Contribuţii Botanice – 2025, LX: 7-17 DOI: 10.24193/Contrib.Bot.60.1
Grădina Botanică "Alexandru Borza"
Cluj-Napoca

GENETIC VARIATION OF SOME QUANTITATIVE AND QUALITATIVE CHARACTERISTICS OF SORRELS GERMPLASM

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Abstract: Sorrels (*Rumex* spp.) from Polygonaceae have been utilized as medicinal plants or vegetable crops and inhabit in some areas of America, Asia and Europe as native or introduced plants. The target of the current investigation was to evaluate the genetic variation of 54 accessions of various species, including *R. alpinus, R. kerneri, R. obtusifolius, R. patientia, R. pseudonatronatus, R. pulcher, R. rugosus, R. scutatus* and *Rumex* spp. The plant materials from German IPK's gene bank (44 accessions) or various geographical areas of Iran (10 accessions), were evaluated in two separate trials, and 24 morphologic quantitative and qualitative characteristics were recorded. The coefficient of variation was very high for all measured traits across both trials whereas fresh and dry weight of leaves ranged from 20.3 to 210.1 g and from 2.7 to about 15.0 g, respectively. The factor analysis revealed four factors; leaf size, leaf number, leaf weight and the petiole length in the first trial while it identified leaf size, leaf weight blade width and the petiole length as important factors in the second trial, thus the importance of leaf size, leaf weight and the petiole length was confirmed at both trials. Also, the factor analysis of qualitative traits indicated five factors; anthocyanin blade and vein, leaf appearance, blade and the petiole properties, anthocyanin of the petiole and the midrib of the petiole. These consistent patterns affirm the reliability of trait-based factor analysis and underscore the potential of identified traits for use in genetic improvement and breeding programs. The study highlights the significant morphological diversity within sorrel germplasm, offering valuable insights for cultivar development and conservation strategies.

Keywords: factor analysis, eigen values, genetic diversity, morphologic traits

Introduction

Taxonomy

The dock or sorrel (*Rumex* spp.) is among the valuable plants of the Polygonaceae family, which has more than 200 species and is distributed in most parts of the world. Iran is also considered one of the distribution areas of this plant and has some species of this genus [2, 4]. Some species of this genus are erect plants, with fleshy and leather-like leaves emerging from the root base. Many species of sorrels are used as vegetables, medicinal plants, or for industrial purposes Cultivation of *Rumex hymenosepalus* species in South America is performed for extraction of tannin from the roots for use in the leather industry [5, 21]. The leaves and stems of sorrels are also used in dyeing to stabilize the color. Also, the species of this genus are rich in metabolites of ascorbic acid, oxalic acid, phenolic acid, flavonoid compounds, phenolic compounds, anthraquinone, naphthalene, sterols and triterpenes, etc. The important anthraquinone of emodin is produced in many species of this genus in their roots, seeds, leaves, stems and flowers [11, 20]. Therefore, it will be important to identify and choose a suitable species or modify and introduce a variety of this valuable plant. In plant breeding, the first step is to select the most suitable individuals [15], so it is necessary to first collect and evaluate the genetic material, and then apply the proper breeding methods to it.

Morphological Characteristics

Due to the importance of this plant, studies have been conducted in various fields to investigate genetic diversity. Raycheva et al. [14] have indicated that the taxonomically morphologic characteristics for the genus *Rumex* like size and number of spines can be found in mature plants. Their recognition guide is based on visible characteristics that are clear and dependable for recognizing the three subspecies. The information about how the plant habitus, the shape of its bottom leaves, and the type of covering on it is thought to be infallible for this goal. The taxonomic assessing of *R. pulcher* has verified the existence of three subspecies; *pulcher*, *woodsii* and *raulinii* in Bulgaria so, morphological investigation as well as genome evaluation have detected the more varying place of subspecies *woodsii* from the others [14]. Also, the morphological characteristics of the fruit of 23 species of sorrel in Iran were studied and it was found that the morphological characteristics of the fruit alone cannot separate the subspecies [16]. To reveal the relationship of *Rumex* species, morphological characters of fruit including achene features were investigated in 23 species of sorrel in Iran [16], and all taxa have trigonous achene but their size and color are different and the classification of the genus *Rumex* into three subgenera is rejected.

Genetic Studies

Research was conducted on the morphological characteristics of two species of sorrel, *R. patientia* and *R. confertus*, which shows that these two species have similar morphological characteristics, but the ecological and altitude niches of these two species are different from each other, which can be a reason for hybridization in the subgenus of sorrel [7]. Also, in the study conducted on the morphological characteristics of Alpine sorrel (*R. alpinus*), it was found that this plant has a rhizome that is preserved in the soil for 5 to 15 years, therefore, this plant can be used as a suitable model for population studies, because information about the historical events preserved in their rhizome and remains as registered morphological markers [17]. The classification of *Rumex* subspecies is done based on their morphological and anatomical features and their chromosome number, but due to polyploidy and introgression in *Rumex* subspecies, there is natural hybridization, so, during evolution, the diversity in morphological traits decreases [6, 8]. Therefore, there is no acceptable taxonomic model for defining subspecies in this genus.

The taxonomic relationship of 20 accessions of *Rumex* spp. including *patientia*, *cristatus*, *confertus* and *valpinus* with 5 native Bulgarian accessions from *pulcher* species was investigated with ISSR markers showed that the studied species were clustered in two main groups, group one includes *cristatus*, *patinetia* and *confertus* species, while group two includes *alpinus* and *pulcher* species [19]. The genetic variation of some genotypes of five species of *Rumex*, were assessed using morphological traits and results indicated that the highest coefficient variation was found in fresh and dry yield of leaves and leaf number [2].

Biochemical Studies

It was found phenol and antioxidants were higher in *R. crispus* than in other species while *R. tuberosus* indicated lower amounts in the measured morphologic and chemical characteristics in comparison to the studied other species [2]. Considering the widespread distribution of this plant in Iran and the importance of this valuable plant, there is a need for further investigation because by studying the morphological diversity of internal and external populations, the positive characteristics of each population can be investigated and finally, the best parents can be selected for crossing, to improve this plant. This research aims to determine the genetic diversity in some sorrel plant accessions using morphological markers, which can be an effective help in the breeding process and explanation of the interrelations of the accessions.

Materials and Methods

Plant Materials

In this study, the seeds of 54 sorrel accessions were used, 10 of which were collected from various geographical areas of Iran and 44 of which were taken from the gene bank of Leibniz Institute of Plant Genetics and Crop Plant Research (IPK), Gatersleben, Germany. The name, species and donor of these accessions are given in Table 1. They were from various species including *R. alpinus*, *R. kerneri*, *R. obtusifolius*, *R. patientia*, *R. pseudonatronatus*, *R. pulcher*, *R. rugosus*, *R. scutatus* and *Rumex spp*. The sorrel accessions were cultivated in two separate trials based on the form of a completely randomized design with three repetitions in pots with a diameter of 30 cm in the controlled greenhouse conditions at 12/12 hours day/night and a temperature of 25/15 degrees Celsius. The cultivation bed consisted of one part of soil, two parts of sand and one part of organic manure. After filling the pots and preparing them, the seeds were planted inside each pot, and irrigation and weeding operations were done regularly during the growth period.

Experimental Design

Some of the quantitative characteristics of the sorrel accessions were measured based on the proposed descriptor of Mohebodini et al. [12] as: blade length (BL), blade width (BW), lamina area (LA), the petiole length (PL), the petiole diameter (PD), number of veins (NV), number of leaves (NL), leaf length (LL), number of plantlets (NP), chlorophyll of leaf (Chl), fresh weight of leaves (FW), and dry weight of leaves (DW). These traits were measured by a sensitive lab caliper, leaf area meter device, sensitive lab-scalar and chlorophyll content meter CCM-200. Also, some of the qualitative characteristics of the sorrel accessions were recorded according to scoring guide of Table 2, as; baled text (BT), leaf shape (LS), the petiole stance (PS), undulate blade (UB), blade color (BC), stipule of leaf (SL), blade apex (BA), the petiole color (PC), anthocyanin of blade (AB), the midrib of the petiole (MP), anthocyanin of vein (AV), and anthocyanin of the petiole (AP).

Table 1: Name and donor origin of 54 *Rumex* spp. accessions.

Code	Species	Name	Donor	Code	Species	Name	Donor
1	*Rumex* spp.	Kashmar	Iran	28	*Rumex rugosus* Campd.	Kerti	IPK
2	*Rumex* spp.	Marand	Iran	29	*Rumex patientia* L.	unnamed	IPK
3	*Rumex* spp	Ardabil	Iran	30	*Rumex rugosus* Campd.	unnamed	IPK
4	*Rumex* spp.	Hour	Iran	31	*Rumex pulcher* L.	unnamed	IPK
5	*Rumex* spp.	Nier	Iran	32	*Rumex rugosus* Campd.	unnamed	IPK
6	*Rumex* spp.	Namin	Iran	33	*Rumex patientia* L.	unnamed	IPK
7	*Rumex* spp.	Khalkhal	Iran	34	*Rumex alpinus* L.	unnamed	IPK
8	*Rumex* spp.	Dezfol	Iran	35	*Rumex rugosus* Campd.	Belvilskij	IPK
9	*Rumex* spp.	Ahwaz	Iran	36	*Rumex patientia* L.	unnamed	IPK
10	*Rumex* spp.	Shiraz	Iran	37	*Rumex rugosus* Campd.	unnamed	IPK
11	*Rumex rugosus* Campd.	Von Belleville	IPK	38	*Rumex rugosus* Campd.	unnamed	IPK
12	*Rumex rugosus* Campd.	unnamed	IPK	39	*Rumex rugosus* Campd.	unnamed	IPK
13	*Rumex rugosus* Campd.	GroBblatriger	IPK	40	*Rumex pseudonatronatus* Murb	unnamed	IPK
14	*Rumex rugosus* Campd.	unnamed	IPK	41	*Rumex rugosus* Campd.	unnamed	IPK
15	*Rumex rugosus* Campd.	unnamed	IPK	42	*Rumex scutatus* L.	unnamed	IPK
16	*Rumex rugosus* Campd.	unnamed	IPK	43	*Rumex rugosus* Campd.	unnamed	IPK
17	*Rumex rugosus* Campd.	unnamed	IPK	44	*Rumex obtusifolius* L.	unnamed	IPK
18	*Rumex rugosus* Campd.	unnamed	IPK	45	*Rumex kerneri* Borbas	unnamed	IPK
19	*Rumex rugosus* Campd.	unnamed	IPK	46	*Rumex patientia* L.	unnamed	IPK
20	*Rumex rugosus* Campd.	unnamed	IPK	47	*Rumex patientia* L.	unnamed	IPK
21	*Rumex rugosus* Campd.	Sirokolistnyi	IPK	48	*Rumex patientia* L.	unnamed	IPK
22	*Rumex rugosus* Campd.	GroBblatriger	IPK	49	*Rumex obtusifolius* L.	unnamed	IPK
23	*Rumex rugosus* Campd.	unnamed	IPK	50	*Rumex obtusifolius* L.	unnamed	IPK
24	*Rumex rugosus* Campd.	unnamed	IPK	51	*Rumex patientia* L.	unnamed	IPK
25	*Rumex rugosus* Campd.	unnamed	IPK	52	*Rumex alpinus* L.	unnamed	IPK
26	*Rumex rugosus* Campd.	unnamed	IPK	53	*Rumex alpinus* L.	unnamed	IPK
27	*Rumex rugosus* Campd.	unnamed	IPK	54	*Rumex patientia* L.	unnamed	IPK

Statistical Analyses

The normal distribution shape of measured traits in sorrel accessions was assessed via the Shapiro-Wilk procedure with the Normality menu in Minitab application ver. 17.0 (Minitab Inc., USA). Factor analysis was performed to uncover patterns and interrelationships among the measured traits. This multivariate technique is particularly valuable for decreasing many associated variables into a small set of unassociated factors, thus simplifying the interpretation of complex trait relationships. The factor analysis employed varimax rotation to enhance the interpretability of the factor structure. Only factors with eigenvalues greater than one were retained and considered significant. This analysis was conducted using Statistica software version 14.0 (TIBCO Inc., USA). Communalities were also computed to assess the proportion of variance in each trait explained by the extracted factors, thereby highlighting traits that contribute most significantly to the observed variability among genotypes.

Table 2: The scoring guide of qualitative traits of *Rumex* spp. accessions.

Trait	Code	Trait	Code	Trait	Code
Leaf Shape		**Blade apex**		**Midrib of petiole**	
Circle	1	Circle	1	Smooth with depth	1
Oval	2	Oval-circle	2	Smooth withuot depth	2
Egg shape	3	Oval	3	rough with depth	3
Heart shaped	4	Half drawn	4	rough withuot depth	4
Triangular	5	Drawn	5		
Half drawn	6				
Drawn	7	**Petiole stance**		**Blade color**	
		Erect	1	Light green	1
Anthocyanin of blade		Semi-erect	2	Dark green	2
Existence	1	Curved petiole	3	Midnight blue	3
Non-existence	2				
		Stipule of leaf		**Petiole color**	
Anthocyanin of vein		Existence	1	Light green	1
Existence	1	Non-existence	2	Dark green	2
Non-existence	2				
		Undulate blade		**Baled text**	
Anthocyanin of petiole		Existence	1	Smooth	1
Existence	1	Non-existence	2	Semi-wrinkled	2
Non-existence	2			wrinkled	3

Results and Discussion

According to descriptive indices (Table 3), the magnitudes of coefficient of variation (CV) were very high (>100%) for all measured traits of sorrel accessions in both trials except number of leaves (NL) and number of plantlets (NP). Thus, the genetic variation of sorrel accessions was high and can be used to achieve a favorable combination of traits. Similarly, Mohebodini et al. [12] reported high CV values for most morphologic traits of sorrel accessions except number of leaves. The fresh weight of leaves (FW) ranged from 32.2 to 210.1 g in the first trial, and increased from 20.3 to 197.6 g in the second trial. Also, the dry weight of leaves (DW) ranged from about 3.4 to about 15.0 g in the first trial, and increased from 2.7 to 14.3 g in the second trial. Bourang et al. [2] evacuated 14 populations of *Rumex* species from two provinces of Iran in the greenhouse conditions and reported 1.28 to 92.0 g for fresh weight of leaves with CV equal 76% while founding 0.46 to 9 g for the dry weight of leaves with CV equal 72%. However, the range of variation, as well as CV values of current sorrel accessions, were more than the previous reports due to their international widespread characteristics and number of studied accessions.

The factor analysis revealed that the first four eigenvalues exceeded unity, collectively explaining 84.8% of the observed variance in the first trial (Table 4). The first factor, which explained 42.2% of the variability, encompassed blade length (BL), lamina area (LA), number of veins (NV) and leaf length (LL), suggesting a focus on leaf size in the first trial. Conversely, the second factor, which described for 19.5% of the overall variation, displayed high values for number of leaves (NL), number of plantlets (NP) and chlorophyll of leaf (Chl) traits so this indicates a preference for leaf number within this factor (Table 4). The third factor, explaining

12.0% of the variance, comprised fresh weight of leaves (FW) and dry weight of leaves (DW) traits, leading to the designation of leaf weight for this factor in the first trial (Table 4). Meanwhile, the fourth factor, which explained for 11.1% of the detected variability, included the petiole length (PL) trait, hence it was labeled as the petiole length factor. In terms of communalities, BL, LA, PL, LL, FW and DW traits of the sorrel accessions demonstrated good reliability, underscoring their genetic consistency based on the results of the first trial. Erfani et al. [3] used factor analysis for the evaluation of some sorrel accessions and found three factors explain about 51% of the total variance among traits, the first factor accounted 25% of the identified variation related to leaf and the petiole traits, the second factor described 15% of the variation related to the number of plantlets and chlorophyll content, and the third factor explained 11% of the observed variance and associated to some qualitative traits of sorrel.

Table 3: Descriptive statistics of quantitative traits of *Rumex* spp. accessions.

Trial-I	Mean	SEM	SD	Median	Minimum	Maximum	CV
BL	21.67	0.590	9.70	19.0	6.00	63.00	223.4
BW	6.56	0.165	2.72	6.0	1.83	16.83	241.4
LA	105.13	1.881	30.91	104.4	23.04	209.34	340.1
PL	17.11	0.391	6.43	16.8	4.00	39.00	266.3
PD	4.37	0.114	1.87	4.0	0.83	13.39	234.5
NV	29.36	0.910	14.96	26.0	3.00	88.00	196.3
NL	22.17	1.714	28.17	12.0	0.05	205.00	78.7
LL	37.43	0.721	11.85	36.3	12.00	77.00	315.9
NP	2.30	0.176	2.89	1.0	0.05	12.00	79.6
Chl	32.01	0.563	9.26	30.4	13.70	60.20	345.7
FW	84.76	1.923	31.60	81.6	32.23	210.10	268.2
DW	6.85	0.124	2.04	6.7	3.38	14.94	336.3
Trial-II	**Mean**	**SEM**	**SD**	**Median**	**Minimum**	**Maximum**	**CV**
BL	21.75	0.561	9.22	19.0	6.50	54.00	236.0
BW	6.54	0.153	2.51	6.0	2.00	15.50	260.9
LA	109.39	2.162	35.53	105.6	21.33	230.84	307.9
PL	17.42	0.387	6.37	17.0	5.00	42.00	273.6
PD	4.54	0.100	1.64	4.3	1.18	10.71	276.6
NV	29.40	0.899	14.78	26.0	3.00	86.00	198.9
NL	21.81	1.790	29.41	11.5	4.00	265.00	74.2
LL	37.37	0.685	11.26	36.8	10.00	86.00	331.9
NP	2.10	0.152	2.49	1.0	0.06	10.00	84.0
Chl	31.45	0.490	8.05	30.1	16.70	55.30	390.5
FW	89.34	2.579	42.38	82.3	20.31	197.65	210.8
DW	7.16	0.167	2.74	6.7	2.69	14.33	260.9

SEM, Standard error of mean; **SD**, Standard deviation. **Abbreviation of traits:** blade length (BL), blade width (BW), lamina area (LA), the petiole length (PL), the petiole diameter (PD), number of veins (NV), number of leaves (NL), leaf length (LL), number of plantlets (NP), chlorophyll of leaf (Chl), fresh weight of leaves (FW), and dry weight of leaves (DW).

Table 4: Scores of factor analysis for quantitative traits of *Rumex* spp. accessions.

Trial-I	F1	F2	F3	F4	Comm.†
BL	0.91	-0.11	-0.07	-0.26	0.90
BW	0.18	-0.78	0.14	0.28	0.74
LA	0.66	-0.67	0.24	0.03	0.94
PL	-0.03	0.03	-0.08	0.95	0.92
PD	0.80	-0.18	-0.02	0.17	0.70
NV	0.82	-0.06	-0.23	-0.38	0.86
NL	-0.55	0.57	0.33	-0.09	0.75
LL	0.91	-0.07	-0.16	0.27	0.94
NP	-0.50	0.61	0.31	0.25	0.79
Chl	0.11	0.78	-0.07	0.27	0.69
FW	-0.11	-0.05	0.98	-0.03	0.97
DW	-0.12	-0.05	0.98	-0.03	0.97
Eigenvalues	5.06	2.34	1.44	1.33	
% of Variance	42.2	19.5	12.0	11.1	
Cumulative %	42.2	61.7	73.7	84.8	
Trial-II	**F1**	**F2**	**F3**	**F4**	**Comm.**
BL	0.89	0.18	0.02	-0.28	0.90
BW	0.15	0.11	0.81	0.12	0.71
LA	0.65	0.55	0.48	-0.05	0.96
PL	-0.06	0.11	-0.03	0.97	0.96
PD	0.64	0.30	0.45	0.14	0.72
NV	0.91	-0.06	-0.11	-0.26	0.88
NL	-0.64	0.16	-0.50	-0.14	0.71
LL	0.89	0.20	0.03	0.25	0.90
NP	-0.53	0.09	-0.46	0.44	0.69
Chl	0.10	0.01	-0.71	0.23	0.56
FW	0.08	0.98	0.02	0.08	0.98
DW	0.08	0.98	0.03	0.08	0.98
Eigenvalues	4.91	2.31	1.51	1.22	
% of Variance	40.9	19.2	12.6	10.2	
Cumulative %	40.9	60.2	72.8	83.0	

†Communalities

Abbreviation of traits: blade length (BL), blade width (BW), lamina area (LA), the petiole length (PL), the petiole diameter (PD), number of veins (NV), number of leaves (NL), leaf length (LL), number of plantlets (NP), chlorophyll of leaf (Chl), fresh weight of leaves (FW), and dry weight of leaves (DW).

In the second trial, the factor analysis indicated that the first four factors had eigenvalues more than unity, described collectively 83.0% of the total variability (Table 4). The first factor described 40.9% of the variance, was similar to the first factor of the first trial and consisted of

BL, LA, NV and LL, so named as leaf size. However, the second factor, which explained 19.2% of the variability, demonstrated high values for (FW) and dry weight of leaves (DW) traits so this proved a preference for leaf weight in this factor (Table 4). The third factor, describing 12.6% of the observed variance, related to blade width (BW), leading to the designation of blade width for this factor in the second trial (Table 4). Finally, the fourth factor, which explained 10.2% of the variation, was similar to the first trial and included the petiole length (PL), so it was named as the petiole length factor. The communalities of the second trial were the same as the first trial and identified BL, LA, PL, LL, FW and DW as the most influencing traits in the variation of current sorrel germplasm. A comparison of two trials indicates that three factors, leaf size, leaf weight and the petiole length, were confirmed in both experiments while two factors, leaf number and blade width, were not verified across both trials. Munir et al. [13] studied the morphological traits in *Rumex dentatus* from four regions of Pakistan and found that the first principal component contributed 80% of total variation while the second principal component contributed 13% of observed variability and they were named as weight and aera of leaf as well as inflorescence factors, respectively. Thus, the importance of leaf size and leaf weight in morphologic variation among sorrel accessions is emphasized in previous reports.

Table 5: Scores of factor analysis for qualitative traits of *Rumex* spp. accessions.

	F1	F2	F3	F4	F5	Comm.†
BT	0.06	0.01	-0.87	0.06	0.05	0.76
LS	-0.22	0.88	-0.08	-0.02	-0.02	0.84
PS	-0.57	0.51	0.09	0.07	-0.12	0.62
UB	0.13	-0.26	0.55	-0.56	-0.15	0.73
BC	0.16	-0.60	0.27	0.28	-0.51	0.81
SL	-0.84	0.19	-0.05	0.09	0.11	0.76
BA	-0.14	0.86	-0.03	0.13	-0.12	0.80
PC	0.27	-0.06	0.66	0.21	0.35	0.69
AB	0.74	-0.20	0.32	-0.03	-0.13	0.71
MP	-0.18	-0.13	0.09	-0.06	0.88	0.83
AV	0.75	-0.07	-0.07	0.40	-0.13	0.74
AP	0.06	-0.01	0.06	0.86	-0.12	0.74
Eigenvalues	3.68	1.85	1.40	1.07	1.03	
% of Variance	30.7	15.4	11.7	8.9	8.6	
Cumulative %	30.7	46.1	57.8	66.7	75.2	

†Communalities

Abbreviation of traits: baled text (BT), leaf shape (LS), the petiole stance (PS), undulate blade (UB), blade color (BC), stipule of leaf (SL), blade apex (BA), the petiole color (PC), anthocyanin of blade (AB), the midrib of the petiole (MP), anthocyanin of vein (AV), and anthocyanin of the petiole (AP).

The factor analysis of qualitative properties (Table 5) demonstrated that the first five factors indicated eigen-values larger than unity, and accounted for 75.2% of the variation. The first factor described 30.7% of the variability, consists of anthocyanin of blade (AB) and anthocyanin of vein (AV), so named as anthocyanin blade and vein. The second factor, which accounted for 15.4% of the total variance, indicated high values for leaf shape (LS), the petiole stance (PS) and blade apex (BA) traits so this proved a preference for leaf appearance in the current factor (Table 5). The third factor, describing 11.7% of the identified variance, related to undulate blade (UB) and the petiole color (PC), leading to the designation of blade and the petiole characteristics for this factor. The fourth factor, which explained 8.9% of the variation, included anthocyanin of the petiole (AP), so it was named as the anthocyanin of the petiole. Finally, the fifth factor, which described 8.6% of the identified variance, included the midrib of the petiole (MP), so was named as the midrib of the petiole factor. The communalities of the qualitative traits identified almost all of the measured qualitative traits as the most influencing characteristics in the variation of current sorrel germplasm. Erfani et al. [3] employed factor analysis for analyzing some qualitative traits of sorrel accessions and showed, that the first factor is related to the petiole stance and blade apex traits, the second is associated with the anthocyanin of blade and vein, and the third factor is related to stipule of leaf. Thus, the importance of anthocyanin of blade, anthocyanin of vein, the petiole stance and blade apex are confirmed among the measured qualitative traits of sorrel accessions.

The studied sorrel accessions showed significant differences in many of the measured traits, especially the yield performance and its components. From the aspect of vegetable crops, this plant can be regarded as having a high number of leaves and leaf size, so it has a good economic potential for cultivation. A few cultivars of *Rumex* spp. are available, such as Profusion which is released three decades ago with dark green color and round leaf shape [9]. Also, the number of plantlets in the plant and the high amount of chlorophyll will help to increase biomass production. According to the association between the leaf length and the petiole diameter, it can be used to select stable parents in the breeding programs. Therefore, the assessing of morphological traits was able to distinguish current sorrel accessions in distinct groups based on the differences in some quantitative and qualitative characteristics, which was a very suitable criterion for grouping these genotypes. Sorrel is an undomesticated crop with high potential for using as vegetable crop and medicinal plant [18], so, *Rumex* spp. need more attention in future investigations, in agronomy and plant breeding [10]. Such efforts will increase more interest in sorrel production and commercial use. The study did not find any strong association between the genetic variation and the geographical origin of the genotypes, so that the genotypes from different regions were placed in the same category. This lack of relationship is probably the result of the free transfer of pollen from one place to another. Since, relatively few reports have been published on the morphological and vegetative characteristics of sorrel accessions, it can be expected that the results of this investigation will be important in future research on sorrel species. Sorrel is a healthy crop which has a clear value and can be produced many areas. Genetic improvement could be performed to develop promising high-yielding cultivars, with low oxalic acid [1]. Regarding medicinal aspects of sorrel, it is obvious that more studies are required on chemical compounds to demonstrate its real impact and find reliable confirmation for the medicinal impacts of sorrel and to help the generate of new cultivars for industrial utilization.

Conclusions

The results of this study revealed substantial genetic diversity among sorrel accessions, as evidenced by the high coefficients of variation across two trials. Factor analysis of both quantitative and qualitative traits highlighted the importance of leaf size, leaf weight, and petiole characteristics in explaining morphological variation. The consistent identification of major factors and the high proportion of accessions grouped similarly in both trials indicate the robustness and reliability of trait-based classification. These findings underscore the potential of the studied sorrel germplasm for use in future breeding programs targeting desirable leaf morphology and biomass traits.

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VARIAȚIA GENETICĂ A UNOR CARACTERISTICI CANTITATIVE ȘI CALITATIVE ALE GERMOPLASMEI DE MĂCRIȘ

(Rezumat)

Speciile de măcriș (*Rumex* spp.) din familia Polygonaceae au fost utilizate de-a lungul timpului ca plante medicinale sau legumicole și se găsesc în unele zone din America, Asia și Europa ca plante native sau introduse. Scopul actualei investigații a fost evaluarea variației genetice a 54 de probe de la diferite specii, inclusive *R. alpinus, R. kerneri, R. obtusifolius, R. patientia, R. pseudonatronatus, R. pulcher, R. rugosus, R. scutatus* și *Rumex* spp. Materialele vegetale din banca germană de gene IPK (44 de probe) sau din diverse zone geografice ale Iranului (10 probe) au fost evaluate în două studii separate și au fost înregistrate 24 de caracteristici morfologice cantitative și calitative. Coeficientul de variație a fost foarte mare pentru toate trăsăturile măsurate în ambele studii, în timp ce greutatea proaspătă și uscată a frunzelor a variat de la 20,3 la 210,1g și, respectiv, de la 2,7 la aproximativ 15,0g. Analiza factorială a relevat patru factori: dimensiunea frunzelor, numărul frunzelor, greutatea frunzelor și lungimea pețiolului pentru primul studiu și dimensiunea frunzei, greutatea frunzei, lățimea limbului și lungimea pețiolului pentru al doilea studiu. Astfel, importanța dimensiunii frunzei, greutății frunzei și lungimii pețiolului a fost confirmată în ambele studii. De asemenea, analiza factorială a trăsăturilor calitative a indicat cinci factori: antocianii din limb și nervură, aspectul frunzei, proprietățile limbului și pețiolului, antocianii pețiolului și nervura mediană a pețiolului. Aceste modele consistente confirmă fiabilitatea analizei factoriale bazate pe trăsături și subliniază potențialul trăsăturilor identificate pentru utilizarea în programele de ameliorare genetică și înmulțire. Studiul evidențiază diversitatea morfologică semnificativă din cadrul germoplasmei de măcriș, oferind informații valoroase pentru dezvoltarea de soiuri noi și pentru strategiile de conservare.

Received: 28.01.2025; Accepted: 30.07.2025