Scientific Papers. Series B, Horticulture. Vol. LXIX, No. 1, 2025
Print ISSN 2285-5653, CD-ROM ISSN 2285-5661, Online ISSN 2286-1580, ISSN-L 2285-5653

VARIABILITY OF BIOMETRIC AND BIOCHEMICAL CHARACTERISTICS IN SOME APPLE VARIETIES

Daniela Nicoleta SCEDEI, Olimpia IORDĂNESCU, Casiana MIHUȚ, Renata SUMĂLAN, Ramona ȘTEF, Carmen DURĂU, Antonela COZMA, Vlad Dragoslav MIRCOV, Maria Mihaela MOATAR, Dacian LALESCU

University of Life Sciences "King Mihai I" from Timișoara,
119 Calea Aradului Street, Timişoara, Romania

Corresponding author emails: lalescu@usvt.ro, mihaela.moatar@usvt.ro

Abstract

Apples, Malus × domestica Borkh., are the third most produced fruit in the world after bananas and watermelons (FAO Statista, 2023) and the most consumed fruit in Romania. The fruit market in Romania is invaded by apple varieties imported from Turkey, Poland, Italy, or Hungary. In recent decades, hybrid varieties obtained in Europe or the United States have also influenced domestic production. For this study, five varieties of apples with different origins were studied, which were purchased from the supermarket (in the year 2024). The varieties studied were Starkrimson, Jonaprince, Jonaprince, Idared, and Golden Delicious. In these varieties, the biometric and biochemical characteristics of the fruits were studied, such as the average weight of the fruit, the height and the diameter (large diameter, small diameter) of the fruits,thefruit firmness,thecontent in soluble dry matter, the percentage of sugar,thefruit acidity and vitamin C. This research focused on the comparisons and linear relationships between the biometric and biochemical characteristics of the studied varieties, followed by principal component analysis (PCA) and cluster analysis.

***Key words**: varieties, apples, biometric characteristics, biochemical characteristics, character variability.*

INTRODUCTION

Apples, *Malus × domestica* Borkh., are the third most produced fruit in the world after bananas and watermelons (FAO Statista, 2023) and the most consumed fruit in Romania. They are associated with a healthy lifestyle due to their richness in vitamins and antioxidants, such as phenolic acid, which has been shown to reduce cancer risk. With their high adaptability, apples can be grown economically in different environmental conditions, from high altitudes to subtropical regions. In addition to price, other criteria are increasingly important for consumers, such as whether the apples are organically grown or the country of origin. Mainly regarding European countries, regionally produced food is becoming increasingly popular among consumers (Denver & Jensen, 2014). In addition, the taxonomic variety is relevant because it is decisive for the apple's flavor (Siekierzynska et al., 2021). The fruit market in Romania is invaded by apple varieties imported from Turkey, Poland, Italy, or Hungary. In recent decades, hybrid varieties obtained in Europe or the United States have also influenced domestic production. Cultivated in Romania and adapted to pedo-climatic conditions, these varieties created more resistant fruits with a commercial appearance but less tasty.

The nutritional value of apple fruits is well known, and there are variable amounts of ascorbic acid, sugars, organic acids, phenolics, and minerals. The therapeutic value of apples is widely known for curing several diseases. Qualitative parameters such as skin color, fruit firmness, sweetness and acidity, and other organoleptic traits can influence consumer acceptance of specific genotypes (Miloševićet et al., 2023; Mehdi, 2020; Meng, et al., 2014). The biological properties of apple varieties are the essential factors that determine tree growth, production, and the economic effects of their cultivation (Goddrie & Kemp.1991; Ugolik et al.,1994;Wrona et al., 1994;Włodarczyk, 1996; Błaszczyk & Poniedziałek, 1998; Makosz, 2005; Kapłan & Wociór, 2002). Therefore, the main goal of apple breeding programs is to obtain new apple genotypes characterized by high yields and good fruit qualities (shape, size, acidity, juiciness, sweetness, color) and low susceptibility/resistance of trees to fungal pathogens, as well as adaptation to the climatic conditions of a given area (Lewandowski & Żurawicz, 2007; Laurens, 1998; Sansavini et al., 2004; Kellerhals, 2009; Kumar et al., 2014). Tang et al., 2018, reported that sugar content is one of the most important fruit characteristics to ensure better customer experience repeat purchases and is one of the main attributes in fruit quality classification (Choi et al., 2006). Furthermore (Aprea et al., 2017) demonstrated that the search for increased sweetness in apple breeding programs must consider not only sugar content but also factors such as volatile compounds, textural parameters, and polyphenols.

Although there are over 7,500 apple varieties worldwide, many heritage varieties have been abandoned, despite a resurgence seen in recent years, in favor of mainstream varieties that have emerged from intensive selective breeding programs over the past few decades, leading to the decline of traditional apple orchards in many countries, including the United Kingdom. The reason for this is the drive for sweet, crisp apples that are uniform in size and appearance and have acceptable disease resistance and extended shelf life (Anastasiadi et al., 2017). The fruit content in chemical compounds, respectively the nutritional value, depends on genotype, tissue structure, fruit maturation, pedoclimatic conditions, and the culture technology used but also on harvesting and storing conditions (Drogoudi & Pantelidis, 2011; Stănică et al., 2008; Mitre, 2008; Stopar et al., 2002; Iordănescu et al., 2021).

The nutritional value of apples is well known. It is a variable amount of ascorbic acid, organic sugars, acids, phenolics, and minerals.

The therapeutic value of the apple is widely known to cure several diseases. Qualitative parameters such as skin color, fruit firmness, sweetness and acidity, and other organoleptic features can influence consumer acceptance of specific genotypes (Iordănescu & Olaru, 2014; Sediqi, 2025). In 2023, apple production in Romania was just over 400,000 tons, similar to the previous year's and below the average of the last five years. Our country is the seventh European apple producer, surpassed by Spain, Hungary, Germany, France, Italy, and Poland. According to the National Institute of Statistics data, Romania imported 66,100 tons of fresh apples worth 31.7 million euros in the first five months of last year. The most significant amount came from Poland, which produces around 4 million tons of apples annually.

In 2024, difficult climatic conditions significantly affected apple production in Romania. Summer heat and drought accelerated fruit ripening and reduced fruit size, so many orchards experienced significant losses in production and quality. For example, farmers in Bacău County reported decreases from 80 tons/hectare in 2023 to 60 tons/hectare in 2024, despite irrigation. In addition, the drought led to earlier harvests and poorer fruit quality, with many being diverted to processing instead of being sold for fresh consumption. As a result of the decrease in production, prices increased, with apples sold directly by farmers reaching 2.5-4 lei/kg. In hypermarkets, prices rise to 5-10 lei/kg, even 12 lei for organic apples. In addition, an increase in apple imports is anticipated to meet domestic demand, which is consistently higher than domestic production. According to INS, fruit imports reached almost 1 billion euros in 2023 and generate Romania's second largest trade deficit on the food balance. According to the National Institute of Statistics data, Romania imported in the first five months of the year (2022) 66,100 tons of fresh apples, worth 31.7 million euros, 23.7% more in volume than in a similar period last year. The most significant quantities come from Poland, Moldova, and Germany. The average consumption of apples in Romania is approximately 15-20 kg per year per capita, which underlines the importance of this fruit in the daily diet.

The apple industry faces challenges due to climate change and the need for quantitative production control.

MATERIALS AND METHODS

The biological material

For this study, five varieties of apples with different origins were studied, which were purchased from the supermarket (in 2024). The varieties studied were Starkrimson (Hungary), Jonaprince (Hungary), Jonaprince (Romania), Idared (Poland) and Golden Delicious (Poland). In these varieties, the biometric and biochemical characteristics of the fruits were studied, such as the average weight of the fruit; height and diameter (large diameter, small diameter) of the fruits; fruit firmness (Sediqi, 2025); content in soluble dry matter; sugar percentage, fruit acidity (pH) and vitamin C.

This research focused on the comparative study between varieties with respect to the characters studied, correlations and regressions, principal component analysis (PCA), and cluster analysis.

The analyzed biometric and biochemical properties

The fruits (25 fruits/variety) were harvested from different parts of the tree. The fruits' diameter and their length have been measured with the help of a caliper. The weight was established by using an analytical balance. Fruit sugar content, expressed as soluble carbohydrates (Brix degree - %), has been obtained with a digital refractometer (Kruss DR 201-95). Fruit flesh firmness was determined with thepenetrometer (Force Gauge PCE-FM 200), and results have been expressed in lbs. The fruit juice acidity was determined using a multiparameter analyzer - pH (Consort C 933). The variability of biometric and biochem ical characteristics in apple varieties iscritical to understanding their quality, nutritional value, and suitability for different uses. This analysis synthesizes findings from multiple studies to provide a comprehensive overview of the differences in biometric traits (diameter, weight, height, firmness) and biochemical traits (Brix, sugar, pH, and Vitamin C) across various apple varieties. The Vitamin C content wasestimatedusing the 2,6-dichlorophenolindophenol titration method. Briefly, 5 g of fresh sample wash omogenized in 50 mL of 0.02 g·mL^{-1} oxalic acid solution and thencentrifuged at 15,000 x for 15 min at 4°C. The supernatant (10 mL) wastitratedto a permanent pink color by 0.1% 2,6-dichlorophenolindophenol (Moldovan et al., 2006). All statistical analyses were done using R Statistical Software [v4.4.1; RCoreTeam, 2024). Comparations (ANOVA and Duncan tests), Pearson's linear correlation coefficients, principal component analysis (PCA), and cluster analysis were performed.

RESULTS AND DISCUSSIONS

A one-way ANOVA was performed to compare the effect of apple variety on large diameter. It was revealed that there was a statistically significant difference in the large diameters between at least two groups ($F(4, 45) = 29.28$, $p < .001$; Eta2 = 0.72, 95% CI [0.59, 1.00]). Duncan test for multiple comparisons found that the mean value of large diameter was significantly different between: Idared and Golden ($p < .05$, 95% C.I. = [4.5890813, 12.328919]); Jonaprince_H and Golden ($p < .05$, 95% C.I. = [12.9057631, 20.820237]); Jonaprince_H and Idared ($p < .05$, 95% C.I. = [4.8389112, 11.969089]); Jonaprince_RO and Idared ($p < .05$, 95% C.I. = [2.857838, 10.3561619]); Starkimson and Idared ($p < .05$, 95% C.I. = [1.410911, 8.5410888]); Jonaprince_RO and Jonaprince_H ($p < .05$, 95% C.I. = [11.141081, 18.8809187]); Starkimson and Jonaprince_H ($p < .05$, 95% C.I. = [9.630838, 17.1291619]) (Table 1). Apple varieties like Scarlet Spur and Starkrimson Delicious were found to have larger diameters, with Scarlet Spur exhibiting the highest fruit weight (289.96 g) and length (32.61 mm) (Ates et al., 2023). Similarly, Starkrimson Delicious had a high fruit width (34.86 mm) (Ates et al., 2023). A one-way ANOVA was performed to compare the effect of apple variety on small diameter. It was revealed that there was a statistically significant difference in the small diameters between at least two groups ($F(4, 45) = 46.83$, $p <.001$; Eta2 = 0.81, 95% CI [0.71, 1.00]). Duncan test for multiple comparisons found that the mean value of small diameter was significantly different between: Idared and Golden ($p < .05$, 95% C.I. = [4.3292496, 10.756750]); Jonaprince_H and Golden ($p < .05$, 95% C.I. = [14.1937367, 20.766263]); Jonaprince_H and Idared ($p <.05$, 95% C.I. = [6.9763937, 12.897606]);Jonaprince_RO and Idared ($p < .05$, 95% C.I. = [1.667394, 7.5886063]); Starkimson and Idared ($p <.05$, 95% C.I. = [3.207531,9.4344686]);Jonaprince_ROJonaprince_H ($p <.05$, 95% C.I. = [11.451531, 17.6784686]); Starkimson and Jonaprince_H ($p <.05$, 95% C.I. = [13.044250, 19.4717504]) (Table 1.).

A one-way ANOVA was performed to compare the effect of apple variety on height. It was revealed that there was a statistically significant difference in the height between at least two groups ($F(4, 45) = 13.43$, $p < .001$; Eta2 = 0.54, 95% CI [0.35, 1.00]).Duncan test for multiple comparisons found that the mean value of height was significantly different between: Idared and Golden ($p < .05$, 95% C.I. = [1.2304709, 11.2735291]); Jonaprince_RO and Golden ($p < .05$, 95% C.I. = [6.9287323, 17.2952677]);Jonaprince_H and Idared ($p < .05$,95%C.I.=[4.6757323,15.0422677]);Jonaprince_RO and Idared ($p < .05$, 95% C.I. = [1.0850135, 10.6349865]); Starkimson and Idared ($p < .05$, 95% C.I. = [0.6650135, 10.2149865]);Jonaprince_ROand Jonaprince_H ($p < .05$, 95% C.I. = [10.4187807, 21.0192193]);Starkimson and Jonaprince_RO (table 1.) ($p < .05$, 95% C.I. = [6.2784709, 16.3215291]) (Table 1.). Fruit height varied significantly across cultivars. For instance, Royal Gala and Starkrimson exhibited taller fruits than Golden Delicious (Zeroual et al., 2024).

A one-way ANOVA was performed to compare the effect of apple variety on weight. It was revealed that there was a statistically significant difference in the weight between at least two groups ($F(4, 45) = 22.56$, $p < .001$; Eta2 = 0.67, 95% CI [0.52, 1.00]) (Table 1.). Duncan test for multiple comparisons found that the mean value of weight was significantly different between: Jonaprince_H and Golden ($p < .05$, 95%C.I.=[87.20551, 156.02849]); Jonaprince_H and Idared ($p < .05$, 95% C.I. = [79.22729, 145.90271]);Jonaprince_RO and Jonaprince_H ($p < .05$, 95% C.I. = [93.38807, 163.76393]); Starkimson and Jonaprince_H ($p < .05$, 95% C.I. = [69.15907, 132.56093]).

A one-way ANOVA was performed to compare the effect of apple variety on firmness. It was revealed that there was a statistically significant difference in the firmness between at least two groups ($F(4, 45) = 10.88$, $p < .001$; Eta2 = 0.49, 95% CI [0.29, 1.00]) (Table 1.). Duncan test for multiple comparisons found that the mean value of firmness was significantly different between: Idared and Golden ($p < .05$, 95% C.I. = [0.049368869,0.8366311]); Jonaprince_H and Golden ($p < .05$, 95% C.I.=[0.135690392,0.9483096]);Jonaprince_RO-Golden ($p < .05$, 95% C.I.=[0.776522703, 1.6074773]);Jonaprince_RO-Idared ($p < .05$, 95%C.I.=[0.355368869,1.1426311]);Jonaprince_RO-Jonaprince_H($p < .05$, 95% C.I. = [0.275695022, 1.0243050]);Starkimson and Jonaprince_RO ($p < .05$, 95% C.I. = [0.4196904, 1.232309608]) (Table 1.). A one-way ANOVA was performed to compare the effect of apple variety on brix. It was revealed that there was a statistically significant difference in the brix between at least two groups ($F(4, 45) = 7.22$, $p < .001$; Eta2 = 0.39, 95% CI [0.17, 1.00]).Duncan test for multiple comparisons found that the mean value of brix was significantly different between: Idared and Golden ($p < .05$, 95% C.I. = [0.82595692, 3.5140431]); Jonaprince_H and Golden ($p < .05$,95%C.I.=[0.02182595,2.4981741]); Starkimson and Golden ($p < .05$, 95% C.I. = [0.19789642, 2.8021036]); Jonaprince_RO and Idared ($p < .05$, 95% C.I. = [1.4956309, 4.24436913]);Jonaprince_ROand Jonaprince_H ($p < .05$,95%C.I.=[0.6578964,3.26210358]);Starkimson-Jonaprince_RO ($p < .05$, 95% C.I. = [0.85595692, 3.5440431]) (Table 1). Starkrimson Delicious and Fuji had high Brix values, with Starkrimson Delicious reaching 14.30% and Fuji reaching 14.27% (Ates et al., 2023) (Yarilgaç et al., 2023).Super Chief and Kala Kulu had lower Brix values, ranging from 11.65% to 10.56% (Ates et al., 2023; Mehdi, 2020). A one-way ANOVA was performed to compare the effect of apple variety on sugar. It was revealed that there was a statistically significant difference in the sugar content between at least two groups ($F(4, 45) = 7.22$, $p < .001$; Eta2 = 0.39, 95% CI[0.17, 1.00]). Duncan test for multiple comparisons found that the mean value of brix was significantly different between: Idared and Golden ($p < .05$, 95% C.I. = [0.87867723, 3.7353228]); Jonaprince_H and Golden ($p < .05$, 95% C.I. = [0.02418489,2.6558151]); Starkimson-Golden ($p < .05$, 95% C.I. = [0.21024659, 2.9777534]); Jonaprince_RO and Idared ($p < .05$, 95%C.I. = [1.5884495,4.50955046]); Jonaprince_RO and Jonaprince_H ($p < .05$, 95% C.I. = [0.6982466, 3.46575341]); Starkimson-Jonaprince_RO ($p < .05$, 95% C.I. = [0.90767723, 3.7643228]) (Table 1.). A one-way ANOVA was performed to compare the effect of apple variety on Ph. It was revealed that there was a statistically significant difference in the pH between at least two groups ($F(4, 10) = 7.66$, $p = 0.004$; $Eta2 = 0.75$, 95% CI[0.36, 1.00]). Duncan test for multiple comparisons found that the mean value of pH was significantly different between:Starkimson and Golden ($p <.05$, 95% C.I. = [0.05456671 0.54543329]); Starkimson and Idared ($p<.05$, 95% C.I. = [0.24614903,0.75385097]); Starkimson and Jonaprince_H ($p <.05$, 95% C.I. = [0.24614903 0.75385097]); Starkimson and Jonaprince_RO ($p <.05$, 95% C.I. = [0.03180021, 0.50153312]) (Table 1.). A one-way ANOVA was performed to compare the effect of apple variety on vitamin C content. It was revealed that there was a statistically significant difference in the vitamin C content between at least two groups ($F(4, 10) = 9.07e+05$, $p < .001$; $Eta2 = 1.00$, 95%CI [1.00, 1.00]).Duncan test for multiple comparisons found that the mean value of vitamine C content was significantly different between: Starkimson and Golden ($p < .05$, 95% C.I. = [5.6204519,5.6555481]); Jonaprince_H and Golden($p<.05$, 95% C.I .= [3.8622075, 3.8957925]); Jonaprince_P and Golden ($p < .05$, 95% C.I. = [7.9394519, 7.9745481]); Starkimson and Golden ($p<.05$, 95% C.I. = [0.1832075,0.2167925; Jonaprince_H and Idared ($p < .05$, 95% C.I. = [9.4990072, 9.5349928]); Jonaprince_RO and Idared ($p < .05$, 95% C.I. = [13.5767228, 13.6132772]); Starkimson and Idared($p < .05$, 95% C.I. = [5.4212075, 5.4547925]); Jonaprince_RO and Jonaprince_H($p < .05$, 95% C.I. = [4.0612075, 4.0947925]); Starkimson and Jonaprince_H ($p < .05$, 95% C.I. = [4.0614519, 4.0965481]); Starkimson and Jonaprince_RO ($p <.05$, 95% C.I. = [8.1390072, 8.1749928]) (Table 1.). Apples grown in the Moscow region had 3-5% higher antioxidant activity, including Vitamin C, than imported varieties (Motyleva & Borisova, 2019; Bogdanescu et al., 2018). In order to understand and measure the strength and direction of the linear relation ships between biometric and biochemical parameters, Pearson's correlation coefficients were calculated. The Pearson's product-moment correlation between L_diameter and S_diameter is positive, statistically significant, and very large ($r = 0.98$, 95% CI [0.76, 1.00], $t(3) = 9.27$, $p= 0.003$); between L_diameter and Weight is positive, statistically significant, and very large ($r = 0.91$, 95% CI [0.13, 0.99], $t(3) = 3.76$, $p =0.033$); between S_diameter and Weight is positive, statistically significant, and very large ($r = 0.90$, 95% CI [0.10, 0.99], $t(3) = 3.62$, $p =0.036$); between Brix and Vit_C is positive, statistically significant, and very large ($r = 0.77$, 95% CI [0.35, 0.98], $t(3) = 2.10$, $p =0.047$); between Sugar and Vit_C is positive, statistically significant, and very large ($r = 0.77$, 95% CI [0.35, 0.98], $t(3) = 2.10$, $p =0.047$), and between Sugar and Brix is positive, statistically significant, and very large ($r = 1.00$, 95% CI [1.00, 1.00], $t(3) = 2839.52$, $p < .001$) (Figure 1.).

Table 1. Statistical comparisons between the biometric and biochemical characters obtained in the studied apple varieties

Variety	Large diameter (mm)	Small diameter (mm)	Height (mm)	Weight (g)	Firmness	Brix (%)	Sugar (%)	Ph	Vitamin C (mg/100 g)
Starkimson_H	73.862 ± 4.335 c	68.196 ± 1.785 c	73.500 ± 4.460 a	180.527 ± 29.939 b	3.135 ± 0.512 ab	13.13 ± 0.583 a	11.451 ± 0.619 a	3.966 ± 0.057 a	17.673 ± 0.002 d
Jonaprince_H	87.242 ± 4.458 a	84.454 ± 4.741 a	77.919 ± 8.614 a	281.387 ± 65.223 a	2.959 ± 0.211 b	12.89 ± 1.679 a	11.197 ± 1.784 a	3.466 ± 0.208 b	21.552 ± 0.003 c
Idared_PL	78.838 ± 4.306 b	74.517 ± 4.214 b	68.06 ± 3.904 b	168.822 ± 26.984 b	3.058 ± 0.284 b	13.80 ± 1.858 a	12.164 ± 1.975 a	3.466 ± 0.152 b	13.595 ± 0.002 e
Jonaprince_RO	72.231 ± 2.295 c	69.889 ± 1.904 c	62.200 ± 3.559 c	152.811 ± 9.935 b	2.309 ± 0.349 c	10.93 ± 0.266 b	9.115 ± 0.282 b	3.700 ± 0.100 b	27.190 ± 0.020 a
Golden_PL	70.379 ± 3.979 c	66.974 ± 2.638 c	74.312 ± 4.300 a	159.77 ± 14.694 b	3.501 ± 0.594 a	11.63 ± 1.662 b	9.857 ± 1.765 b	3.666 ± 0.057 b	21.752 ± 0.003 b

Different lower-case letters indicate a statistically significant difference in the biometric and biochemical characteristics of studied apple varieties.

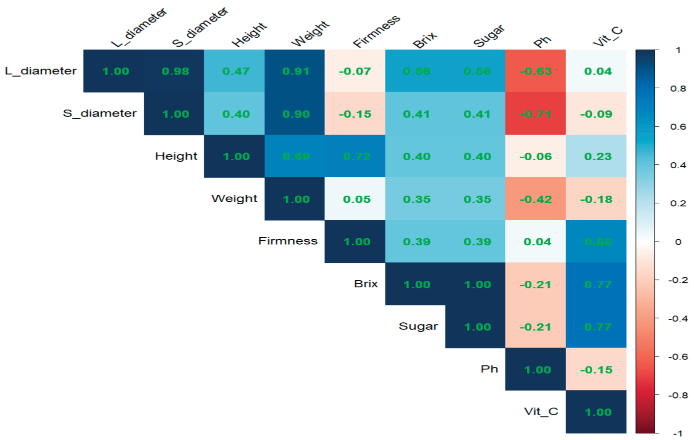

Figure 1. Correlation between the biometric and biochemical characteristics of studied apple varieties

The inertia of the first dimension shows if there are strong relationships between variables and suggests the number of dimensions that should be studied. The first two principal components of analysis express 78% of the total dataset inertia; that means that 78% of the individual's cloud total variability is explained by the plane spanned by the first two principal components (Figure 2).

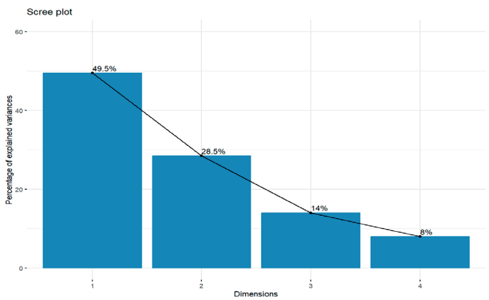

Figure 2. Scree plot of PCA

This percentage is very high; thus, the first plane represents the data variability very well. The variability explained by this plane is thus highly significant (the reference value is the 0.95-quantile of the inertia percentages distribution obtained by simulating 6543 data tables of equivalent size based on a standard distribution). The first principal component factor is significant: it expresses itself 49.5% of the data variability. This axis presents an amount of inertia greater than those obtained by the 0.95-quantile of random distributions. This observation suggests that this axis carries great factual information. The most important contribution for this component comes from the following variables: L_diameter, S_diameter, Sugar, Brix, and Weight (which are all highly correlated) (Figure 3 and Figure 5).

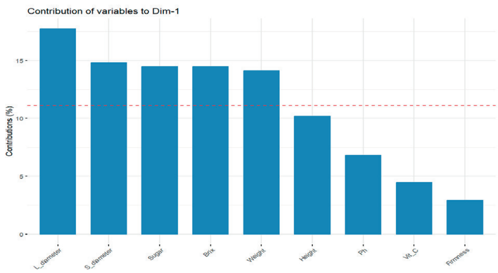

Figure 3. Contribution of variables to the first dimension of PCA

The second principal component expresses itself 28.5% of the data variability. The most important contribution for this component comes from the variables Vit_C, Firmness, and S_diameter (Figure 4 and Figure 5).

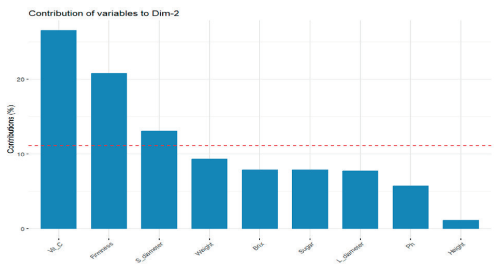

Figure 4. Contribution of variables to the second dimension of PCA

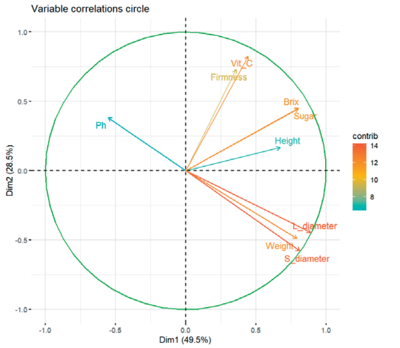

Figure 5. Projection of the variables on the plane spanned by first and second components

Ascending Hierarchical Classification of the individuals.The classification made on individuals reveals 3 clusters. Cluster 1comprises Jonaprince_RO; cluster 2 comprises the following individuals: Golden_PL, Starkimson_H, and Idared_PL, and cluster 3 comprises Jonaprince_H (Figure 6 and Figure 7).

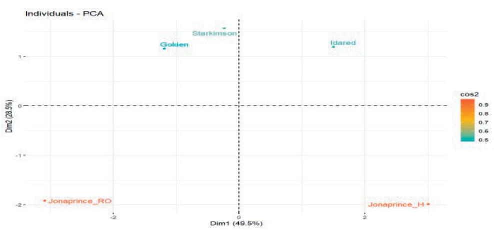

Figure 6. Projection of the observables on the plane spanned by first and second components

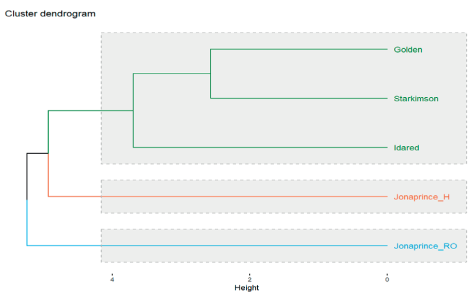

Figure 7. Cluster dendrogram of the population of studied apple varieties

CONCLUSIONS

From the results obtained, it can be observed that there were significant differences in the biometric characters between the same variety of apple with different origins, that is, the Jonaprince_H variety presented higher values in terms of the large diameter (87,242 mm), the small diameter (84,454 mm) and the average height of the fruits (77,919 mm) compared to the Jonaprince_Ro variety with the large diameter of 72,231 mm, 69,889 mm small diameter and average height of 62,200 mm. The content of soluble dry substance (Brix-%) of apple fruits had values between 10.93% (Jonaprince_RO) and 13.80% (Idared_PL), and the values of ascorbic acid varied between 13.595 mg/100 g and 27.190 mg/100 g, the dynamics is seen as soon as the amount of dry substance content decreases ascorbic acid in the fruits apple grows immediately.

REFERENCES

Anastasiadi, M., Mohareb, F., Redfern, S.P., Berry, M., Simmonds, M. S.J., Terry, L. A. (2017). Biochemical profile of heritage and modern apple cultivars and application of machine learning methods to predict usage, age, and harvest season. *Journal of Agricultural and Food Chemistry*, 65(26), 5339–5356.

Aprea, E., Charles, M., Endrizzi, I.,Corollaro, L.M.,Betta, E.,Biasioli, F.,Gasperi, F. (2017). Sweet taste in apple: The role of sorbitol, individual sugars, organic acids and volatile compounds. *Sci. Rep.* 2017, *7*, 44950.

Ates, U., Öztürk, B., Uzun, S. (2023). Characterization of Bioactive Contents and Fruit Traits in Some Apple Cultivars Grown in Kayseri.*Black Sea Journal of Agriculture*.

Błaszczyk, J., & Poniedziałek, W. (1998). Growth and Yielding of 20 Apple Varieties in the Kraków Region. In *Proceedings of the 37 Polish National Scientific Conference of Judical Institute of Pomology and Floriculture, Skierniewice*, Poland, 25–27 August 1998; pp. 363–365.

Bogdanescu, D., Bordean, D.-M., Poiana, M. A., Hadaruga, N., Tataru, O., Rivis, A. (2018). Characterization of the main Romanian apple varieties based on pH, refractometric index and moisture content. *JournaL of Horticulture, Forestry and Biotechnology*, Volume 22(2), 95- 99.

Choi, D., Cho, H.-T., Lee, Y. (2006). Expansins: Expanding importance in plant growth and development. *Physiol. Plant.* 2006, *126*, 511–518.

Denver, S.& Jensen, J.D. (2014).Consumer Preferences for Organically and Locally Produced Apples. *Food Quality and Preference*, 31, 129-134.

Drogoudi, D.P., & Pantelidis, G. (2011). Effects of position on canopy and harvest time on fruit physico-chemical and antioxidant properties in different apple cultivars.*Scientia Horticulturae*. No.129, 752-760.

Goddrie, P.W., & Kemp, H. (1991). Cultivar testing with apple. *Wilherminadorp Res. St Ann. Rep.* , 48–54.

Iordănescu, O.A., & Olaru, D.N. (2014). *Pomologie*, Ed. Agroprint, Timişoara.

Iordănescu, O.A., Iuga, C., Hădărugă, N., Becherescu, A., Drăgunescu, A., Băla, M., Scedei, D. (2021). Research on fruit quality of several apple cultivars from different locations in the area of western Romania.*Scientific Papers.Series B, Horticulture*, Vol. LXV, No. 1.

Kellerhals, M. (2009). Introduction to Apple (*Malus* × *domestica*). In *Genetics and Genomics of Rosaceae*; Folta, K.M., Gardiner, S.E., Eds.; Springer: New York, NY, USA, 2009; pp. 73–84. ISBN 978-0-387-77490-9.

Kumar, S., Volz, R.K., Chagné, D., Gardiner, S. (2014). Breeding for apple (*Malus* × *domestica* Borkh.) fruit quality traits in the genomics era. In *Genomics of Plant Genetic Resources*; Tuberosa, R., Graner, A., Frison, E., Eds.; Springer: Dordrecht, The Netherlands, 2014; pp. 387–416. ISBN 978-94-007-7574-9.

Laurens, F. (1998). Review of the current apple breeding programmes in the world: Objectives for scion cultivar improvement. *ActaHortic.* 1998, *484*, 163–170.

Lewandowski, M., & Żurawicz, E. (2007). Effect of genotype on germination of *Malusdomestica* seeds. In *Natural and Induced Variability in the Genetic Improvement of Horticultural Plants*; UTP in Bydgoszcz: Bydgoszcz, Poland, 2007; pp. 73–80.

Makosz, E. (2005). The Vision of the Fruit Market in Poland. In Proceedings of the 44 *Congress of the Fruit-Growers' Market Fruit, Skierniewice*, Poland, 27 October 2005; pp. 5–13.

Mehdi, A. (2020). Assessment of physico-chemical and phyto-chemical properties of six apple varities cultivated in district Nagar and Hunza Gilgit Baltistan, Pakistan. *Pesquisa Agropecuaria Brasileira*.

Meng, X. J., Gong, L. Y., Huang, G. H., Liu, N. Q., Bi, J., & Li, B. (2014). Physical and Chemical Compositional Characterization of Six Apple Cultivars.*Advanced Materials Research*.

Milošević, T., Milošević, N. T., Miletic, N. (2023). Segregation of apple cultivars on the basis of main fruit physical and chemical properties and antioxidant activity. *Turkish Journal of Agriculture and Forestry*.

Mitre, V. (2008). *Pomologie*, Edit. Todesco, ClujNapoca.

Moldovan, P., Toşa, M.I., Leţ, D., Majdik, C., Paizs, C., Irimie, F. D. (2006). *Aplicaţii pentru laboratorul de biochimie*, Editura Napoca Star, Cluj Napoca, 110-115.

Motyleva, S. M., & Borisova, A. A. (2019). Comparative biochemical composition of apple fruits of domestic and foreign varieties.*Horticulture and viticulture*, № 6, p. 12-18.

RCoreTeam. (2024). R:ALanguage and Environment for Statistical Computing. *R Foundation for Statistical Computing*: Vienna, Austria. Available online: https://www.R-project.org/.

Sansavini, S.,Donati, F., Costa, F.,Tartarini, S. (2004). Advances in apple breeding for enhanced fruit quality and resistance to biotic stresses:new varieties for the european market. *J. Fruit Ornam. Plant Res.*, *12*, 40.

Sediqi, A. S. (2025). Physiological changes in apple fruit in response to physical damage received during post-harvest handling practices. *ESRJ*, *1*(1), 144–163.

Siekierzynska, A., Piasecka-Kwiatkowska, D., Myszka, A. B., Sozanska, B., Sozanski, T. (2021). Apple allergy: Causes and factors influencing fruits Marta allergenic properties–Review. *ClinTransl Allergy*.

Stănică, Fl., Peticilă, A., Dumitrascu, M. (2008). Influence of weather conditions on apple flowering. Proceedings of International Scientific Conference, Jurmala-Dobele. *Sustainable Fruit Growing: From Plant to Product.*173-176.

Stopar, M., Bolcina, U., Vanzo A., Vrhovsek, U. (2002). Lower crop load for Cv. Jonagold apples (Malus x domestica Borkh.) increases polyphenol content and fruit quality. *Journal of agricultural and food chemistry*. Vol. 50/Issue 6, 1643-1646

Tang, C., He, H., Li, E., Li, H. (2018).Multispectral imaging for predicting sugar content of 'Fuji' apples. *Opt. Laser Technol.* 2018, *106*, 280–285.

Ugolik, M.,Kantorowicz-Bąk, M.,Ugolik, D.(1994). Evaluation of the Growth and Yield of Several New Apple Varieties on the M.9 Rootstock. In Proceedings of the 33 Polish National Scientific *Conference of Institute of Pomology and Floriculture, Skierniewice*, Poland, 30 August-1 September; pp. 86–87.

Włodarczyk, P. (1996) Selected Factors Affecting the Early Start Fruiting Apple Trees.*AkademiaRolnicza Lublin: Lublin*, Poland.

Yarilgaç, T., Uzun, S., Karakaya, O., Ates, U., Öztürk, B. (2023). Fruit Characteristics of Some Standard Apple Cultivar/Rootstock Combination in Ordu Ecology. *Journal of the Agricultural* Faculty of Gaziosmanpaşa University.

Zeroual, I., Benaziza, A., Adjal, F., Kheloufi, A. (2024). Evaluation of Morphological Characteristics in Some Apple Varieties *(Malus Pumila Mill.)* from Northeastern Algeria. The *Annals of "Valahia" University of Targoviste*.

*https://revista-ferma.ro/polonia-bate-mar-romania-la-productia-de-mere-cat-costa-kilogramul-la-noi-si-de-ce-vom-importa-si-mai-multe-fructe/

*https://stat.gov.pl/en/topics/agriculture-forestry/agricultural-and-horticultural-crops/.

*https://www.economica.net/romania-produce-11-din-merele-ue-insa-cantitatile-stagneaza-din-2022-nici-productia-de-pere-nu-a-fluctuat-exista-premisa-cresterii-preturilor_691515.html

*https://www.fao.org/statistics/en

*https://www.researchgate.net/publication/283329319_Titrimetric_Determination_of_Ascorbic_Acid_Contents_in_Plant_Samples_by_2_6Dichlorophenolindophenol_Method.