

Multivariate analysis of *Rosa persica* Michx. ex Juss by morphological characters

Ferdous Darabi

Gorgan University of Agricultural Sciences and Natural Resources

Mostafa Khoshhal Sarmast (✉ khoshhal.sarmast@gmail.com)

Gorgan University of Agricultural Sciences and Natural Resources

Hossein Zarei

Gorgan University of Agricultural Sciences and Natural Resources

Seyyed Javad Mousavizadeh

Gorgan University of Agricultural Sciences and Natural Resources

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Abstract

This research evaluated phenotypic diversity among 16 *Rosa persica* accessions collected from their native habitats in Iran. Twenty-two quantitative traits were evaluated in this species based on morphological markers and according to previously described standard methods. An analysis of morphological traits on the accessions revealed significant differences in most of them ($p \leq 0.07$). In addition, the mean comparison showed that the "Neishabor 3" accession had the highest plant height, and the "Arak" accession had the highest flower diameter among the accessions. Principal component analysis revealed five main factors with eigenvalues greater than one, which explained 86.53% of the total variance. Flower weight, petal width, petal length/width ratio, bud length, receptacle width, and receptacle length/width were most distinguishable in the first component. Flower count and receptacle length were most distinguishable in the second component and had the most significant coefficients of determination. Hierarchical cluster analysis placed Bojnord, Neishabor2, Golbahar3, Golbahar4, Neishabor1, and Kashmer accessions in the first cluster. Neishabor3 and Yazd accessions appeared in the second cluster. Since morphological features of native *R. persica* are unavailable, the current research was foundational in exploring notable diversity among *Rosa persica* accessions. The data can be utilized as a valuable source for future *Rose* breeding programs.

Introduction

Rosa persica Michx. ex Juss, syn. *Hulthemia persica* (Michx.) is a perennial plant from the *Rosaceae* family, *Rosidae* subclass, and *Rosales* order. This small, scented, yellow-flowered shrub has short and abundant wooden branches, more or less hairy, white blades, almost egg-shaped leaves with numerous straight spines and curved prickles on the woody stems, and leans over at 50 cm height. The unique rhizomes in this species stand out from other *Rosa* species. This species is commonly distributed in steppes and deserts parts of Kazakhstan, Afghanistan, Central Asia, and southern regions of western Siberia (Basaki et al. 2009; Jafarkhani-Kermani et al. 2010; Ueda et al. 2000). It is mostly distributed in the central and northeastern parts of Iran, bordering the southwest of Turkmenistan and the northwest of Afghanistan (Gahreman 1988). This plant often grows as a weed in crop fields and shows the best growth in sunny areas with alkaline soils. It has also been considered a potential source of resistance to biotic and abiotic stresses in *Rosa* species (Basaki et al. 2009).

Despite the importance of this germplasm in breeding programs, little is known about its genetic and morphological diversity (Basaki et al. 2009). Considering its wide geographic distribution and diverse habitats, this species is rich in genetic diversity. Conservation efforts aimed at native plant species primarily required the appraisal of plant morphological and genetic diversity. Studying germplasm diversity provides distinctness and uniqueness of genotypes as a possible source of unique genes for enhancing cultivar performance in breeding programs (Subudhi et al. 2002). *Rosa persica* has distinct reddish-brown spots in the petal base and is a good candidate for *Rosa* breeding purposes (Jafarkhani-Kermani et al. 2010). In one study, researchers evaluated the phenotypic diversity of Damask rose accessions originating from 21 different geographical regions of Iran, using 36 morphological traits. The highest variation corresponded to petal number, leaf color, leaf stipule, and prickle shape. The highest flower and petal weights were 5.67 and 4.61 g, respectively. Some of the superior accessions were separated from the others in the scatter diagram and were characterized by the highest flower weight, petal weight, and petal count (Khaleghi and Khadivi 2020). In another study, the genetic and phenotypic of 41 wild Damask rose genotypes from different farming regions of Iran (Fars, Kerman, Isfahan, East Azarbaijan, and Razavi Khorasan provinces) and one genotype from Bulgaria were evaluated using 31 RAPD primers and 10 morphological markers. The molecular and morphological markers showed high polymorphism among wild Damask rose genotypes in Iran. They obtained a relatively good correlation ($r = 0.74$) between RAPD marker similarity matrices and morphological markers (Kiani et al. 2007). Amplified fragment length polymorphism (AFLP)-mediated genetic diversity on *R. persica* showed that 48% of *R. persica* genetic variations were within populations and 52% were among them, according to molecular variance analysis. They stated that Iranian rose genotypes are highly variable and genetically different from their origin (Basaki et al. 2009). However, they lacked sufficient information on their morphological diversity.

Material and Methods

Plant materials

In May 2022, 16 wild *Rosa persica* accessions were collected from natural areas in six provinces of Iran, including Markazi, Yazd, Khorasan-e Razavi, Khorasan-e Shomali, Khorasan-e Jonoobi, and Semnan (Fig. 1 and Table 1). The selected populations stretched over 70 km across the country. The climatic parameters of this region were obtained from the Iran Meteorological Organization (Table 2).

Fig. 1

Morphological parameters

Twenty-two standard morphological traits were used for evaluating diversity in this plant species (Khaleghi and Khadivi 2020). Five plants in each population were selected randomly for evaluation. The phenotypic traits under analysis were flower weight, petal weight, flower/petal weight, petal length, petal width, petal length/width ratio, flower count, flower diameter, pedicel length, stem diameter, plant height, bud length, bud width, bud length/width, receptacle length, receptacle width, receptacle length/width, leaf length, leaf width, leaf length/width ratio, lateral shoot count, and lateral flowering shoot count (Fig. 2).

Fig. 2

Statistical analysis

Indicators of variation were determined for morphological traits, including mean, minimum, maximum, standard error (SE), and coefficients of variation (CV%). Pearson's correlation was determined between the traits. To evaluate the collected morphological data, principal component analysis (PCA) was carried out using SPSS (version 21) statistics software. The correlation matrix was generated using mean values per species, and from this matrix, standardized PCA scores were extracted. Subsequently, a scatter plot was conducted on the first two principal components (PCA). PCA was applied to identify the most

important traits in the data set (Khadivi-Khub et al. 2012). Cluster analysis was performed using Ward's methods. The Euclidean distance and a dendrogram were illustrated using SPSS (v.21) software.

Results and discussion

Physical appearance of the species

One of the *Rosa* species that has received much attention in recent years is *Rosa persica* or *Hulthemia persica* (Michx.) which is known as Varak in Iran. This unique plant has yellow-colored petals, with reddish-brown spots at the base of the petals. The plants grow up to 60 cm. *Rosa persica* has different characteristics from other wild species of *Rose*. It has simple leaves without a stipule (a leaf appendage that arises at the base of the petiole). It also forms long underground rhizomes and thus usually grows in colonies that cover large areas sometimes. They grow very well and mostly in sandy saline soils in northeast Iran. They can grow at the EC of 0.7 Desi-Siemens/meter and 3 mg/100gr sodium to EC of 5.4 and 32 mg/100gr sodium.

The characteristics that showed the greatest variation based on 16 plants and 22 quantitative traits considering CV% were plant height, flower count, petal length, petal width, lateral shoot count, and lateral flowering shoot count (Table 3). Bivariate correlations among the *Rosa* traits appear in Table 4. Flower width correlated with petal width ($r = 0.52$), receptacle width ($r = 0.55$), receptacle length/width ($r = 0.59$), leaf length ($r = 0.54$), and lateral shoot count ($r = 0.55$). Petal width positively correlated with bud width ($r = 0.66$), bud length/width ratio ($r = 0.71$), and lateral shoot count ($r = 0.56$). Petal length correlated positively with flower count ($r = 0.62$) and lateral flowering shoot count ($r = 0.70$). Petal width positively correlated with the petal length/width ratio ($r = 0.69$), bud length/width ratio ($r = 0.60$), receptacle width ($r = 0.70$), and lateral shoot count ($r = 0.65$). Flower count correlated with receptacle length ($r = 0.58$), leaf width ($r = 0.80$), and leaf length/width ($r = 0.59$). Bud width positively correlated with bud length/width ratio ($r = 0.80$). Bud length/width ratio positively correlated with receptacle width ($r = 0.78$). The receptacle length positively correlated with the receptacle length/width ($r = 0.71$) and leaf width ($r = 0.69$). Receptacle width correlated positively with leaf width ($r = 0.54$), leaf length/width ratio ($r = 0.54$), and lateral shoot count ($r = 0.70$). The leaf length positively correlated with leaf length and width ($r = 0.66$). Leaf width correlated positively with leaf length and width ($r = 0.56$). Lateral shoot count positively correlated with the lateral flowering shoot count ($r = 0.72$) (Table 4).

Table 1

Table 2

Table 3

Table 4

Principal component analysis

The eigenvalues and cumulative variances explained the first five principal components (Table 5). Up to 86.53 % of the observed variation was explained by the first five components. The first two components explained about 41.53 %. PCA1 described flower weight, petal width, petal length/width ratio, bud length, receptacle width, and receptacle length/width ratio, all of which had a loading coefficient of >0.75 . PCA2 described flower count, receptacle length, and leaf width (loading coefficient > 0.77), accounting for 18.88% of the total variation. PCA3 described petal length, lateral shoot count, and lateral flowering shoot count. PCA4 described petal weight, bud width, and bud length/width. PCA5 described leaf length and leaf length/width, all with loading coefficients of >0.70 . PCA aimed to determine the number of main factors that can be extracted to reduce the number of effective parameters for discriminating genotypes. Morphological characterization continues to be the first step in describing and classifying the germplasm. Statistical methods, such as PCA, help screen accessions per collection (Cantini et al. 1999).

Table 5

Cluster analysis

Hierarchical cluster analysis allowed for distance assessments and clarified relationships among the accessions of the studied species. Initially, a dendrogram with two main clusters was produced (Fig. 3). The first cluster included two subclusters that the first subcluster had, including the accessions of Bojnourd, Neishabor 2, Golbahar 3, Golbahar 4, Neishabor 1, and Kashmar, characterized by flower number, petal width, receptacle length/width ratio, lateral flowering shoot count, and bud length/width ratio. The second sub-cluster included one accession from Shahrod. In addition, accessions of the second cluster appeared in three groups. The first group of this cluster had accessions from Arak, Neishaabor 4, and Birjand. The second group included Neishaabor 3 and Yazd. The third group included Abrovan, Golbahar 2, Golbahar 1, and Shirvan. Henuka et al. (2015) studied morphological diversity in *Rosa* species and reported that cluster analysis divided the species into four different clusters based on the average linkage between groups.

Fig. 3

Scatter plot

A scatter plot was generated using PCA1 and PCA2 scores. It supported cluster analysis results because the accessions are distributed on both sides of the scatterplot (Fig. 4). The accessions in cluster one appeared on the left side (Bojnourd, Neishabor 2, Golbahar 3, Golbahar 4, Neishabor 1, Kashmar, and Shahrood) and the accessions of cluster two appeared on the right side (Arak, Neishabor 4, Birjand, Neishabor 3, Yazd, Abrovan, Golbahar 2, Golbahar 1, and Shirvan). Starting from the positive to the negative values of PC1, these accessions indicated a gradual increase in flower count, flower weight, bud width, receptacle length, receptacle width, leaf length, leaf width, leaf length/width ratio, petal weight, petal length, and petal length/width ratio. From the negative

towards the positive values of PC2 (bottom to upwards), the accessions were characterized by lateral flowering shoot count, lateral shoot count, and receptacle length/width ratio.

Fig. 4

Conclusions

This study revealed considerable morphological diversity among *Rosa persica* accessions growing naturally in Iran. The species showed high variations in plant height, flower count, petal length, petal width, lateral shoot count, and lateral flowering shoot count. Cluster analysis grouped the accessions according to their taxonomic classification and probable potential use. The accessions in these clusters were divided into two sub-clusters. The first cluster included two subclusters. The first subcluster included the accessions of Bojnourd, Neishabor 2, Golbahar 3, Golbahar 4, Neishabor 1, and Kashmar, characterized by flower count, petal width, receptacle length/width, lateral flowering shoot count, and bud length/width. The second sub-cluster included one accession from Shahrood. In addition, the accessions of the second cluster appeared in three groups. Diverse morphological variations occurred among *Rosa persica* germplasms. These morphological features need further details to generate comprehensive knowledge using genetic data. This report is the first published of its kind on the morphological characteristics of this species. To the best of our knowledge, there have been no breeding programs for this species worldwide. Therefore, this germplasm showed good potential as a starting point to prompt a new page in rose breeding programs despite the rare availability of scientific literature on this species.

Declarations

Author contributions All authors contributed to the study conception and design. Material preparation, data collection and analysis were performed by FD, MKS and SJM. The first draft of the manuscript was written by FD and revised by MKS. All authors read and approved the final manuscript.

Conflict of interest The authors declare no competing interests.

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Tables

Table 1 *R. persica* collection sites and their geographical distribution

No.	Province	Collection site	Latitude (N)	Longitude (E)
1	Khorasan-e Razavi	Abravan	36°06'65"	59°91'04"
2	Khorasan-e Razavi	Golbahar 1	36°58'03"	59°20'64"
3	Khorasan-e Razavi	Golbahar 2	36°58'17"	59°09'33"
4	Khorasan-e Razavi	Golbahar 3	36°54'62"	59°19'72"
5	Khorasan-e Razavi	Golbahar 4	36°48'73"	59°99'15"
6	Khorasan-e Razavi	Neishabor 1	36°85'05"	58°48'79"
7	Khorasan-e Razavi	Neishabor 2	36°22'11"	58°99'86"
8	Khorasan-e Razavi	Neishabor 3	36°61'33"	58°54'79"
9	Khorasan-e Razavi	Neishabor 4	36°07'54"	59°42'78"
10	Khorasan-e Razavi	Kashmar	35°48'27"	58°57'35"
11	Khorasan-e Shomali	Shirvan	37°19'05"	57°44'33"
12	Khorasan-e Shomali	Bojnourd	38°05'66"	57°31'38"
13	Khorasan-e Jonoobi	Birjand	32°84'72"	58°95'92"
14	Yazd	Yazd	32°12'78"	54°30'27"
15	Markazi	Arak	34°03'28"	49°39'13"
16	Semnan	Shahrud	36°75'45"	55°03'87"

Table 2 Sixteen accessions of *Rosa persica* from Iran and their climatic parameters

Province-region	Soil Ec	Soil pH	Altitude	ARH	DMT	TP	AT	AmaxT	AminT	Climate
Khorasan-e Razavi Abravan	5.474	8.76	281	32.3	12.5	87	22.4	33.5	11.4	Desert
Khorasan-e Razavi Golbahar 1	1.250	8.08	1085	36.2	10.2	237	18.5	23.5	10.5	<i>Semi-arid warm</i>
Khorasan-e Razavi Golbahar 2	1.220	8.02	1063	36.2	10.2	237	18.5	23.5	10.5	<i>Semi-arid warm</i>
Khorasan-e Razavi Golbahar 3	0.763	7.59	1085	36.2	10.2	237	18.5	23.5	10.5	<i>Semi-arid warm</i>
Khorasan-e Razavi Golbahar 4	0.814	3.32	1500	36.2	10.2	237	18.5	23.5	10.5	<i>Semi-arid warm</i>
Khorasan-e Razavi Neishabor 1	0.963	6.56	1440	39.6	18	265	20.1	24.1	14.6	Moderate climate
Khorasan-e Razavi Neishabor 2	2.055	8.02	1700	39.6	12	265	20.1	24.1	14.6	Moderate climate
Khorasan-e Razavi Neishabor 3	1.693	7.12	1097	39.6	12	265	20.1	24.1	14.6	Moderate climate
Khorasan-e Razavi Neishabor 4	1.412	8.05	1300	39.6	12	265	20.1	24.1	14.6	Moderate climate
Khorasan-e Razavi Kashmar	1.347	7.56	1250	50.5	10.5	210	14.1	18.5	8.7	Moderate climate
Khorasan-e Shomali Shirvan	1.347	7.25	1540	70.3	21	215	12.5	19.8	7.9	<i>Cold semi-arid climate</i>
Khorasan-e Shomali Bojnourd	4.120	8.18	1491	66.8	20	287	13	18.5	6.5	<i>Cold semi-arid climate</i>
Khorasan-e Jonoobi Birjand	3.560	8.01	1216	36.7	7.6	112	18	21	2.3	Desert
Yazd	0.978	8.06	1718	25.1	8.0	68	19.5	32.4	7.6	Warm and dry
Markazi (Arak)	2.147	7.16	2260	46	36	365	13.5	18.6	9.8	Warm Mediterranean
Semnan (Shahroud)	1.853	7.09	1800	41	4.5	365	19	26.6	11.2	Warm and dry

AminT: Average of minimum temperature (°C), AmaxT: Average of maximum temperature (°C), AT: Average of temperature (°C), TP: Total precipitation (mm), DMT: Days with maximum temperature equal 0 and below, ARH: Average of relative humidity (%).

Table 3 Range of variability in Rosa traits, mean, standard deviation (SD), minimum, maximum, and variance

Trait	Unit	Mean	SD	Min	Max	CV (%)
Flower weight	gr	0.2	0.04	0.14	0.33	0
Petal weight	gr	0.025	0.007	0.000	0.06	0
Flower/petal W	gr	0.18	0.20	0.07	1.04	0.04
Petal length	mm	8.03	1.41	4.75	12	2
Petal width	mm	4.50	0.85	1.63	6	0.72
Petal length/width	mm	0.57	0.13	0.27	1.07	0.02
Flower No.		5.04	1.79	1.66	9.66	3.22
Flower Diameter	mm	2.26	0.26	1.44	2.8	0.07
Pedicle length	mm	4.32	0.65	3	5.4	0.42
Stem Diameter	mm	3.81	0.60	3	5.66	0.36
Plant height	cm	26.25	6.13	12.2	41.66	37.6
Bud length	mm	3.68	0.53	2.6	5.2	0.28
Bud width	mm	2.50	0.39	2	3.6	0.15
Bud length/width		0.69	0.13	0.5	1.06	0.02
Receptacle length	mm	3.25	0.44	2.3	4.4	0.19
Receptacle width	mm	2.44	0.41	1.9	3.8	0.17
Receptacle length/width		0.76	0.15	0.55	1.13	0.02
Leaf length	cm	1.56	0.40	0.84	2.42	0.16
Leaf width	cm	0.42	0.1	0.22	0.9	0.01
Leaf length/width		0.27	0.08	0.15	0.63	0.01
Lateral shoot No.		2.38	0.91	0.66	5.66	0.82
Lateral flowering shoot No.		1.71	0.72	0.33	4.66	0.52

Table 4 Bivariate correlations among *Rosa* traits

Traits	Flower weight	Petal weight	Flower/petalW	Petal length	Petal width	Petal length/width	Flower no.	Flower Diameter	Bud width	Bud length/width	Receptacle length	Receptacle width
Flower weight	1											
Petal weight	0.01	1										
Flower/petalW	0.25	-0.09	1									
Petal length	-0.27	-0.26	-0.12	1								
Petal width	-0.52*	-0.42	-0.03	0.34	1							
Petal length/width	-0.35	-0.18	0.04	-0.43	0.69**	1						
Flower No.	-0.13	0.04	0.13	0.62*	0.38	-0.07	1					
Flower Diameter	0.1	0.13	0.36	-0.32	-0.22	0.03	-0.21	1				
Bud width	-0.14	-0.66**	0.01	0.49	0.48	0.07	0.24	-0.37	1			
Bud length/width	-0.37	-0.71**	0	0.31	0.60*	0.36	0.18	-0.31	0.80**	1		
Receptacle length	0.16	-0.33	0.27	0.29	0.13	-0.08	0.58*	0	0.53*	0.31	1	
Receptacle width	-0.55*	-0.44	-0.01	0.29	0.70**	0.49	0.50	-0.34	0.54*	0.78**	0.45	1
Receptacle length/width	-0.59*	0.02	-0.32	-0.03	0.42	0.44	-0.21	-0.29	-0.13	0.27	-0.71**	0.45
Leaf length	0.54*	0.09	0.16	-0.20	-0.27	-0.13	-0.04	0.11	-0.09	-0.16	0.07	-0.07
Leaf width	0.09	-0.20	-0.07	0.42	0.25	-0.06	0.80**	-0.28	0.39	0.30	0.69**	-0.07
Leaf length/width	-0.30	-0.29	-0.22	0.49	0.39	0.01	0.59*	-0.36	0.40	0.35	0.43	-0.07
Lateral shoot no.	0.55*	0.56*	0.09	-0.60*	-0.65**	-0.18	-0.47	0.06	-0.44	-0.56*	-0.32	-0.07
Lateral flowering shoot no.	0.22	0.33	0.06	-0.70**	-0.48	0.10	-0.48	0.27	-0.49	-0.27	-0.23	-0.07

Table 5 Eigen values and cumulative variance for five major factors obtained from principal component analysis (PCA)

Traits	PC1	PC2	PC3	PC4	PC5
Flower weight	<u>-0.61</u>	0.17	-0.36	0.07	-0.50
Petal weight	-0.16	-0.03	-0.13	<u>-0.90</u>	-0.01
Petal length	-0.17	0.22	<u>0.83</u>	0.22	0.30
Petal width	<u>0.71</u>	0.17	0.38	0.27	0.13
Petal length/width ratio	<u>0.85</u>	0.02	-0.28	0.07	-0.07
Flower No.	0.10	<u>0.81</u>	0.46	-0.14	0.15
Bud length	<u>-0.81</u>	0.11	0.11	-0.25	-0.11
Bud width	0.06	0.25	0.30	<u>0.82</u>	0.09
Bud length/width	0.53	0.13	0.16	<u>0.76</u>	0.11
Receptacle length	-0.16	<u>0.85</u>	-0.02	0.41	0.02
Receptacle width	<u>0.71</u>	0.46	0.22	0.36	0.19
Receptacle length/width	<u>0.70</u>	-0.54	0.24	-0.16	0.13
Leaf length	-0.15	0.11	0.03	-0.05	<u>-0.97</u>
Leaf width	0.06	<u>0.87</u>	0.33	0.11	-0.10
Leaf length/width	0.10	0.52	0.24	0.18	<u>0.72</u>
Lateral shoot No.	-0.44	-0.25	<u>-0.67</u>	-0.33	-0.13
Lateral flowering shoot No.	-0.03	-0.20	<u>-0.89</u>	-0.21	0.12
Eigen value	3.85	3.21	2.90	2.80	1.96
Variance%	22.65	18.88	17.04	16.44	11.51
Cumulative%	22.65	41.53	58.57	75.01	86.53

Figures

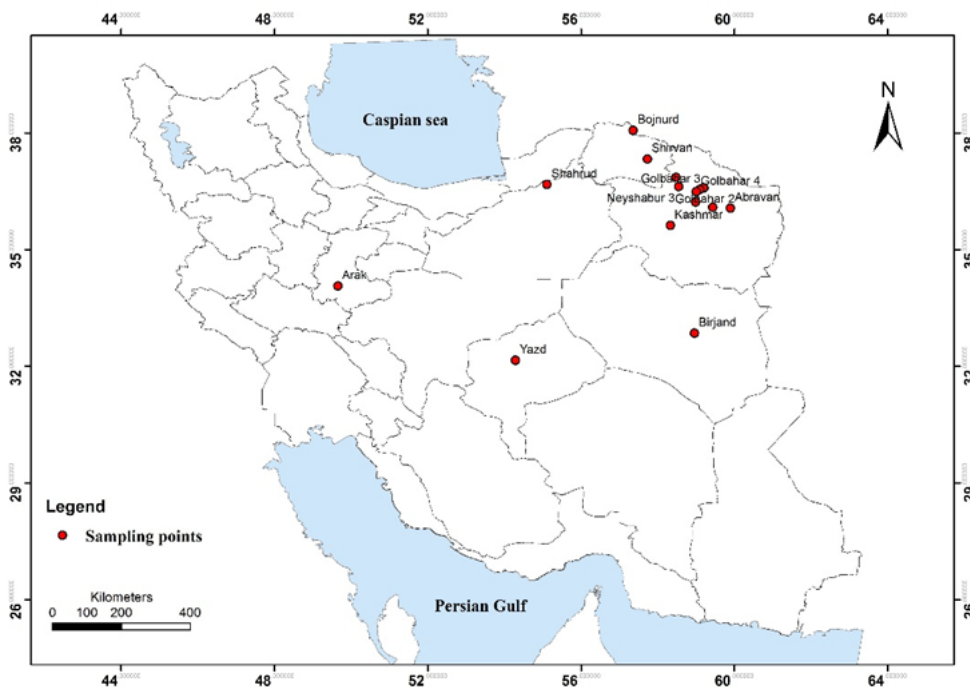


Figure 1

Collecting sites of *Rosa persica* in Iran



Figure 2

Flower shape in wild species of *Rosa persica*

aAbravan. **b** Golbahar1. **c** Kashmar. **d** Golbahar 2. **e**Golbahar 3. **f** Golbahar 4. **g** Neishabor 1. **h** Shirvan. **i**Neishabour 2. **j** Neishabour 3. **k** Neishabour 4. **l** Birjand. **m**Yazd. **n** Arak. **o** Bojnourd. **p** Shahroud

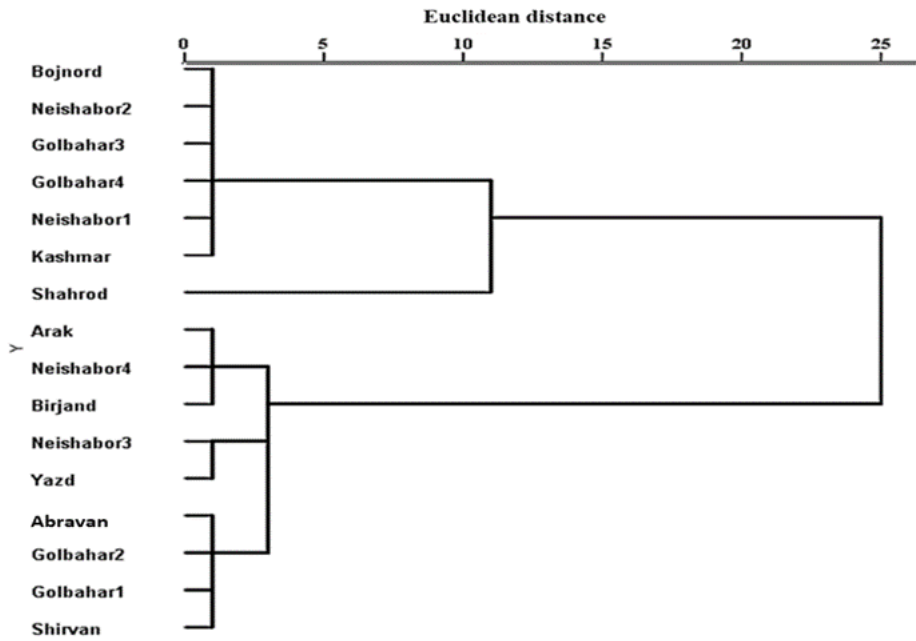


Figure 3

Dendrogram of *Rosa* accessions based on morphological components

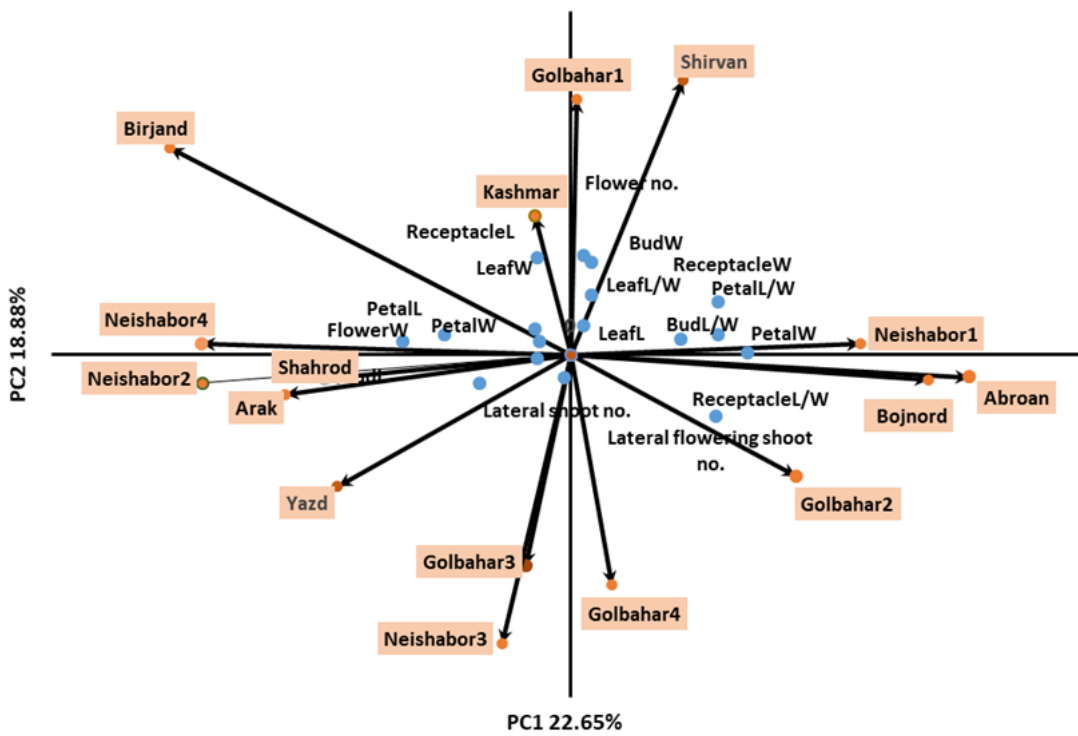


Figure 4

Factor scores for the first two principle components (PCs) for morphological features and 16 *Rosa* accessions. Factors with superior correlation coefficients are marked by arrows