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

MULTIVARIATE ANALYSIS OF GENOTYPE BY YEAR INTERACTION FOR SOME FRUIT TRAITS IN ROSEHIP (*ROSA CANINA* L.)

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Abstract

Rosehip grows wildly in many different regions of Romania, revealing high environmental adaptability. Due to cross-pollination, the natural populations of rosehip present a certain degree of heterogeneity. Given the multifaceted pharmacological properties, the rosehip fruits acquire an increasingly and wide application in food, cosmetics, and pharmaceutical industries. The 24-rosehip population was collected from different Arad County locations in the West of Romania. The rosehip fruits were randomly picked from different canopy sides for three shrubs of each population. The present study was conducted to assess the variation of fruit traits for 24 populations of rosehip under the effect of different climatic conditions over three years and to select populations with good stability of desirable fruits. The results indicated significant differences among rosehip populations' fruit traits across testing years due to genotype-by-year interaction. Suitable rosehip populations with specific and broad adaptability were identified for the studied traits.

Key words*: adaptability, AMMI, fruit variation, rosehip, stability.*

INTRODUCTION

The genus Rosa includes up to 200 species distributed throughout the northern hemisphere's diverse temperate and subtropical environments. (Bruneau et al., 2007; Tomljenovic & Pejić, 2018). In the flora of Romania there are five hybrids in addition to the 29 spontaneous and sub-spontaneous species of the *Rosa* L. genus (Oarga Porumb et al., 2024).

Rosehips are pseudo-fruits that develop in a fleshy pericarp and comprise an outer hypanthium having achenes in-grained inside (Winther et al., 2016). Rosehip fruits are well known for having human health-promoting compounds like mineral nutrients, vitamins, fatty acids, and phenolic compounds (Medveckiene et al., 2023). Rosehips have antioxidant and anti-inflammatory, antibacterial, anti-mutagenic, probiotic, anti-ulcerogenic, antinociceptive, and anti-carcinogenic properties (Gruenwald et al., 2019; Gulbagca et al., 2019).

Due to the growing interest in plant agents enriched with antioxidant properties, these plants are acquiring an increasingly wider application in the food, cosmetics, and pharmaceutical industries as efficient materials to improve the quality of final products (Cosmulescu et al., 2017).

Harvesting time is very important in improving the quality and nutritional value of the rosehip-processed product. The qualitative and quantitative composition of the biologically active compounds in rosehips, such as fatty acids (Kulaitiene et al., 2020), phenolic compounds, or vitamin C (Chae et al., 2021; Elmastas et al., 2017; Medveckiene et al., 2021), varies during the stages of maturity.

Shrubs of *Rosa canina* have considerable importance in agri-environment measures due to the reduced environmental requirements, especially those from the soil. As such, rosehip can be used in different ways: the establishment on land, a consolidation role in the establishment of shelterbelts, a role in combating deflation wind, and the establishment of biological barriers against the destructive action of snow (Soare et al., 2015). Rose hip ofis important in breeding the *Rosa* genus, especially as rootstocks for ornamental roses (Shirdel et al., 2013; Soare et al., 2014).

Wild rosehip genotypes show high morpho-biochemical diversity. These genotypes possess a higher frequency of genes that trigger resistance and accumulation of different phytochemicals due to their tolerance to natural enemies and environmental stresses (Mertoglu et al., 2024).

It is very important to select rosehip genotypes morphologically and biochemically adapted to diverse unfavourable ecological conditions due to global climate change. These possible selected genotypes can be used directly for production and as genitors in breeding programs to develop new superior genotypes (Cheikh-Affene et al., 2013; Gunes & Dolek, 2010).

The genetic variation between populations and the influence of specific environmental factors in the growing areas can explain the differences regarding rosehip fruits. Geographical location has an important contribution through specific microclimate and radiation, temperature, rainfall, and soil nutrient availability (Andronie et al., 2019; Munteanu et al., 2023).

The additive main effects and multiplicative interaction (AMMI) model has been used extensively for analyses of multi-environment trials to understand complex genotype, environment/year, and genotype-by-year interactions (Zobel et al., 1988; Gauch & Zobel, 1990).

The knowledge of the variability in the fruit traits of rosehip is valuable for fundamental and practical medicinal purposes, and for designing efficient breeding programs of these species (Butkeviciute et al., 2022). The present study was conducted to assess the variation of fruit traits for 24 populations of rosehip under the effect of different climatic conditions over three years and to select populations with good stability of desirable fruits.

MATERIALS AND METHODS

The 24-rosehip populations were collected from different Arad County locations, in the West of Romania. The ripe rosehip fruits were randomly picked from different canopy sides for three shrubs of each population. The harvested fruits were randomly sampled, and 50 fruits per shrub/replicate were selected for analysis to determine the weight and fresh pulp percentage (100* pulp weight/fruit weight). The geographical coordinates of the collection sites for rosehip populations are presented in Table 1. Amid the high temperatures during the summer associated with the very low level of rainfall, the conditions of 2024 were considered the most unfavorable.

Table 1. Geographical coordinates of the collection sites for rosehip populations from Arad County

No.	Population	Latitude	Longitude	No	Population	Latitude	Longitude
1.	'Gurba'	46°32’19.53” N	21°49’57.30” E	13	'Beliu'	46°27’49.59” N	21°59’12.12” E
2.	'Seleus'	46°23’0.31” N	21°39’59.75” E	14	'Ineu'	46°25’38.00” N	21°52’27.47” E
3.	'Zimandu Nou'	46°17’30.30” N	21°24’57.49” E	15	'Olari'	46°24’19.24” N	21°34’56.29” E
4.	'Sebis'	46°23’0.00” N	22°5’05.00” E	16	'Bocsig'	46°25’28.78” N	21°54’56.20” E
5.	'Lipova TF'	46°04’41.14” N	21°41’13.29” E	17	'Buteni'	46°19’05.47” N	22°08’02.74” E
6.	'Lipova'	46°04’51.60” N	21°40’43.15” E	18	'Siria'	46°15’08.45” N	21° 34’10.09” E
7.	'Ususau'	46°04’37.26” N	21°47’00.23” E	19	'Chesinț'	46°03’46.88” N	21°38’39.29” E
8.	'Patars'	46°04’37.26” N	21°47 00.23” E	20	'Almas'	46°17’0.73” N	22°14’55.78’’ E
9.	'Bacaul de Mijloc'	45°58’27.53” N	22°06’55.75” E	21	'Zabrani'	46°04’19,09” N	21°35’44.35” E
10.	'Capalnas'	45°58’37.29” N	22°13’41.01” E	22	'Brazi'	46°14’11.44” N	22°19’48.6” E
11.	'Cermei'	46°32’14.67” N	21°52’50.25” E	23	'Arad'	46°08’19.84” N	21°21’55.41” E
12.	'Vladimirescu'	46°08’30.74” N	21°24’48.36” E	24	'Fantanele'	46°04’52,18” N	21°30’56.73” E

The data collected for fruit weight and fruit pulp percentage were statistically processed by combined ANOVA and AMMI analysis using MATMODEL Version 3. The AMMI model which combines the standard analysis of variance with principal component analysis (Zobel et al., 1988), allows for investigating the nature of genotype x environment interaction. The means for each trait were compared using the Multiple Range Test (Ciulca, 2006). The significance of differences between means was presented based on letters, which were considered significant differences between means marked with different letters (a, b, c -for population x year comparisons; A, B, C - for years comparisons).

Populations were clustered using the UPGMA (unweighted pair group method with arithmetic

mean), with the NEIGHBOR program of the PHYLIP package, version 3.5c (Felsenstein, 1993).
The basic principle of the biplot technique was used to display each population's performance for both fruit traits during the three years in a single graph (Yan & Kang, 2002).

RESULTS AND DISCUSSIONS

Phenotypic expression and observed variation of plant growth and development are functions of genetic background, environment, and interaction, including temporal variation due to the genotype x year effect (Redpath et al., 2021).
The variation of different fruit traits or compounds can be revealed between different sites and in the same site (Stamin et al., 2024).

The combined analysis of the variance based on the AMMI 2 model for rosehip populations over the study period (Table 2) indicates that both the genotype and the yearly conditions, respectively, and their interaction had highly significant effects on fruit weight. The population x year interaction showed the highest influence (27.43%) on fruit weight variability, followed by population (27.23%), amid a lower influence (14.24%) of the yearly conditions during the study. The high contribution to this trait's variation indicates the existence of major differences between rosehip populations. Based on the first two principal components, this model fully expresses the effect of population x year interaction on fruit weight. As such, it is relevant to assess the stability of this trait in rosehip populations based on the first two principal components.

Table 2. Combined analysis of variance according to the AMMI 2 model for fruit weight of rosehip populations

Source of variation	SS	DF	MS	F	SS %[1]
Total	73.9	215			
Block	0.4	6	0.06	3.33	
Population	20.12	23	0.87	52.03**	27.23
Year	10.52	2	5.26	312.88**	14.24
Population x Year	20.27	46	0.44	26.21**	27.43 (*100*)
IPCA 1	13.17	24	0.55	32.64**	*64.97*
IPCA 2	7.10	22	0.32	19.20**	*35.03*
IPCA residuals	0	0			
Error	2.32	138	0.02		

[1]% of model sum of squares for population, year and population x year; **significant at $P \leq 0.01$.

Based on the data from Table 3, the conditions of 2023 have favoured the achievement of significantly higher values of fruit weight, while in 2024, the mean values were lower compared to other years. Under the conditions from 2022 the fruit weight recorded values between 1.27 g at 'Bacaul de Mijloc' and 2.25 g at 'Olari' population, amid a middle variability and arelatively symmetrical distribution of populations: 12.5% with values over 2 g; 16.7% with values of 1.7-2 g; 50% with values of 1.5-1.7 g; 20.8% with values below 1.5 g. This year, the populations 'Olari', 'Cermei', and 'Capalnas' were highlighted, which achieved a fruit weight of over 2 g. Given the conditions of 2023 the rosehip populations showed smaller amplitude of this trait, with the limits from 1.39 g at 'Buteni' to 2.2 g at 'Olari' population, associated with a 12.01 coefficient of variation and the following distribution: 16.7% of the populations with fruit weight over 2 g; 29.2% with values of 1.7-2 g; 41.6% with values of 1.5-1.7 g; 12.5% with values below 1.5 g. The amplitude of fruit weight in 2024 was intermediate to that recorded in previous years, with values ranging from 1.23 g in 'Brazi' to 2.15 g for the 'Gurba' population. Thus, the distribution of populations in 2024 showed a clear left asymmetry: only one population over 2 g; 25% with values of 1.7-2 g; 41.7% with values of 1.5-1.7 g; 20.8% with values below 1.5 g.

Table 3. Variation of fruit weight in rosehip populations during 2022-2024

No.	Population	Year			Population Mean
		2022	2023	2024	
1.	'Gurba'	1.48 z	1.77 y	2.15 x	1.80 bcd
2.	'Seleus'	1.62 x	1.66 x	1.31 y	1.53 fgh
3.	'Zimandu Nou'	1.48 y	1.70 x	1.35 y	1.51 gh
4.	'Sebis'	1.61 y	1.83 x	1.65 xy	1.70 cde
5.	'Lipova TF'	1.81 y	2.03 x	1.63 y	1.82 bc
6.	'Lipova'	1.65 x	1.76 x	1.68 x	1.70 cde
7.	'Ususau'	1.59 x	1.63 x	1.72 x	1.65 ef
8.	'Patars'	1.85 x	1.60 y	1.39 y	1.61 efg
9.	'Bacaul de Mijloc'	1.27 y	1.68 x	1.33 y	1.43 h
10.	'Capalnas'	2.04 x	1.50 y	1.42 y	1.65 ef
11.	'Cermei'	2.24 x	1.42 y	1.52 y	1.73 cde
12.	'Vladimirescu'	1.60 y	1.95 x	1.50 y	1.68 de
13.	'Beliu'	1.70 xy	1.59 y	1.87 x	1.72 cde
14.	'Ineu'	1.53 zy	1.69 y	1.92 x	1.71 cde
15.	'Olari'	2.25 x	2.20 x	1.89 y	2.11 a
16.	'Bocsig'	1.82 y	2.08 x	1.55 z	1.82 bc
17.	'Buteni'	1.47 x	1.39 x	1.52 x	1.46 h
18.	'Siria'	1.89 xy	1.97 x	1.74 y	1.87 b
19.	'Chesinţ'	1.52 y	1.81 x	1.55 y	1.63 efg
20.	'Almas'	1.71 x	1.66 x	1.54 x	1.64 efg
21.	'Zabrani'	1.66 x	1.61 x	1.76 x	1.68 de
22.	'Brazi'	1.37 xy	1.49 x	1.23 y	1.36 i
23.	'Arad'	1.66 x	1.62 x	1.54 x	1.61 efg
24.	'Fantanele'	1.77 x	1.89 x	1.71 x	1.79 bcd
Year mean		1.69 B	1.73 A	1.60 C	

Populations $LSD_{5\%}$ = 0.13 g; Years $LSD_{5\%}$ = 0.04 g; Population x Year $LSD_{5\%}$ = 0.22 g
Different letters indicate significance at $P \leq 0.05$; x, y, z -for population x year comparisons.
A, B, C - for years comparisons; a,b,c –for populations comparisons

Regarding the annual values of fruit weight, it was found that about 29.17% of the populations did not show significant variations during the study period, while for two populations, the mean values differed significantly from one year to another. The top-ranking populations across the study period were 'Olari', 'Siria', 'Bocsig', 'Lipova TF', and 'Gurba', which achieved a mean fruit weight of over 1.8 g. In other studies, the fruit weight of rosehip genotypes was also found to vary around the mean of 2g (Bozhuyuk et al., 2021; Cheikh-Affene et al., 2013; Demir et al., 2021; Mertoglu et al., 2024).

Based on the biplot from Figure 1, the rosehip populations are more dispersed than the environments, indicating that population variability is greater than year-related variability, consistent with the results of ANOVA. Also, given the position of the year's points related to the x-axis, it can be noted that the values recorded in 2022-2023 are higher than those of 2024, indicating the favourability of the associated yearly conditions. 'Olari' population expresses an average stability of fruit weight associated with the highest mean over the study period, amid close values during 2022-2023. In the case of the 'Siria' population, the high mean weight of fruit was obtained because of a parallel response to the favourability of the climatic conditions, with the highest value in 2023 and the lowest in 2024. The variation of this trait in the 'Lipova TF' population indicates their specific adaptability to the favourable conditions. 'Fantanele' population registered a low and insignificant variation in fruit weight amid a general performance above the experience mean. The populations 'Lipova', 'Almas', and 'Zabrani' registered significantly constant values over the years, with an average fruit weight above the experimental mean. Also, low and insignificant variation of fruit weight was recorded by the 'Buteni' population, who had the third-lowest mean value.

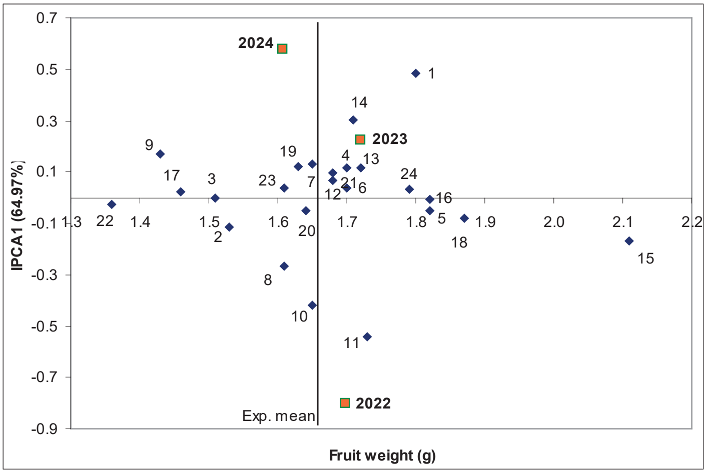

Figure 1. Biplot of mean and IPCA1 axis for fruit weight in rosehip populations during 2022-2024

Considering that the IPCA1 axis expresses approximately 64.97% of the population x year interaction from Figure 2, the conditions from 2022 showed a higher contribution to the population x year interaction, compared to those from 2023-2024. The populations close to the vector of a given year indicate a strong association with this one. Thus, the populations 'Gurba' and 'Ineu' showed a specific adaptation to the conditions of 2024 when they registered a significantly higher fruit weight than in other years. Also, the populations 'Capalnas', 'Cermei', and 'Patars' showed a strong specific adaptation to the conditions in 2022, achieving significantly higher values than those from 2023-2024. 'Bacaul de Mijloc', 'Vladimirescu', and 'Bocsig', populations recorded the highest values of fruit weight under the conditions from 2023, showing a specific adaptation to these conditions. In case of populations: 'Ususau', 'Lipova', 'Zabrani', 'Fantanele', 'Almas', and 'Arad', the close position to the origin indicates high stability of fruit weight. Considering the distance from the origin, it is observed that the populations 'Cermei', 'Gurba', and 'Capalnas' showed a low stability associated with high variation during years and different types of population x year interaction.

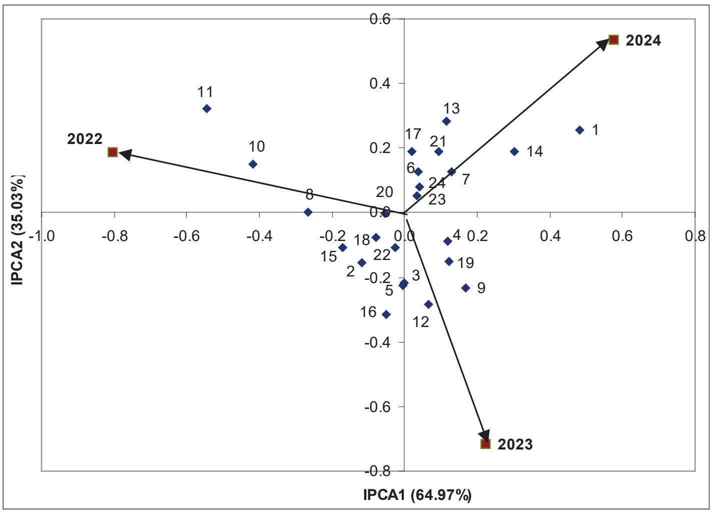

Figure 2. Biplot of interaction for principal component axis (IPCA1 and IPCA2)
for fruit weight in rosehip populations during 2022-2024

The flesh ratio is one of the most important criteria regarding the quality of rosehip fruits. In developing rosehip cultivars suitable for industry, cultivars with large-sized fruits and a high flesh ratio are desired (Celik et al., 2009). The pulp percentage of rosehips increases during ripening and is highly genotype dependent (Ersoy & Salman, 2017; Medveckiene et al., 2023).

According to the analysis of the variance based on the first two components of the interaction (Table 4), it was found that all three main sources of variation had a significant influence on the fruit pulp percentage of the rosehip population during the three years. The contributions of the three sources of variation are not as balanced as in fruit weight, so the pulp percentage variability was influenced to a high extent by the population (26.18%) and the population x year interaction (23.29%). In contrast, the years had a lower influence (4.14%). Given that the first two main components fully express the effect of population x year interaction, it turns out that the AMMI2 model is suitable for assessing pulp percentage at this set of populations.

Table 4. Combined analysis of variance according to the AMMI 2 model for fruit pulp percentage of rosehip populations

Source of variation	SS	DF	MS	F	SS %[1]
Total	5295	215			
Block	73	6	12.17	1.46	
Population	1386	23	60.26	7.23**	26.18
Year	219	2	109.50	13.13**	4.14
Population x Year	1233	46	26.80	3.21**	23.29 (*100*)
IPCA 1	775	24	32.29	3.87**	*62.85*
IPCA 2	458	22	20.82	2.50**	*37.15*
IPCA residuals	0	0			
Error	1151	138	8.34		

[1]% of model sum of squares for population, year and population x year; **significant at P ≤ 0.01.

Table 5. Variation of fruit pulp percent in rosehip populations during 2022-2024

No.	Population	Year 2022	2023	2024	Population Mean
1.	'Gurba'	57.46 y	67.24 x	68.16 x	64.29 cdef
2.	'Seleus'	62.34 x	60.20 x	60.24 x	60.93 ghijk
3.	'Zimandu Nou'	58.08 y	54.51 y	64.16 x	58.92 jkl
4.	'Sebis'	56.19 y	60.73 y	66.96 x	61.29 ghij
5.	'Lipova TF'	67.83 x	67.62 x	69.60 x	68.35 a
6.	'Lipova'	65.40 y	65.56 y	71.29 x	67.42 ab
7.	'Ususau'	64.42 x	62.11 x	61.71 x	62.75 defgh
8.	'Patars'	66.55 x	64.57 x	67.30 x	66.14 abc
9.	'Bacaul de Mijloc'	58.77 x	61.38 x	62.12 x	60.76 hijkl
10.	'Capalnas'	58.15 y	65.43 x	64.93 x	62.84 defgh
11.	'Cermei'	60.69 y	65.86 x	67.55x	64.70 bcde
12.	'Vladimirescu'	58.93 x	56.58 x	59.07 x	58.19 l
13.	'Beliu'	59.43 y	60.44 y	66.42 x	62.10 defghi
14.	'Ineu'	61.86 x	66.41 x	66.07 x	64.78 bcd
15.	'Olari'	64.35 xy	60.91 y	68.75 x	64.67 bcde
16.	'Bocsig'	62.78 xy	61.04 y	66.69 x	63.50 cdefg
17.	'Buteni'	62.29 x	62.58 x	61.01 x	61.96 fghi
18.	'Siria'	57.43 xy	56.31 y	61.64 x	58.46 kl
19.	'Chesinț'	66.54 x	60.61 y	61.75 y	62.97 defgh
20.	'Almas'	60.32 x	64.63 x	61.08 x	62.01 efghi
21.	'Zabrani'	67.33 x	60.35 y	61.03 y	62.90 defgh
22.	'Brazi'	60.12 y	66.38 x	60.14 y	62.21 defghi
23.	'Arad'	60.80 x	59.35 x	58.81 x	59.65 ijkl
24.	'Fantanele'	62.83 x	62.13 x	62.14 x	62.37 defgh
Year mean		61.70 B	62.20 B	64.11 A	

Populations $LSD_{5\%}$ = 2.69; Years $LSD_{5\%}$ = 0.95; Population x Year $LSD_{5\%}$ = 4.66

Different letters indicate significance at P ≤ 0.05; x, y, z - for population x year comparisons.

A, B, C - for years comparisons; a, b, c - for populations comparisons.

The yearly conditions during the study influenced fruit pulp percentage, causing significant variations (Table 5). Thus, the conditions from 2024 were significantly more favourable for increasing the pulp percentage of fruit compared to those of 2022-2023.
The amplitude of the plant height for the rosehip population in 2022 was 11.64, ranging from 56.19 in 'Sebis' to 67.86 in 'Lipova TF'. Thus, the distribution of genotypes showed a low asymmetry: only 33.3% of the populations had values below 60; 45.8% had values of 60-65; and 20.9% had a pulp percentage over 65.
Under the conditions from 2023 the fruit pulp percentage recorded values between 54.51 in 'Zimandu Nou' and 67.62 in 'Lipova TF' population, on the background of a right asymmetry of the population's distribution: 29.2% of the populations with values over 65; 54.2% with values of 60-65%; 16.6% with a pulp percentage of fruits below 60. The highest fruit percentage in 2022-2023 was recorded by the 'Lipova TF' population.

Given the conditions of 2024, there was an increase in fruit pulp percentage for most populations. The amplitude of this trait (12.48) was intermediate to the previous years, ranging from 58.81 in 'Arad' to 71.29 in 'Lipova' population. The distribution of genotypes in this year showed a left asymmetry, with the following structure: 41.7% of the populations had values over 65; 50% had values of 60-65; only two populations had a pulp percentage of fruit below 60. Other studies reported similar pulp percentage values between 60 and 70 (Bozhuyuk et al., 2021; Ercisli & Esitken, 2004).
Considering the annual averages of pulp percentage, approximately 50 % of the population did not register significant variations in fruit pulp percentage during the study. Most populations (54.2%) used the conditions from 2024 better, showing significantly higher pulp percentages than 2022-2023. The populations 'Lipova TF' and 'Lipova' are highlighted through significantly higher mean values compared to 75 % of the populations.

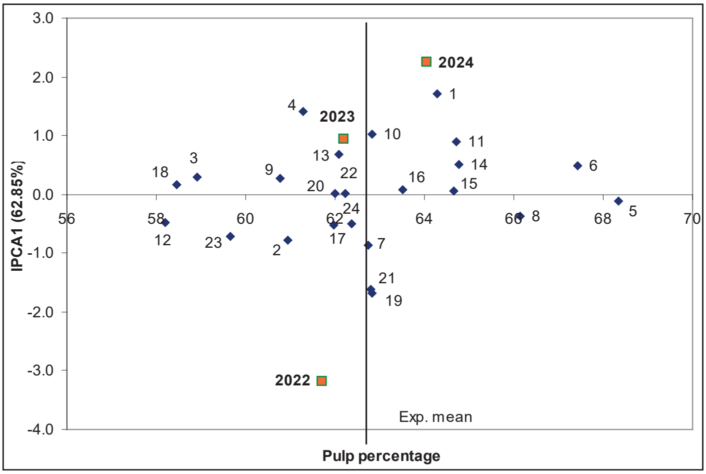

Figure 3. Biplot of mean and IPCA1 axis for pulp percent in rosehip populations during 2022-2024

Depending on the positions of the three years concerning the first component axis (Figure 3), the most favourable conditions for the growth of rosehip fruits were recorded in 2024, while the fruit weight presented the lowest values in 2022.
The high stability of the 'Lipova TF' population, revealed by its low IPCA1 value, was associated with the highest fruit pulp percentage over the three years. Also, the 'Lipova' population showed the second-ranking performance and average stability. The populations 'Olari' and 'Bocsig' achieved values above the general mean and good stability. In the case of the 'Vladimirescu' population, the high stability of this trait was associated with the lowest performance.

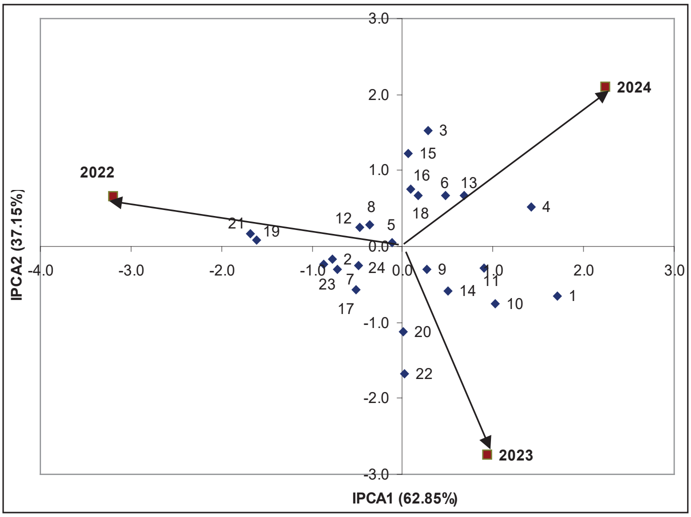

Figure 4. Biplot of interaction for principal component axis (IPCA1 and IPCA2) for pulp percent in rosehip populations during 2022-2024

The biplot from Figure 4, based on the first two components, indicates that 2022 contributed the most to the interaction between populations and climatic conditions, while 2023-2024 had considerably lower effects. According to the distance from the origin, the populations 'Lipova TF', 'Patars', 'Seleus', 'Vladimirescu', and 'Arad' presented the highest stability of fruit pulp percentage.

The length and position of the vectors for lines 'Gurba' and 'Sebis' indicate a high instability of fruit weight, associated with the highest values in 2024 and the lowest in 2022. In the 'Chesint' and 'Zabrani' populations, the low stability was associated with the highest fruit pulp percentage in 2022 and the lowest in 2023. The populations 'Almas' and 'Brazi' expressed a specific adaptation to the conditions from 2023, being positioned close to the vector of this year. 'Zimandu Nou', 'Sebiş', and 'Beliu' populations have shown a specific adaptation to the conditions from 2024, registering a significantly higher increase than in the other years.

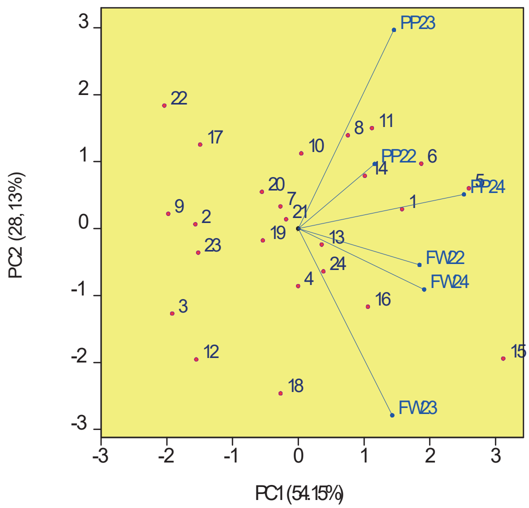

Figure 5. Biplot of the first two principal components for pulp percentage and fruit weight in rosehip populations during 2022-2024

Considering the rosehip populations' performances for the two traits during 2022-2024, the first two principal components from Figure 5 express 82.28% of the total variability. Negative PC2 values indicate populations with high fruit weight values, while positive PC2 values are characteristic of populations with a high pulp percentage. Pulp percentage is one of the most important criteria for the quality of rosehip fruit.
Depending on their position about the vectors of the various characters x years, the 'Lipova TF', 'Lipova', and 'Cermei' populations recorded the highest pulp yields over the entire period. The second-ranking group for this trait comprised the populations 'Gurba', 'Patars', and 'Ineu'. All these populations achieved fruit weight over the general mean.
The highest fruit weight of the 'Olari' population was associated with a pulp percentage above the mean, while the population 'Bocsig' presented high fruit weight with an average pulp percentage. The populations 'Siria' and 'Fantanele' have shown fruit weight over the mean with a pulp percentage below the mean. The small fruits of 'Brazi' and 'Buteni' populations were associated with an average pulp percentage. Cultivars with large-sized fruits and a high pulp percentage are desired and suitable for the industry (Celik et al., 2009).

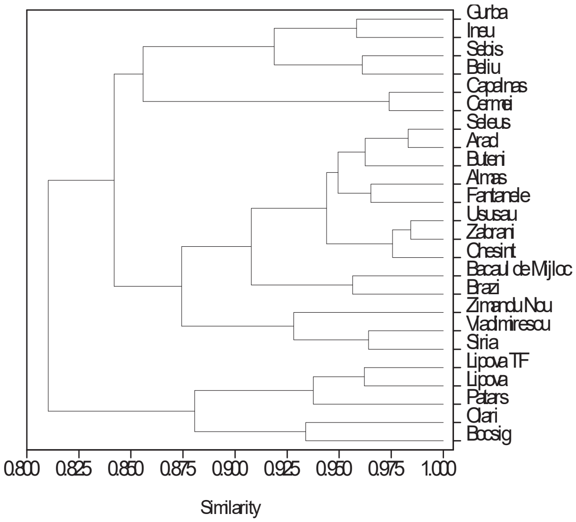

Figure 6. UPGMA clustering of rosehip populations regarding the pulp percentage and fruit weight during 2022-2024

Based on the UPGMA method, the hierarchical clustering from Figure 6 grouped the rosehip populations in four major clusters. The cluster size varied, with a larger number of populations in cluster two containing ten populations (42%), grouped into four subclusters, with an approximately 91 % intra-cluster similarity. Cluster one was the second largest, comprising six populations (25%), with a diversity of 16%. Cluster three was the smallest, with three populations sharing a 63 % similarity. Cluster four was composed of five populations, which possessed about 88% common characteristics of the two fruit traits. The diversity between the studied populations can result from the degree of heterogeneity normal in cross-pollinating plants of any natural rosehip population (Ersoy & Salman, 2017; Guler et al., 2021; Rovna et al., 2020).

CONCLUSIONS

The population has the highest contribution of 25.83-26.18% to the variability of both fruits' traits, followed by the population x year interaction with a contribution of 23.29-26.02%. The effect of the yearly conditions was lower, at 13.5% for fruit weight and 4.14 % for pulp percentage, respectively. The populations 'Lipova', 'Almas', and 'Zabrani' expressed a stable fruit weight over the years, with an average above the experience mean. The high stability of 'Lipova TF' and 'Patars' populations was associated with fruit pulp percentage over the general mean.

The present study identified a thorn-free rosehip population ('Lipova TF'), which can be helpful both for production and breeding programs to obtain thorn-free genotypes for easy harvest. 'Olari' and 'Bocsig' populations with large fruits and high pulp percentages can be propagated vegetatively and used for production, or might be used as parents in breeding programs to develop new rosehip genotypes with large fruits.

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