS/TA values but low aril main color (AMC), juice b* values, h° values, seed yield (SY), and calix color (CC) values; it consisted of four different cultivars ('Kristal', 'Dividiš', 'Konjski zub', and 'Slatki tankokorac'). The second cluster was generally characterized by higher values for fruit peel red color (Fa*), fruit extent of overcolor (FEOC), juice b* and h° values, and lower values for aril width (AW). A more pronounced aril main color (AMC), fruit peel red color (a*), total acidity (TA), as well as juice h° (Jh°), juice color (JC), and seed yield (SY) characterize the three cultivars ('Wonderful', 'Hicaznar', 'Granada'), forming the sub-cluster in the lower part of the heatmap display. On the other hand, these cultivars have lower values of aril weight (AWg), petiole anthocyanin color (PAC), TSS/TA ratio, and fruit peel h° value. 'Barski slatki', 'Pastun', 'Slatki crveni', and 'Šerbetaš' have higher total aril weight (TAW) and seed length (SL), along with lower juice color (JC) values and intensity of red color in the juice (a*). 'Zamorac', 'Domaći kiseli', and 'Bokežan' are cultivars that, in addition to the cluster characteristics mentioned above, are distinguished by lower petiole anthocyanin coloration and TSS/TA ratio, and a higher predominant number of leaves per node (DNL), aril h°, aril b* value, and seed weight (SWg) (Figure 2).

In addition, the morphological characteristics of the tree, flower, fruit, aril, and seed, as well as the chemical properties of the juice, could be divided into three categories by cluster analysis (Figure 2). The intensity of the red color of the aril (Aa*) was closely related to the weight of the aril (AWg) and the taste characteristic of the juice (TSS/TA). Juice yield (JY) was related to total aril weight (TAW) and seed characteristics (SL, SW, SCS). Tree characteristics, i.e., plant vigor, plant growth habit, and predominant number of leaves per node on young shoots (PV, PGH, and DNL, respectively), were clustered together; they are closely related to corolla color (CoC) and crown type (CT). The acidity of the juice (TA), the red color of the fruit peel (Fa*), fruit overcolor, and fruit extent of overcolor (FOC and FEOC, respectively) were grouped together (Figure 2).

According to the correlation analysis of the analyzed characteristics (Supplementary Materials, Table S1), the fruit weight (FWg) was generally proportional to the total aril weight (TAW), while the juice yield (JY) was proportional to aril weight (AWg). Seed hardness is a genetic characteristic of the cultivar, but consumers prefer soft seeds for fresh consumption, while the processing industry uses cultivars with hard seeds. Seed hardness is significantly negatively correlated with seed length (SL), while it is positively correlated with the intensity of the red color of the juice (Ja*). There is no significant correlation between the intensity of the red color of the fruit peel (Fa*) and the red color of the aril or juice (Aa*, Ja*), while FEOC and FOC are significantly positively correlated with acidity and the red color of the fruit peel (TA and Fa*).

4. Discussion

4.1. Morphological Characteristics

The results of this study showed considerable variability between the cultivars studied in terms of qualitative and quantitative characteristics (Tables 1–10, Figure 1). Narzary et al. [14] found that the leaf sizes varied between 2 and 11 cm in length and 1 and 3 cm in width. According to these data, the cultivars in our study belong to the group of cultivars with medium leaf lengths and widths. A significant difference between cultivars was also observed in the flower characteristics (Table 4). All studied cultivars had long petals, except for 'Bokežan', whose petals were medium-sized. The average leaf length and width of the studied cultivars were similar to Spanish pomegranates [15], while calyx and petals were longer and wider than in Spanish cultivars. Although significant diversity was found among cultivars, the

coefficients of variation (CVs) among cultivars were lower, with 6.65–10.97% for leaf characteristics and 2.90–12.81% for flower characteristics, suggesting that these characteristics have less discriminating power.

The morphological characteristics examined showed considerable differences between the cultivars in the ex situ collection. Fruit weight and peel weight showed coefficients of variation of more than 15% (Table 5). Audergon (1987), cited in Mansour et al. [16], considered values between 15 and 20% as medium and above 20% as significant, indicating a large variability related to the studied traits. The fruit weight of the pomegranate is considered the most commonly used measure for identifying some cultivars. Fruit size and peel color are important characteristics that attract the attention of consumers in the market. Consumer preferences show that Indian consumers [17] value small- to medium-sized fruits more, while in Croatia, medium-to-large fruits are preferred [18]. Studies by Parashuram et al. [17] in India, Mansour et al. [16] in Lebanon, Chen et al. [19] in China, Khadivi and Arab [20] in Iran, and Ferrara et al. [21] in Italy found similar values for fruit weight, while Tapia-Campos et al. [22] in Mexico reported slightly lower values for the fruit weights of different pomegranate cultivars. The fruits of the 'Glavaš' cultivar were significantly smaller than in earlier studies [18,23]. The fruit weights of the cultivars 'Barski slatki', 'Konjski zub', 'Sladun', and 'Šerbetaš' were higher (and for 'Dividiš'—lower) than the fruit weights of the same cultivars grown in a production plantation under agroecological conditions in Metković, Croatia [24]. This was most likely due to different environmental conditions, as the study by Ghasemi-Soloklui [25] found that the change in the initial climate of pomegranate cultivars affects the weight of the fruit, aril, and peel. We divided the cultivars into three groups according to fruit weight: cultivars with medium ('Dubrovački kasni', 'Medunac', 'Mojdiški sitnozrni'), large ('Bokežan', 'Domaći kiseli', 'Glavaš', 'Kristal', 'Zamorac', 'Granada', and 'Wonderful'), and very large ('Barski slatki', 'Dividiš', 'Konjski zub', 'Pastun', 'Sladun', 'Slatki crveni', 'Slatki tankokorac', 'Šerbetaš', and 'Hicaznar') fruits. According to the UNECE international standards [26], 9 of the investigated cultivars belong to class B by weight, while 16 cultivars belong to class A by diameter. Fruit size is a genetic characteristic of the cultivar, but can vary considerably depending on climatic conditions, year, and cultivation technique. In the present study, the fruit weight variability was more genetically determined, as the ex situ collection and fruit testing took place at one location. The peel weight, crown type, fruit shape, fruit shape in cross-section, total aril weight, aril weight, number of arils per fruit, seed length and width, seed yield, total acidity, and TSS/TA value were characteristics that had the greatest discriminating power.

The fruit length/diameter ratio of Italian native pomegranates [27] was similar to the FL/diameter ratio in our study. Martinez et al. [28] used the Fruit Form Index (IF), which is the ratio between the equatorial fruit diameter and the fruit length excluding the crown. In our study, the IFF was between 109.4% ('Granada') and 123.4% ('Glavaš'), while in Spain it was between 108.7% and 115.1% [28].

There were significant differences in the shape of the fruit and the shape of the fruit cross-section of the cultivars ($p < 0.001$ and $p = 0.033$, receptively). Most cultivars had an oblate shape (74%), a semi-open crown (47%), and a round to angular shape in the cross-section (42%) (Table 2). The crown index (IC) ranged from 14% ('Zamorac') to 19% ('Medunac'). The cultivars in our study have higher ICs than the cultivars from Morocco (11.7–14.9%) or Spain (15.0–18.9%) [28]. Fruits with a higher IC are prone to crown breakage. We found three types of crowns: closed-convergent sepals (21%), semi-open right sepals (47%), and open divergent sepals (32%) (Table 2). The advantage of a closed crown is that the sepals break less, while an open crown is preferable due to easier disease control. A significant difference was observed in peel weight and thickness (Table 5). The thickness of the peel is influenced by the genotype and the cultivation practices. Peel thickness ranged between 2.85 mm and 5.86 mm, while the index of peel thickness (IPT) varied between 3.1% and 5.9%. This is similar to the Turkish [29] and Spanish cultivars [28]. Consumers generally prefer pomegranate fruit with a thin peel, as this causes less fruit waste and is easy to clean. However, the thinner peel of the fruit dries out faster and the external

appearance of the fruit often repels consumers, making it unattractive in the market, even if the quality of the arils has not changed. In a previous study by Radunić et al. [24] conducted in a production orchard in Metković, the total aril weights of 'Barski slatki' and 'Dividiš' were higher and weights of 'Konjski zub' and 'Šerbetaš' were lower, indicating that they were under the influence of the environment and the year. The results of the aril yield (Table 7) were consistent with the aril yield results of cultivars in Morocco [28], Iran [30], Italy [27], and Turkey [31]. Cultivars with a higher number of arils in the fruit had a lower individual aril weight. Our results, 336 to 692 arils per fruit (Table 7), are slightly higher than in reports from Oman [32], but significantly higher than reports from Turkey [31]. The number of arils in the fruit depends on the percentage of successfully fertilized ovules [33], as each aril originates from one ovule.

The coefficients of variation for seed length and seed width were 23.71 and 23.77%, respectively (Table 7). The longest seeds had 'Konjski zub' and 'Kristal', and the shortest 'Domaći kiseli' compared to all cultivars, except 'Dubrovački kasni'. The widest seed was 'Dividiš', while the narrowest was 'Mojdiški sitnozrni'. The cultivars differed in seed hardness ($p = 0.032$). A total of 63% had hard seeds and 37% had medium seeds (Table 2). People prefer pomegranate fruits with soft seeds for fresh consumption [19]. In general, the wild genotypes have lower aril yield and higher seed hardness [32].

4.2. Color of the Fruit Peel, Arils, and Juice

The color perceived by the human eye is easily influenced by individual differences and environmental factors. Colorimeters can accurately evaluate colors [34] by using different color spaces and determining a quantitative color value [35]. Although there are many different color spaces, the CIE L*a*b* color space is most commonly used for food because it has a uniform color distribution and the color perception is closest to the human eye [35]. Appearance influences consumer behavior; in particular, the red color and size are considered the most important external quality parameters for pomegranates [8,36]. The color of the pomegranate peel varies from yellow, green, or pink to deep red or indigo, to completely red [37], depending on the characteristics of the genotype, and is influenced by climate, fertilization, irrigation, and many factors during ripening. The pomegranate is known for its attractive color, with high color variability between cultivars from different collections around the world [38]. Color parameters in our study—the yellow–blue (b*) value of aril and juice, the C* value of juice, the red–green (a*) value of fruit and juice, and the h° value of fruit, aril, and juice—were characteristics that had a coefficient of variation above 20 (see Tables 6, 8 and 9). The fruit color is related to the accumulation of chlorophyll, carotenoids, anthocyanins, and other pigments [34].

According to the literature, anthocyanin accumulation in plants is sensitive to environmental conditions such as sunlight, temperature, and altitude, but fruit maturity, canopy position, and cultivar also have significant impacts on some qualitative characteristics of fruit, including color development [39–41]. It is known that high temperatures inhibit the synthesis of anthocyanins. The position of the canopy influences the quality characteristics of the fruit. Shaded fruits have a greener base color than unshaded fruits [42,43], and the results of our study show variability in the color of the peel as well as the arils and juice. According to the color of the peel, the cultivars studied were divided into two groups: cultivars whose fruits were uniformly red–purple-colored over the entire upper surface (coefficient of variation < 20%), which included the commercial cultivars 'Hicaznar', 'Granada', and 'Wonderful' as well as the native cultivar 'Bokežan', as well as a group of cultivars with a dominant yellow color spectrum of the peel and a more or less pronounced overcoloring on the sunny side of the fruit. Based on the overcoloring of the peel, cultivars were divided into five subgroups: the first subgroup: 'Domaći kiseli' and 'Pastun' had a red–purple peel overcolor; the second subgroup: 'Barski slatki', 'Dubrovački kasni', 'Medunac', 'Sladun', and 'Zamorac' had a pink–red peel overcolor; the third subgroup: 'Konjski zub', 'Kristal', and 'Slatki crveni' had a pink peel overcolor; the fourth subgroup:

'Dividiš', 'Glavaš', 'Slatki tankokorac', and 'Šerbetaš' had a red peel overcolor, and the fifth subgroup, 'Mojdiški sitnozrni', had a yellow–green peel color.

While our data on the color characteristics of the juice were consistent with those of Tarantino et al. [44] the values for a* and b* of the peel, aril, and juice were lower in the cultivar 'Wonderful' than in the same cultivars described by Passafiume et al. [45]. Carreno et al. [12] propose a color index for red grapes, which is best suited for evaluating the color of red table grapes and can be used for the objective evaluation of their external color. In the same study, the average color index value was 1.55 for yellow, 2.49 for pink, 3.66 for red, 4.75 for purple, and 5.57 for dark purple. According to our data, a pomegranate cultivar with an optimal commercial color should have a value of 1.50 for the peel, 2.70 for the aril, and 5 for the juice. The significant differences in the color attributes of pomegranate cultivars can be used as indicators of maturity indices for harvest management and classifying harvested fruit into grades.

There was no relationship between the red peel color and the red aril color (Tables 6 and 8 and Supplementary Table S1), which is consistent with other studies [32,37,46]. The 'Granada', 'Hicaznar', 'Wonderful', and 'Bokežan' cultivars had more pronounced red colors and much more attractive appearances, which certainly affected the visual preferences of customers in the markets.

The juice yield in our study was between 73.69% and 61.86% (Table 10) and was higher than in the study by Martinez et al. [28]. The juice yield is influenced by the cultivar, the technology, and the juice extraction method.

4.3. Juice Yield, Total Soluble Solids, and Total Acidity Content

The quality of pomegranate fruit can be assessed based on external characteristics such as shape, size, and color [37,47], as well as internal quality traits. Although external characteristics may not always determine the ideal harvest time, crucial internal factors such as aril color, total soluble solid content, and titratable acidity are paramount for optimal harvest maturity [37,47–51]. The chemical composition of the fruit is influenced by the cultivar, growing region, climate, maturity, growing practices, and storage conditions. In our study, the values for total soluble solids ranged from 12.8 °Brix ('Mojdiški sitnozrni') to 18.9 °Brix ('Sladun'), and for acidity from 0.46% ('Konjski zub' and 'Kristal') to 2.50% ('Granada') (Table 10). The coefficient of variance for total acidity (63.08%) indicates a significant difference between the cultivars studied, which serves as a good discriminating feature (Table 10), with the values obtained in line with other studies [27,28,30,49,52]. Chace et al. [48] reported that a TA value < 1.85%, a TSS $\geq$ 17%, and a TSS/TA ratio between 11 and 16 is recommended for the 'Wonderful' cultivar grown in California. In our study, the TA value (2.15%, Table 10) of 'Wonderful' was higher than in previous studies and belonged to the sour cultivar group under our agroecological conditions. According to the classification by Onur and Kaska [53] and Kader [47], 'Barski slatki', 'Dubrovački kasni', 'Konjski zub', 'Kristal', 'Medunac', 'Mojdiški sitnozrni', 'Sladun', 'Slatki crveni', 'Slatki tankokorac', and 'Šerbetaš' belong to the group of sweet cultivars; 'Dividiš' and 'Pastun' belong to the sour–sweet cultivars, while 'Bokežan', 'Domaći kiseli', 'Glavaš', and 'Zamorac', and the introduced cultivars 'Hicaznar', 'Granada', and 'Wonderful' are considered sour cultivars. Our growing area is further north than the growing area of the introduced cultivar, which affects higher overall acidity. The sweet and sour–sweet cultivars are suitable for fresh consumption. The TSS/TA ratio plays an important role in determining fruit quality and ripeness and is a common parameter for determining the quality of pomegranate fruit [30,50]. In our study, the TSS/TA ratio varied between 6.60 ('Glavaš') and 34.30 ('Konjski zub'). We found that nine of the cultivars studied had a TSS/TA ratio of less than 9 (Table 10). Among them, commercial cultivars are introduced that do not achieve a harmonious ratio between TSS and TA under our agroecological conditions. Chace et al. [48] reported that fruits with an MI (TSS/TA ratio) of 12 are better accepted.

Categorizations or groupings of cultivars are usually based on only one characteristic, usually the fruit, seeds, or juice. Looking at the whole picture, including an extremely large number of parameters (44 parameters with medium and high coefficients of variability out of a total of 81 analyzed) led to clearer groupings (Figure 2). The cultivars were divided into two major clusters: (1) cultivars with more pronounced green and yellow colors in the fruit peel, larger arils with lighter colors, and juice; and (2) cultivars with darker red colors in the peel, aril, and juice. Further clusters of cultivars were distinguished as subgroups, which can help in selecting assortments when planning plantations and also in determining their intended use, whether for fresh consumption or processing in the industry.

5. Conclusions

By evaluating the morphological and some fruit chemical characteristics of pomegranate cultivars, significant diversity was determined. Plant vigor, plant growth habit, the predominant number of leaves per node on young shoots, crown type, fruit shape, fruit shape in cross-section, peel weight, total aril weight, aril weight, number of arils per fruit, seed length and width, seed yield, total acidity, TSS/TA ratio, color parameters of the peel, arils, and juice showed high variability, indicating their great discriminating power in determining the diversity of pomegranate cultivars. The database created provides a solid basis for further research to determine the genetic and chemical diversity of pomegranate cultivars and their potential for sustainable use. In addition, the selected number of characteristics needed to describe the cultivars will facilitate easier and faster evaluations in our subsequent studies as well as in other collection plantations.

Supplementary Materials: The following supporting information can be downloaded at https://www.mdpi.com/article/10.3390/horticulturae10060563/s1, Table S1. Correlation matrix of the pomegranate's physical and chemical properties.

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