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Fruit size variability in rosehip (*Rosa canina* L.) populations from Arad County

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Abstract
The rosehip is a perennial shrub that can grow as a solitary plant or in small groups in thickets, open areas, forest edges. Due to the gro
wing interest in plant agents enriched with antioxidant activities properties; these plants acquire an increasingly wider application in the food, cosmetics, and pharmaceutical industries. Rosehips are pseudocarp or false fruit, consisting of fleshy walls surrounding a cavity containing the single-seeded fruits or achenes. Fruit size and shape are two major factors determining yield, quality and the utility for many crops species, and also in rosehip. 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 harvested fruits were sampled into three categories: small (below 1 g), medium (1-2 g) and large (over 2 g). The contribution of the fruits categories to the harvest was calculated based on percent from total fruits weight and from total fruits number. The aim of this study was to determine the impact of the climatic conditions over 2022-2024 on the fruit size in 24-rosehip populations from Arad County. The variation of climatic conditions had the highest influence on fruit size in populations Bacaul de Mijloc, Vladimirescu, Bocsig, where the proportion of large fruits as a percentage of the total fruits weight was considerably reduced, and in populations Gurba, Beliu, Bocsig as a percentage of the total fruits number. In the case of the number of large fruits, the effects of the genotype-environment interaction were lower than in the case of fruit weight

Keywords: dog rose, environment effect, fruits size categories.

Introduction

Rose hips are the accessory fruits of various *Rosa* species [1,11]. Traditionally, in many countries, these pseudo-fruits have been harvested for food or medicinal purposes [7]. Post harvest fruit quality characteristics are influenced by many factors. Some properties such as flesh firmness, soluble solid content and total acidity are important parameters affecting post-harvest quality and the shelf life of fruits [21].

Several studies have reported that rose hips are rich in biologically active molecules such as anthocyanins, ascorbic acid, and phenolic compounds [7, 10]. These bioactive compounds contribute to the nutritional quality of the plant [10] and can exert a positive effect on health thanks to their antioxidant and antimutagenic activities, through which they can contribute to the prevention of cancer cell proliferation and cardiovascular diseases [12, 22, 26].

Rose hips are found in different sizes and colours, from yellow–orange to dark red and sometimes even black, depending on the pattern of pigments such as carotenoids, flavonoids, or anthocyanins [4,13]. The fruit of the rosehip has an accessory fruit structure and can vary in shape from ovoid to round or spherical [24]. The morphological traits of rosehip fruits depend on the genotype and on the climatic conditions and/or growing techniques [14]. Also, both genotype and ripening stage significantly influenced size, weight, flesh proportion, color, and texture across species and cultivars [16]. Latitude and harvest timing strongly influenced weight: later harvests often produced higher dry weights, while early harvests had much lower [6].

Wild genotypes show higher morpho-biochemical diversity than cultivars [17]. These genotypes have a higher frequency of genes that trigger resistance and phytochemical accumulation, due to their tolerance to natural enemies and stress factors in their environment [15]. Fruits of Cultivated *R. canina* populations were heavier and slightly larger in diameter and length compared to fruits of wild populations [8]. In several studies [2, 3, 11, 18] these characteristics showed middle-to-high variation.

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Temporal variation can influence plant development and phenotypic variation of fruit size and quality. The temporal regulation includes mainly the effects of the year and the biotic and abiotic events between years which are involved in fruit production and quality differences [23]. The aim of this study was to determine the impact of the climatic conditions over 2022-2024 on the fruit size in 24-rosehip populations from Arad County.

Material and Method

The 24-rosehip populations were collected from different locations of Arad County located in the West of Romania, during 2022-2024. Given the high temperatures during the summer months associated with a very low level of rainfall, the climatic conditions from 2024 were considered the most unfavourable. The geographical coordinates of the collection locations for rosehip populations are presented in Table 1.

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, considering the shrub as a replication. The full maturity fruits (uniform colour) were harvested from same shrubs each year. The fresh fruits were weighed using a KERN digital scale (precision 0.01 g). The harvested fruits from each shrub were sampled into three categories: small (below 1 g), medium (1-2 g) and large (over 2 g). The contribution of the fruits categories to the harvest was calculated based on percent from total fruits weight and from total fruits number.

The data was first analysed using ANOVA as per method for randomized block design, while the varieties mean was compared using Least Significant Difference Test as described by Ciulca [5]. Principal component analysis based on 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

Under the conditions of 2022, the percentage of small fruits in relation to the total mass of harvested fruits varied from 15.40 in the population of Arad to 44.44 in the population of Beliu (Table 2). Four of the populations presented a percentage of small fruits lower than 20, while 7 populations had values between 20 and 30, 10 populations recorded values of 30-40, and in the case of three populations the percentage of small fruits was over 40. Regarding the percentage of medium fruits, there is a range from 33.41 in the Sebiş population to 65.03 in the case of the Chesinţ population. Most populations presented a percentage of medium fruits of 40-50, while six achieved percentages of 50-60, and five populations exceeded 65 percent. The percentage of large fruits ranged from 13.33 in the Buteni population to 43.44 in the Sebiş population. Most of the populations (54.6%) had values below 20, followed by those with values of 20-30 percents.

Most of the populations (54.16 %) presented a significantly higher proportion of medium fruits compared to the other two categories. In the case of eight genotypes the percentage of large fruits was significantly lower than the percentage of small and medium fruits, respectively. In the Şiria and Ineu populations, a more obvious homogeneity of fruit size is observed, with only the frequency of large fruits varying significantly compared to that of medium fruits. A particular case is presented by the Sebiş population where the frequency of large fruits was significantly higher than the other categories.

The number of small fruits recorded in 2022 frequencies between 21.17 for the population of Arad and 54.60 for the population of Bacăul de Mijloc. The distribution of the populations was relatively symmetrical, considering that six populations had values of 20-30 percents, seven populations had percentages of 30-40 and eight populations had values of 40-50 percents. Regarding the number of medium fruits, an amplitude was observed from 64.29 percent for the Chesinţ population to 32.43 percent for the Sebiş population. Most populations (45.83%) recorded frequencies of 40-50, while four populations exceeded 60 percent. The number

of large fruits showed a smaller variation, ranging from 8.80 percent for the Seleuş population to 35.14 percent for the Sebiş population. Most populations (71%) recorded a frequency of large fruits between 10 and 20 percents, while two populations showed percentages of 20-30, and three populations had values below 10 percent.

Most populations showed a significantly lower percentage of large fruits than small and medium fruits. In the case of seven populations, the proportion of medium fruits was significantly higher than small and large fruits, while the Beliu population showed a significantly higher percentage of small fruits. The Sebiş population showed significantly equal frequencies of the three fruit categories.

Table 2. Percentage of fruits categories for rosehip populations in 2022

No.	Population	% fruits categories (FW)			% fruits categories (FN)		
		Small	Medium	Large	Small	Medium	Large
1	Gurba	31.03 b	46.35 a	22.62 b	39.69 a	44.07 a	16.24 b
2	Seleus	33.99 b	52.15 a	13.86 b	44.44 a	46.76 a	8.80 b
3	Zimandu Nou	29.98 b	42.05 a	27.97 b	38.63 a	40.28 a	21.09 b
4	Sebis	23.15 b	33.41 b	43.44 a	32.43 a	32.43 a	35.14 a
5	Lipova TF	21.48 b	53.71 a	24.81 b	26.82 b	53.18 a	20.00 b
6	Lipova	40.89 a	42.17 a	16.94 b	50.48 a	38.10 a	11.42 b
7	Ususau	35.89 a	49.08 a	15.03 b	46.38 a	43.83 a	9.79 b
8	Patars	23.78 b	50.27 a	25.95 b	33.81 ab	47.62 a	18.57 b
9	Bacaul de Mijloc	43.75 a	38.02 a	18.23 b	54.60 a	33.33 ab	12.07 b
10	Capalnas	37.30 a	45.77 a	16.93 b	49.72 a	39.11 a	11.17 b
11	Cermei	30.02 b	51.97 a	18.01 b	39.05 a	48.07 a	12.88 b
12	Vladimirescu	36.26 a	48.27 a	15.47 b	47.76 a	42.31 a	9.93 b
13	Beliu	44.44 a	35.46 a	20.09 b	52.92 a	32.48 b	14.60 b
14	Ineu	32.98ab	45.38 a	21.64 b	42.69 a	43.27 a	14.04 b
15	Olari	26.65 b	50.13 a	23.22 b	36.36 a	46.02 a	17.62 b
16	Bocsig	38.07 a	45.54 a	16.39 b	45.63 a	44.11 a	10.26 b
17	Buteni	37.38 a	49.29 a	13.33 b	46.03 a	45.08 a	8.89 b
18	Siria	33.24 ab	41.76 a	25.00 b	44.33 a	38.42 a	17.25 b
19	Chesinţ	16.56 b	65.26 a	18.18 b	22.38 b	64.29 a	13.33 b
20	Almas	18.37 b	59.64 a	22.59 b	25.12 b	59.42 a	15.46 b
21	Zabrani	20.22 b	60.89 a	18.89 b	30.31 b	56.45 a	13.24 b
22	Brazi	23.50 b	60.83 a	15.67 b	28.49 b	61.05 a	10.46 b
23	Arad	15.40 b	61.16 a	23.44 b	21.17 b	60.95 a	17.88 b
24	Fantanele	17.95 b	65.03 a	17.02 b	25.30 b	62.45 a	12.25 b

FW- Percentage of the total fruits weight; FN- Percentage of the total fruits number
Means with different letters (in the row) are significantly different at $p<0.05$

Under the effect of the conditions of 2023, the number of small fruits recorded values from 14.68 percent in the population of Arad to 44.44 percent in the population of Zimandu Nou (Table 3). In the case of five populations, the percentage of small fruits was below 20, while 9 populations had values between 20 and 30 percents, 8 populations recorded values of 30-40 percents, and in the case of two populations the percentage of small fruits exceeded the level of 40 percent. In the case of medium-sized fruits, the amplitude was higher, with limits from 34.29 percent in the Sebiș population to 67.17 percent in the case of the Fantanele population. Most populations presented a percentage of medium-sized fruits of 50-60, while seven achieved percentages of 40-50, and five populations exceeded 60 percent. The percentage of large fruits recorded a considerably lower amplitude than the other categories, with values ranging from 12.62 for the Brazi population to 25.46 percent for the Arad population. Most of the populations (75%) presented values above 20%, while only six populations had a quantity of large fruits below 20 percent.

In the case of seven populations, a significantly higher proportion of small and medium fruits was observed compared to large fruits. In most populations, the percentage of medium fruits was significantly higher than the percentage of small and large fruits, which recorded significantly equal values. In the Ineu, Vladimirescu and Gurba populations, a more obvious homogeneity of fruit size is observed, given that only the frequency of large fruits varied significantly compared to that of medium fruits.

The frequency of small fruits as number of the total recorded values in 2023 increased from 20.73 percent in the Zabrani population to 53.36 percent in the Sebis population. The distribution of the populations showed a certain degree of symmetry, so that eight populations had values below 30 percent, six populations

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recorded frequencies of 30-40 percents and ten populations presented values above 40 percent. The amplitude for the number of medium fruits was 33.26 percent, with limits from 30.87 percent for the Sebiș population to 64.13 percent for the Brazi population. Eight of the populations had values of 30-40 percents, six populations recorded frequencies of 40-50 percents and seven populations had a number of medium fruits above 50percent. The variability for the number of large fruits was considerably lower, ranging from 6.99 percent for the Brazi population to 19.56 percent for the Arad population. Most populations (15) recorded a frequency of large fruits between 15 and 20 percent, while two populations presented percentages below 10, and seven populations had values below 10-15 percents.

Table 3. Percentage of fruits categories for rosehip populations in 2023

No.	Population	% fruits categories (FW)			% fruits categories (FN)		
		Small	Medium	Large	Small	Medium	Large
1	Gurba	32.44 ab	43.80 a	23.76 b	40.07 a	43.43 a	16.50 b
2	Seleus	18.18 b	59.24 a	22.58 b	24.88 b	59.45 a	15.67 b
3	Zimandu Nou	44.44 a	35.47 a	20.09 b	52.92 a	32.48 b	14.60 b
4	Sebis	42.92 a	34.29 a	22.79 b	53.36 a	30.87 b	15.77 b
5	Lipova TF	25.97 b	49.91 a	24.12 b	32.01 b	49.08 a	18.91 b
6	Lipova	21.91 b	55.34 a	22.75 b	27.52 b	54.59 a	17.89 b
7	Ususau	25.48 b	59.01 a	15.51 b	33.20 b	56.02 a	10.78 b
8	Patars	15.02 b	60.95 a	24.03 b	22.97 b	59.46 a	17.57 b
9	Bacaul de Mijloc	21.91 b	55.34 a	22.75 b	27.52 b	54.59 a	17.89 b
10	Capalnas	38.05 a	37.76 a	24.19 b	49.61 a	34.25 ab	16.14 b
11	Cermei	36.41 a	49.31 a	14.28 b	44.64 a	45.80 a	9.56 b
12	Vladimirescu	33.51 ab	41.36 a	25.13 b	44.04 a	39.45 a	16.51 b
13	Beliu	34.78 a	43.12 a	22.10 b	43.09 a	40.96 a	15.95 b
14	Ineu	33.91 ab	42.77 a	23.32 b	43.41 a	40.12 a	16.47 b
15	Olari	26.15 b	50.16 a	23.69 b	35.26 a	47.43 a	17.31 b
16	Bocsig	39.31 a	39.31 a	21.38 b	48.92 a	35.93 a	15.15 b
17	Buteni	23.81 b	60.90 a	15.29 b	31.41 b	58.01 a	10.58 b
18	Siria	26.71 b	51.07 a	22.22 b	36.6 a	49.43 a	13.96 b
19	Chesinţ	38.35 a	42.21 a	19.44 b	47.44 a	39.21 a	13.35 b
20	Almas	24.77 b	50.46 a	24.77 b	33.83 a	48.33 a	17.84 b
21	Zabrani	12.47 b	63.87 a	23.66 b	20.73 b	62.20 a	17.07 a
22	Brazi	21.12 b	66.26 a	12.62 b	28.88 b	64.13 a	6.99 b
23	Arad	14.68 b	59.86 a	25.46 b	22.51 b	57.93 a	19.56 b
24	Fantanele	17.28 b	67.17 a	15.55 b	25.27 b	63.74 a	10.99 b

FW- Percentage of the total fruits weight; FN- Percentage of the total fruits number
Means with different letters (in the row) are significantly different at $p<0.05$

In the case of 11 populations, the number of large fruits was significantly lower than that of small and medium fruits. For ten of the populations, the number of medium fruits was significantly higher than that of small and large fruits, which were significantly equal. The Zimandu Nou and Sebiş populations presented a significantly higher number of small fruits.

Under the conditions of 2024, the percentage of small fruits relative to the total mass of harvested fruits ranged from 8.73 percent in the Bocsig population to 30.60 percent in the Lipova population (Table 4). Three of the populations had a percentage of small fruits lower than 10, while most populations had values between 10 and 20 percents, and in the case of four populations the percentage of small fruits was above 20 percent. Regarding the percentage of medium fruits, significantly higher values are observed, associated with an amplitude of 29.73 percent, from 50.01 in the Lipova population to 79.74 percent in the Seleuș population. Most populations presented a percentage of medium fruits of 60-70 respectively over 70 percent, while three achieved percentages below 60. The percentage of large fruits ranged from 6.16percent in the Seleuș population to 25.86 percent in the Arad population. Populations with frequencies of 10-15 and 15-20 percents had equal frequencies, while five populations had values above 20 and two below 10 percent. All populations had a significantly higher proportion of medium fruits compared to the other two categories, which were significantly equal.

The number of small fruits in 2024 recorded frequencies ranging from 12.50 percent in the Bocsig population to 37.03 percent in the Ususău population. Most populations had values of 10-15 and 15-20 percents, respectively, five populations recorded percentages over 20 and two populations presented values

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below 10 percent. Regarding the number of medium fruits, an amplitude of 25.29 percent was observed with values from 51.27 percent for the Ususău population to 76.56 percent for the Olari population. Most populations (14) recorded frequencies of 60-70 percents, while six populations exceeded 70 percent. The number of large fruits recorded a smaller variation with limits from 3.92 percent for the Seleuş population, to 19.89 percent for the Lipova TF population. For ten populations the frequency of large fruits was below 10 percent, for 11 populations it was 10-15 percent and only three populations had frequencies of 15-20 percent. All populations presented a significantly higher proportion of medium fruits compared to the other two categories, which were significantly equal.

Table 4. Percentage of fruits categories for rosehip populations in 2024

No.	Population	% fruits categories (FW)			% fruits categories (FN)		
		Small	Medium	Large	Small	Medium	Large
1	Gurba	14.02 b	63.86 a	22.12 b	21.18 b	66.47 a	12.35 b
2	Seleus	14.10 b	79.74 a	6.16 b	20.63 b	75.46 a	3.92 b
3	Zimandu Nou	16.39 b	69.90 a	13.71 b	25.09 b	67.42 a	7.49 b
4	Sebis	19.91 b	62.77 a	17.32 b	26.55 b	61.06 a	12.39 b
5	Lipova TF	22.42 b	52.67 a	24.91 b	28.41 b	51.70 a	19.89 b
6	Lipova	30.60 b	50.01 a	19.39 b	36.40 b	48.25 a	15.35 b
7	Ususau	29.65 b	52.76 a	17.59 b	37.03 b	51.27 a	11.71 b
8	Patars	15.48 b	73.64 a	10.88 b	26.15 b	66.85 a	7.01 b
9	Bacaul de Mijloc	17.64 b	71.61 a	10.75 b	27.93 b	65.84 a	6.23 b
10	Capalnas	16.55 b	63.53 a	19.92 b	24.02 b	62.46 a	13.51 b
11	Cermei	20.05 b	67.91 a	12.04 b	29.56 b	62.77 a	7.66 b
12	Vladimirescu	15.51 b	70.86 a	13.63 b	17.16 b	75.25 a	7.59 b
13	Beliu	14.90 b	71.57 a	13.53 b	20.77 b	69.37 a	9.86 b
14	Ineu	9.34 b	72.90 a	17.76 b	14.59 b	72.60 a	12.81 b
15	Olari	8.98 b	77.11 a	13.91 b	14.29 b	76.51 a	9.21 b
16	Bocsig	8.73 b	75.49 a	15.78 b	12.50 b	76.10 a	11.40 b
17	Buteni	19.10 b	72.41 a	8.49 b	25.96 b	68.59 a	5.45 b
18	Siria	11.59 b	69.77 a	18.64 b	18.05 b	69.55 a	12.41 b
19	Chesinţ	16.45 b	63.13 a	20.42 b	22.83 b	62.60 a	14.57 b
20	Almas	11.19 b	73.33 a	15.48 b	17.58 b	72.41 a	10.01 b
21	Zabrani	14.37 b	64.78 a	20.85 b	22.41 b	63.10 a	14.48 b
22	Brazi	14.05 b	72.58 a	13.37 b	22.74 b	69.68 a	7.58 b
23	Arad	13.74 b	60.40 a	25.86 b	20.20 b	59.93 a	19.87 b
24	Fantanele	12.38 b	69.74 a	17.88 b	19.47 b	68.32 a	12.21 b

FW- Percentage of the total fruits weight; FN- Percentage of the total fruits number
Means with different letters (in the row) are significantly different at $p<0.05$

Based on Figure 1, it can be seen that first two principal components explain 95.6 percent of the variability in the number and weight of small fruits. Populations Bocsig, Ineu, Olari, Zimandu Nou, Vladimirescu showed the highest values of the number and weight of small fruits under the favorable conditions of 2023 associated with the lowest values recorded in 2024.

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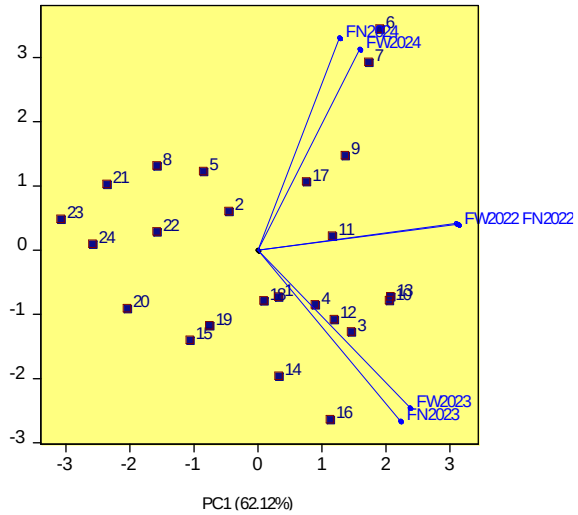

Figure 1. Biplot of first two principal components for the variation of small fruits

Populations Lipova and Ususau showed good adaptation to the less favorable conditions in 2024, recording the highest values for the two traits, against the background of the lowest values in 2023. Populations Bacaul de Mijloc, Buteni and Cermei achieved the highest values in 2022 and 2024, associated with average values for 2024. Populations Lipova TF, Patars, Seleus, Zabrani, Brazi had values above the average of 2024 and values slightly below the average of 2022-2023. Depending on the angle between the vectors of the different characters, it is observed that the strongest correlation is found between the number and weight of fruits in 2022, while in 2024 the association of the two traits was significant but lower than in 2022.

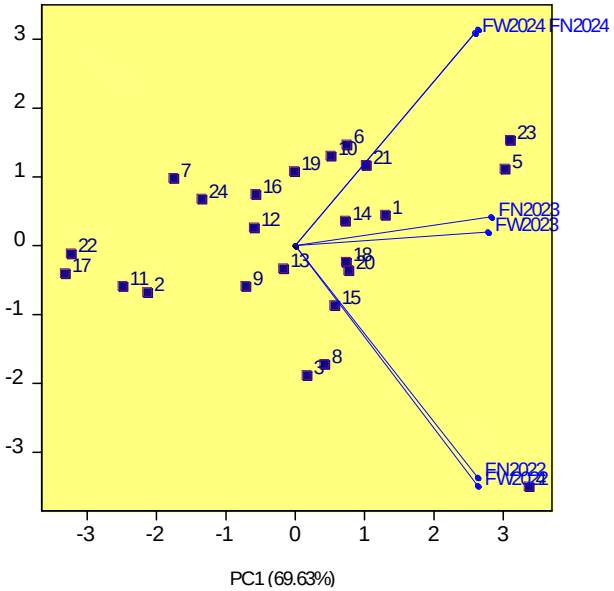

Figure 2. Biplot of first two principal components for the variation of large fruits

For large fruits, approximately 95.86 percent of the variation in number and weight can be explained by the first two principal components (Figure 2). Populations 23 and 5 were highlighted by the highest values in the period 2023-2024 correlated with values close to the average for the year 2022. In the case of populations 3, 8 and 15 the highest values recorded in the year 2022 were associated with average values for the year 2023 and respectively low values in 2024. The weight and number of large fruits in populations 22, 17, 11 and 2 presented the lowest values in 2023, against the background of values close to the average for 2022 and 2024. The link between the two traits was very close during the study period, so that in 2024 the strongest correlation between the number and weight of large fruits was manifested.

The large variation of fruit size during the study indicates a major influence of environmental and especially climatic conditions, a fact also reported by several studies [25, 27]. The identified variability among

the studied rosehip populations can be used to select desirable clones regarding the morphological quality of fruits [9]. Even the differences between the recorded values are caused by several factors; the genotype x environment interaction plays an important role [19]. The diversity within the natural rosehip populations highlights the importance of research and conservation in order to preserve the genetic diversity and benefits of rosehip [20].

Conclusions

The variation of climatic conditions had the highest influence on fruit size in populations Bacaul de Mijloc, Vladimirescu, Bocsig, where the proportion of large fruits as a percentage of the total fruits weight was considerably reduced, and in populations Gurba, Beliu, Bocsig as a percentage of the total fruits number. Populations Lipova, Ususau, Arad, Lipova TF, Zabrani showed the best tolerance to the unfavorable climatic conditions of 2024 in terms of their effect on the percentage of large fruits. In the case of populations Ususau, Chesint, Arad, Lipova, Fantanele, the number of large fruits presented the best stability during the study period. The production of large fruits in populations Bocsig, Beliu, Ineu Zimandu Nou showed a high genotype-environment interaction. In the case of the number of large fruits, the effects of the genotype-environment interaction were lower than in the case of fruit weight, due to large variations in the number of large fruits in populations Sebis, Patars and Zimandu Nou. Populations that showed good fruit size stability during the study period will be analyzed to determine the fruit content of various active compounds.

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