JOURNAL of Horticulture, Forestry and Biotechnology
Volume 29(2), 2025, 522-530
https://jhfb.ro/index.php/jhfb
Print ISSN: 2066-1797
Online ISSN: 3045-1876

Assessment of pomological diversity between rosehip (*Rosa canina* L.) populations from Arad County

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Manuscript received: 8 December 2025; revised: 10 December 2025; accepted: 15 December 2025

Abstract
The fruits of rosehip are known to be used as medicinal plants, having in present high interest in different nutraceuticals foods. The fruit quality is assessed by many pomological parameters, which can differ with climate conditions, geographical location, or geographic ecological origin. Wild fruits like rosehip have distinct combinations of gene in addition to a higher level of gene diversity caused by frequent out-crossing. The 24-rosehip populations were collected from different locations of Arad County located in the West of Romania. The rosehip ripe fruits were randomly picked from different sides of the canopy for three shrubs of each population. The objective of this study was to assess the pomological diversity between rosehip populations from Arad County to obtain information about their potential for yield under different natural conditions of this region. Significant differences for fruits traits were found among the rosehip populations studied. The diversity of rosehip population from Arad County was indicated by grouping them into different clusters and subclusters. The populations Lipova TF and Patars from South region, and Bocsig population from North region of Arad County expressed high pulp yields and fruit mass. As such, these populations might be used for different production and breeding purposes.

Keywords: dog rose, fruits traits, phenotypic similarity.

Introduction

Rosehips are native to cold and highland areas but exhibit high environmental adaptability, given that is widespread in different climate regions of Europe, such as Croatia [2, 14], Lithuania [4, 20]. Romania [13, 24, 34], Serbia [28, 29], Slovakia [31], Turkey [3, 12]. In horticulture, rosehip is mostly used as a rootstock in the development of rose varieties [32], while in forestry it is considered one of the most used edible wild fruits [15, 35]. Given its phytoremediation potential, rosehip is also used as a landscape plant to prevent air pollution [19, 21].

The rosehip is a pseudocarp or false fruit, consisting of fleshy walls surrounding a cavity containing the single-seeded fruits or achenes [16]. The pseudo-fruits of rosehip contain high quantity of vitamin C and other important active compounds such as phenols, fatty acids, several carotenoids and carbohydrates [1, 8, 22]. The utilization of rosehip fruits has a long tradition, it is used in tea, jam, syrup, marmalade etc [34]. It has been demonstrated that rosehips have strong antioxidant, antimicrobial, anti-inflammatory, antidiabetic, and anticarcinogenic activities [18, 27]. rosehips are a promising source of functional ingredients to enrich food with nutritious and antioxidant substances, which is the reason for the growing interest in studying them [25].

In Romania 29 spontaneous and subspontaneous species and five hybrids of Rosa genus, have been identified [24]. The wild genotypes possess higher level of genes frequency for resistance and accumulation of phytocompounds, based on their good tolerance to several biotic and abiotic stress factors [21]. Wild species with edible fruits possess distinct combinations of gene in addition to a higher level of gene diversity [26]. Several studies reported the existence of significant variability for morphological traits and biochemical composition of rosehip fruits from spontaneous flora of different Romanian regions: Oltenia [34, 35], Transylvania [24], Moldova [30]. The diverse Romanian rosehip populations that grow naturally in a wide climate and soil conditions are a valuable source for direct use or as a breeding material.

The diverse range of genotypes within *Rosa canina* species highlights the importance of continued research and conservation efforts to preserve the genetic diversity and potential benefits of these plants [24]. The

knowledge of the variability for fruits traits of rosehip genotypes is valuable both for medicinal purposes and for designing efficient breeding programs [3]. The objective of this study was to assess the fruits traits diversity between rosehip populations from Arad County to characterize their potential for yield under different natural conditions of this region and obtain useful information both for fruits production and breeding purposes.

Materials and Method

The 24-rosehip populations were collected from different locations of Arad County located in the West of Romania. The geographical coordinates of the collection locations for rosehip populations are presented in Table 1. Given the temperatures during the summer associated with the level of rainfall, the climatic conditions from 2022 were suitable for the grow and development of rosehip fruits.

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	Chesinţ	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 rosehip ripe fruits were randomly picked from different sides of the canopy for three shrubs of each population. The harvested fruits of each population were sampled into three categories: small, medium and large. From each shrub 20 mature fruit were randomly chosen for measurements. The weight of fruit and pulp was determined using a KERN digital scale (sensitive to 0.01 g).

The data was first analysed using ANOVA as per method for randomized block design, while the populations mean were compared using Least Significant Difference test as described by Ciulca [7]. The distance matrix was computed (UPGMA method) for cluster analysis, using the Neighbor program of the Phylip 3.5c package. Principal component analysis with the first two dimensions was used to express the performances of rosehip populations during the study period. The data was statistically processed using MATMODEL Version 3 software.

Results and Discussion

In terms of the small fruits weight, the rosehip populations recorded values ranging from 0.86 g at Bacaul de Mijloc and 1.51 g at Olari, associated with an amplitude of 0.65 g (Table 2). In populations Lipova TF, Cermei and Olari this trait was significantly superior to the rest of the populations with relative increases of over 12.5%. Most populations (75%) had significantly equal values ranging between 0.93 and 1.16 g.

The weight of the average fruit showed amplitude of 1.27 g with limits from 1.08 g at Brazi to 2.35 g at Olari. The highest frequency (67%) was observed in populations with a fruit weight of 1.44-1.75 g. Population Olari recorded a significantly higher fruit mass than the rest of the populations except for population Cermei which showed significant increases of 0.4-1 g compared to 67% of the populations.

The large fruits showed a variation in weight from 1.7 g at Bacaul de Mijloc to 2.82 g at Cermei, with an amplitude of 1.12 g. Populations Cermei, Olari, Capalnas, Buteni, Siria, Bocsig had a fruit mass of over 2.5 g and significantly higher than 62% of the populations. Most populations (58%) achieved a fruit weight of 2-2.5 g, while only five populations had values below 2 g.

The highest fruit weight uniformity was presented by the Zimandu Nou, Bacaul de Mijloc, Brazi, Ususau and Beliu populations, while the fruits of the Capalnas, Buteni, Siria, Cermei and Bocsig populations recorded the highest fruit heterogeneity for this trait. The mean values of fruit weight in the 24 rosehip populations from Arad County were compatible with those reported for regions with different ecological conditions from Romania [34, 35] and other countries [3, 5, 9, 21].

JOURNAL of Horticulture, Forestry and Biotechnology
Volume 29(2), 2025, 522-530
https://jhfb.ro/index.php/jhfb
Print ISSN: 2066-1797
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Table 2. Average weight of fruits categories for rosehip populations in 2022

No	Population	Small	Medium	Large	DSS	Rank DSS
1	Gurba	0.93 def	1.50 defg	2.16 defgh	2.27	*9*
2	Seleus	1.02 cdef	1.58 efg	2.08 efgh	1.69	*14*
3	Zimandu Nou	1.16 bcd	1.50 h	1.96 gh	0.97	*24*
4	Sebis	0.99 cdef	1.45 defg	1.99 fgh	1.50	*16*
5	Lipova TF	1.35 a	1.68 cdef	2.39 bcdef	1.69	*13*
6	Lipova	1.12 bcde	1.74 efgh	2.09 efgh	1.45	*18*
7	Ususau	1.12 bcde	1.50 bcde	2.04 fgh	1.28	*21*
8	Patars	1.13 bcde	1.73 bcd	2.49 abcde	2.79	*6*
9	Bacaul de Mijloc	0.86 f	1.21 bcd	1.70 i	1.07	*23*
10	Capalnas	0.91 ef	1.92 a	2.67 ab	4.68	*1*
11	Cermei	1.36 a	2.08 fgh	2.82 a	3.20	*4*
12	Vladimirescu	0.98 cdef	1.49 cdefg	2.09 efgh	1.85	*11*
13	Beliu	1.20 bc	1.58 defg	2.12 efgh	1.28	*20*
14	Ineu	1.03 cdef	1.34 ab	2.00 fgh	1.47	*17*
15	Olari	1.51 a	2.35 bc	2.79 ab	2.54	*7*
16	Bocsig	1.15 bcde	1.84 gh	2.55 abcd	2.94	*5*
17	Buteni	1.01 cdef	1.84 bcde	2.63 abc	3.94	*2*
18	Siria	1.10 bcdef	1.75 defg	2.59 abc	3.35	*3*
19	Chesinţ	0.94 def	1.44 bcde	1.89 gh	1.36	*19*
20	Almas	1.06 cdef	1.60 cdef	2.12 efgh	1.69	*15*
21	Zabrani	1.01 cdef	1.51 efgh	2.08 efgh	1.72	*12*
22	Brazi	0.98 cdef	1.08 defg	1.78 h	1.14	*22*
23	Arad	1.11 bcde	1.46 cdefg	2.21 cdefg	1.90	*10*
24	Fantanele	1.01 cdef	1.47 defg	2.26 bcdefg	2.40	*8*

DSS- Deviations sum squares
Means (g) with different letters (in the row) are significantly different at p<0.05

The weight of the pulp of small fruits in the 24 rosehip populations recorded values from 0.52 g in Bacaul de Mijloc to 0.92 g in Lipova TF, with an amplitude of 0.4 g, associated with a medium variability at the interpopulation level (Table 3). Regarding the comparisons between populations, it can be observed that populations 5 and 15 express a significantly higher pulp weight than most of the other populations. Also, 15 populations presented close values of this trait, ranging between 0.52 and 0.66 g.

In the case of medium fruits, the pulp weight showed a higher variability compared to the previous category, associated with amplitude from 0.63 g at Brazi to 1.55 g at Olari. 11 populations achieved values over 1 g, while two populations had values over 1.25 g. Thus, population Olari achieved a significantly higher pulp mass by over 24,5% compared to the other populations. Population Cermei showed a significant increase of 0.27-0.62 g compared to 54% of the populations.

For large fruits, the smallest differences between populations are observed in terms of pulp weight. Thus, this character varied from 0.96 g in Bacaul de Mijloc to 1.84 g in Olari, given that 14 populations had significantly equal values of 1.1-1.35 g, and in seven populations a reduced variation was observed from 1.39 to 1.59 g. In this category too, the fruits of population Olari stood out with a pulp mass significantly higher than 87.5% of the populations.

The pulp weight recorded the highest heterogeneity in the fruits of the Olari, Cermei, Capalnas, Patars and Bocsig populations, while in the fruits of the Bacaul de Mijloc, Zimandu Nou, Beliu and Sebiş populations, the pulp weight showed reduced variations between the three categories.

Table 3. Average pulp weight of fruits categories for rosehip populations in 2022

No	Population	Small	Medium	Large	DSS	Rank DSS
1	Gurba	0.54 fg	0.88	1.19 efgh	0.63	15
2	Seleus	0.62 defg	1.01	1.30 defg	0.70	12
3	Zimandu Nou	0.68 bcdef	0.87	1.13 fgh	0.31	23
4	Sebis	0.58 efg	0.77 ghi	1.12 fgh	0.45	21
5	Lipova TF	0.92 a	1.17 bc	1.56 bcd	0.62	16
6	Lipova	0.69 bcde	1.13	1.39 cdef	0.75	10
7	Ususau	0.61 defg	1.01	1.28 efg	0.68	14
8	Patars	0.77 bc	1.15 bc	1.59 abc	1.01	4.5

9	Bacaul de Mijloc	0.52 g	0.71 hi	0.96 h	0.29	24
10	Capalnas	0.56 efg	1.12	1.44 cde	1.19	3
11	Cermei	0.81 ab	1.25 b	1.72 ab	1.24	2
12	Vladimirescu	0.57 efg	0.86 fghi	1.3 defg	0.81	9
13	Beliu	0.74 bcd	0.91	1.25 efg	0.40	22
14	Ineu	0.62 defg	0.86 fghi	1.24 efg	0.59	18
15	Olari	0.92 a	1.55 a	1.84 a	1.33	1
16	Bocsig	0.74 bcd	1.14 bcd	1.56 bcd	1.01	4.5
17	Buteni	0.61 defg	1.02	1.35 cdefg	0.82	8
18	Siria	0.66 cdefg	0.97	1.45 bcde	0.95	6
19	Chesinţ	0.62 defg	0.97	1.30 defg	0.69	13
20	Almas	0.64 cdefg	0.98	1.27 efg	0.60	17
21	Zabrani	0.64 cdefg	1.07	1.33 cdefg	0.73	11
22	Brazi	0.59 efg	0.63 i	1.10 gh	0.48	19.5
23	Arad	0.69 bcde	0.91	1.25 efg	0.48	19.5
24	Fantanele	0.63 cdefg	0.94	1.41 cde	0.93	7

DSS- Deviations sum squares
Means (g) with different letters (in the row) are significantly different at p<0.05

Table 4. Average pulp percentage of fruits categories for rosehip populations in 2022

No	Population	Small	Medium	Large	DSS	Rank DSS
1	Gurba	58.06 g	58.67 cd	55.09 hij	21.95	*16*
2	Seleus	60.78 bcdefg	63.92 b	62.50 bcde	14.87	*19*
3	Zimandu Nou	58.62 efg	58.00 cde	57.65 efghi	1.44	*24*
4	Sebis	58.59 efg	53.10 e	56.28 fghij	45.53	*7*
5	Lipova TF	68.15 a	69.64 ab	65.27 abc	29.62	*11*
6	Lipova	61.61 bcdefg	64.94 b	66.51 ab	37.54	*8*
7	Ususau	54.46 h	67.33 ab	62.75 bcd	255.42	*1*
8	Patars	68.14 a	66.47 ab	63.86 abcd	27.99	*12*
9	Bacaul de Mijloc	60.47 cdefg	58.68 cd	56.47 fghi	24.08	*14*
10	Capalnas	61.54 bcdefg	58.33 cd	53.93 ij	87.52	*4*
11	Cermei	59.56 defg	60.10 bcd	60.99 cdef	3.14	*22*
12	Vladimirescu	58.16 fg	57.72 cde	62.20 bcde	36.62	*10*
13	Beliu	61.67 bcdef	57.59 cde	58.96 defgh	25.81	*13*
14	Ineu	60.19 cdefg	64.18 b	62.00 bcde	23.94	*15*
15	Olari	60.93 bcdefg	65.96 ab	65.95 ab	50.47	*6*
16	Bocsig	64.35 ab	61.96 bc	61.18 cdef	16.41	*18*
17	Buteni	60.40 cdefg	55.43 de	51.33 j	123.75	*2*
18	Siria	60.00 cdefg	55.43 de	55.98 ghij	37.33	*9*
19	Chesinţ	65.96 ab	67.36 ab	68.78 a	11.95	*20*
20	Almas	60.38 cdefg	61.25 bc	59.91 defgh	2.79	*23*
21	Zabrani	63.37 bc	70.86 a	63.94 abcd	104.31	*3*
22	Brazi	60.20 cdefg	58.33 cd	61.80 bcde	18.04	*17*
23	Arad	62.16 bcde	62.33 bc	56.56 fghi	64.64	*5*
24	Fantanele	62.38 bcd	63.95 b	62.39 bcde	4.87	*21*

DSS- Deviations sum squares
Means (%) with different letters (in the row) are significantly different at p<0.05

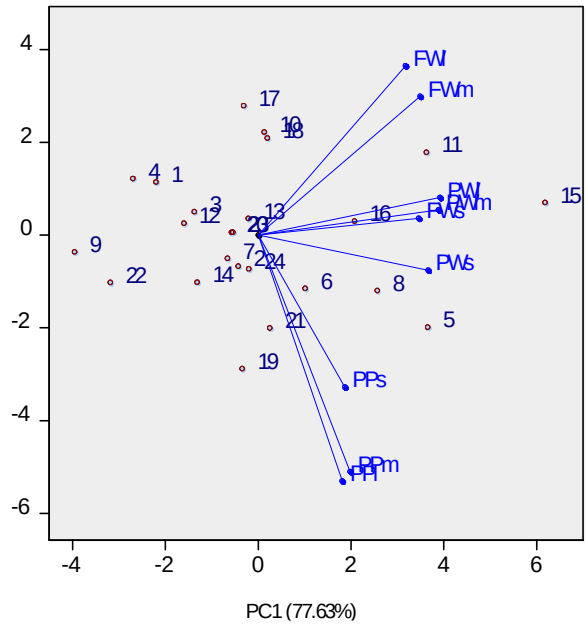
The small fruits showed a variation in pulp percentage from 54.46% at Ususau to 68.15% at Lipova TF, with amplitude of 13.69% (Table 4). Populations Lipova TF, Patars, Bacaul de Mijloc, Bocsig had a pulp percentage of over 64% and significantly higher than 12 of the populations. Most populations (15) achieved a pulp percentage of 58.06-61.61%, while in four populations the values were 61.67-63.37%.

Regarding the pulp percentage of medium fruits, the rosehip populations recorded values ranging from 53.1% at Sebis to 70.86% at Zabrani, associated with amplitude of 17.76%. In populations Zabrani, Lipova, Chesint, Ususau, Patars and Olari this trait was significantly higher than 10 populations with increases of over 7.28%. 10 of the populations had significantly equal values ranging from 55.43 to 60.1%.

The pulp percentage of large fruits showed amplitude of 17.45% with limits from 51.33% at Buteni to 68.78% at Chesint. The highest frequency was observed in populations with a pulp yield of 58.96-63.54%.

JOURNAL of Horticulture, Forestry and Biotechnology
Volume 29(2), 2025, 522-530
https://jhfb.ro/index.php/jhfb
Print ISSN: 2066-1797
Online ISSN: 3045-1876

Population Chesint recorded a fruit mass significantly higher than 75% of the populations. Also, populations Lipova and Olari showed significant increases of 4.77-15.18% compared to 12 populations.



FW-Fruit weight; PW-Pulp weight; PP-Pulp percentage

Figure 1. Biplot with PC1 and PC2 for fruits traits of rosehip populations in 2022

In the conditions of 2022, the principal component analysis (Figure 1) using the first two dimensions includes 91.35% of the variability of the fruit traits studied in rosehip populations. Considering the vectors of the different traits, it is observed that the greatest differences between populations were recorded for the weight of medium fruits and their pulp mass, while in terms of pulp percentage, the interpopulation variability in the three fruit categories was the lowest.

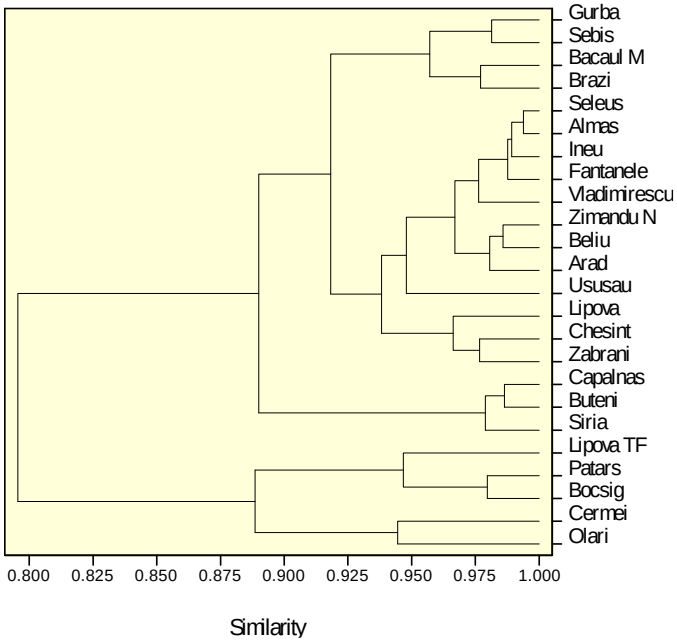


Figure 2. UPGMA clustering of rosehip populations in 2022 based on fruits traits

Based on each population projection on the vectors of different traits, it is found that under the conditions of this year in population Olari the highest level of fruit weight is associated with the highest values for pulp weight and pulp percentage. Population Cermei presented a higher weight of the three categories of

JOURNAL of Horticulture, Forestry and Biotechnology
Volume 29(2), 2025, 522-530
https://jhfb.ro/index.php/jhfb
Print ISSN: 2066-1797
Online ISSN: 3045-1876

fruits and their pulp against the background of an average pulp percentage. In the case of populations Lipova TF and Patars, high pulp yields and an average fruit mass are observed. The high pulp yield in populations Chesint and Zabrani was associated with fruit weight below average. Populations Bacaul de Mijloc and Brazi achieved the lowest values of fruit weight and pulp.

The highest uniformity of pulp percentage was presented by the Zimandu Nou, Almas, Cermei, Fantanele and Chesint populations, while the fruits of the Ususau, Buteni, Zabrani, Capalnas and Arad populations recorded the highest fruit heterogeneity for this trait.

The pulp ratio is one of the most important criteria regarding rosehip fruit quality. In the development of rosehip cultivars suitable for industry purposses, genotypes with large fruits and a high pulp ratio are preferred [5]. Our results were lower compared with the results of other studies from Romania (50-66%) [34], Lithuania (71-86%) [20], Turkey (62-80) [3, 10, 17].

Based on the dendrogram from Figure 2, the rosehip populations were grouped into four clusters, between which an average diversity of approximately 21% is manifested. The first cluster is composed of the Gurba, Sebis, Bacaul de Mijloc and Brazi populations between which an average similarity of approximately 96% is expressed. The second cluster has a more complex structure, composed of 12 populations grouped into three sets, between which a phenotypic diversity of approximately 6% exists. The first of these sets includes the populations Seleus, Almas, Ineu, Fantanele, Vladimirescu, which present a similarity of 98 % between them. The second set is composed of the populations Zimandu Nou, Belui and Arad, characterized by an intergenotypic diversity of 2 %. The third set includes the populations Ususau, Lipova, Chesint, Zabrani. The third cluster is made up of the Capalnas, Butenbi and Siria populations with an average phenotypic similarity of 98%. There is a phenotypic diversity of approximately 11% between the genotypes in the first three clusters. The last cluster is made up of the Lipova TF, Patars, Bocsig populations, along with the Cermei and Olari populations, similar in a proportion of 88% for fruit traits.

Table 5. Variance analysis for fruits traits of rosehip populations in 2022

Traits	Between groups		Within groups		F value
	SS	DF	SS	DF	
Small fruit weight	12.47	1	10.47	22	26.21**
Medium fruits weight	9.07	1	13.89	22	14.36**
Large fruits weight	9.19	1	13.87	22	14.59**
Pulp weight of small fruits	15.60	1	7.45	22	46.05**
Pulp weight of medium fruits	11.43	1	11.55	22	21.78**
Pulp weight of large fruits	14.58	1	8.42	22	38.07**
Pulp percentage of small fruits	5.75	1	17.24	22	7.34*
Pulp percentage of medium fruits	2.67	1	20.33	22	2.89
Pulp percentage of large fruits	2.86	1	20.14	22	3.13

Regarding the analysis of variance for fruit characters in rosehip populations (Table 5), it is observed that high and significant values of variance were recorded especially in the case of pulp weight in small fruits with a contribution of 18.66% to the total diversity, while pulp weight in large fruits contributed with 17.44%. The pulp percentage had a reduced influence of 3.19-6.88% on the diversity between the 24 populations. These subgroups were discriminated mainly due to the values of pulp weight. The results of our study agree with those presented by Singh et al. [33] who pointed out that cluster analysis can be considered as a valuable tool for evaluation of similarities of wild roses.

Table 6. Variance analysis for hierarchical classification of rosehip populations in 2022

No	Populations	Between groups		Within groups		F value
		SS	DF	SS	DF	
1	Gurba	156.93	1	28.69	7	38.29**
2	Seleus	186.20	1	23.24	7	56.08**
3	Zimandu Nou	153.50	1	30.88	7	34.80**
4	Sebis	153.57	1	36.19	7	29.71**
5	Lipova TF	185.83	1	40.55	7	32.08**
6	Lipova	184.86	1	21.53	7	60.10**
7	Ususau	170.12	1	9.84	7	121.01**
8	Patars	187.90	1	41.80	7	31.47**

Print ISSN: 2066-1797
Online ISSN: 3045-1876

9	Bacaul de Mijloc	203.61	1	33.36	7	42.73**
10	Capalnas	133.35	1	44.00	7	21.22**
11	Cermei	103.99	1	28.03	7	25.97**
12	Vladimirescu	169.79	1	25.91	7	45.87**
13	Beliu	153.24	1	39.39	7	27.23**
14	Ineu	196.99	1	24.15	7	57.10**
15	Olari	106.58	1	19.82	7	37.65**
16	Bocsig	152.27	1	37.67	7	28.30**
17	Buteni	118.14	1	45.07	7	18.35*
18	Siria	123.53	1	39.57	7	21.85**
19	Chesinţ	252.37	1	28.61	7	61.75**
20	Almas	167.92	1	27.33	7	43.01**
21	Zabrani	219.13	1	22.17	7	69.19**
22	Brazi	207.87	1	33.81	7	43.03**
23	Arad	167.67	1	36.84	7	31.86**
24	Fantanele	190.15	1	29.93	7	44.47**

Based on the analysis of variance related to the hierarchical classification of genotypes (Table 6), it is observed that the Chesint, Zabrani, Brazi, Bacaul de Mijloc populations generate the greatest differences between the studied characters, having high contributions to the total variability recorded between the four clusters. The lowest variability was observed in the Cermei, Olari and Buteni populations. It is also found that the highest variability for the genotypes of the first cluster was recorded in the Gurba population, while for the second cluster the Beliu and Arad populations stood out in this regard. In the last cluster, the Lipova TF and Pataraş populations generated most of the diversity.

Fruit weight can vary widely and is affected by many factors such as genotype, growing conditions [23] altitude and climatic conditions [13, 37], harvesting period and maturation stages [36]. The fruit traits studied in the rosehip populations from Arad County showed middle variation, close to the findings of other studies [11, 21].

Conclusions

Significant differences for fruits traits were found among the studied rosehip populations. The fruits diversity of rosehip population from Arad County was indicated by grouping them into different clusters and subclusters. Besides the genetic factors, some of the natural conditions like elevation or nutrient content of the soil seem to have an important effect on growth and development of rosehip fruits. The diversity between the populations located at close distance suggested that the fruit traits of a particular population in a given location are mediated by the genetic component which enables the genotype to adapt to a particular environment.

The populations Lipova TF and Patars from South region, and Bocsig population from North region of Arad County expressed high pulp yields and fruit mass. As such, these populations might be used for different production and breeding purposes. Future additional physicochemical and molecular studies aimed at selecting the best samples for use in food and pharmaceutical products are also needed.

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