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Morphological and Phytochemical Diversity among Some Iranian *Rosa damascena* Mill. Landraces

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Abstract

Essential oil of Iranian damask rose has high quality because of its desirable climatic and growing conditions. In the present study, an RCBD design was used to investigate the morphology and phytochemical characteristics of six damask rose landraces, collected from East Azerbaijan province. The investigated landraces showed a significant difference among morphological traits. According to the morphological characteristics, the landraces were grouped in two distinct classes including thorny and thornless. Qazi Jahan, Nadilu, and Kharaju (thornless) were the most suitable ecotypes in terms of flower yield and growth. Interestingly, petal, bud, and flower fresh and dry weight, bud number per branch, and essential oil content had a positive and significant correlation with flower yield. Essential oil analysis showed that citronellol, geraniol and n-nonadecane were the major components of the rose landraces. The amount of citronellol in the thorny genotypes was higher than that in thornless ones. On the other hand, n. nonadecane was the dominant component in the thornless genotypes. Our results demonstrated significant differences among the two classes of genotypes (with/without thorn) in terms of essential oil quality and flower yield. The important indices that influenced yield and percentage of essential oil of damask rose were petal fresh/dry weight, flower weight, petal length/width, and petal number among the 14 morphological traits, in addition to yield and essential oil percentage. There was a significant difference in odor between the thorny landraces and thornless ones. There was no significant difference in leaf length and width and number of branches per area between different landraces. These differences introduced a new variety of damask rose for breeding programs and industry.

Keywords: Essential oil, Flower yield, Genetically diversity, Phenotype.

INTRODUCTION

Damask rose (*Rosa damascena* Mill.), which belongs to the Rosaceae family (Kaul *et al*., 2000), is one of the most commercial flowers of *Rosa*. So far, over 200 species and more than 18000 cultivars have been identified in this family (Gudin, 2000). Among which some native and wild species such as *Rosa canina* are widespread in Iran (Mahboubi, 2016). Three species including *R. moschata* J. Herm., *R. gallica* L., and *R. fedtschenkoana* Reg. have been recorded as the ancestors of *R. damascena* Mill. (Iwata *et al*., 2000). The Middle East is the origin of *R. damascena* Mill. and there are some documents demonstrating that Iran is the rose water origin, but the origin of its fragrant oil and extracts is Greece (Mahboubi, 2016).

The extraction of essential oil from damask rose has been originated from Iran since the 7th century A.D. (Gudin, 2000). It is called Gol-e-Mohammadi by Iranians (Tosun *et al*., 2002). The plant is cultivated throughout the world; however, the major producers include Iran, Turkey, Bulgaria, France, Italy, Morocco, the USA, and India (Krussman, 1981). In Iran, the most common places for the cultivation of damask rose are Kashan, Shiraz, and Azerbaijan. But, Kashan is the leading producer of rose oil and water (Nikbakht and Kafi, 2004). Damask rose is famous for its medicinal effects and is regarded to be holy.

Rosa damascena is famous because of its applications, for example, as an ornamental species in landscapes and gardens, for perfume production, its pharmacological effects, and in the food industry (Jabbarzadeh and Khosh-Khui, 2005). However, *R. damascena* is principally known for its odorous effect (Widrlechner, 1981). Due to the low cost, significant profitability, and adaptability of *R. damascena*, its cultivation is increasing.

Damask rose is an odorous species of *Rosa* that is cultivated for rose essential oil (Kaul *et al*., 2009), rose water (a flavoring agent), rose extract, rose perfume (Nilgun *et al*., 2004) and as the essential fragrance for cosmetics and other by-products that have a higher added value and are abundant in the pharmaceutical, health, and cosmetic industries (Mahboubi, 2016). On the other hand, the essential oil of damask rose is famous for its antimicrobial and antioxidant activities (Basim and Basim, 2003; Achuthan *et al*., 2003). Rose essential oil is expensive in the world owing to its combinations for valuable odorous compositions and low oil performance (Baydar and Baydar, 2005; Kaul *et al*., 2009). In this case, Iran has been the main rose oil producer until the 16th century, exporting it to other countries (Tabaei Aghdaei *et al*., 2007). So, *Rosa damascena* Mill. is one of the major ornamentals for essential oil extraction in Iran. To have a unique rose essential oil that is competitive in global markets, highly odorous summer *Rosa damascena* is commercially cultivated in regions that are suitable for its growth and development in Iran. Damask roses flower for only about 25–30 days from April to May every year (Kaul *et al*., 2009), but some landraces flower continuously over the year.

The evaluation of wild populations is essential for proper maintenance and utilization of appropriate germplasms. Variation is the primary principle in breeding programs. In this regard, morphological studies are still used as the basis and the first step in germplasm investigation and breeding research. Since *Rosa damascena* shows some morphological diversity in different parts of Iran (Tabaei Aghdaei *et al*., 2003; Tabaei Aghdaei and Rezaei, 2004; Tabaei Aghdaei *et al*., 2004 a,b; 2005 a,b; Yousefi *et al*., 2005), attention has also been drawn to phytochemical aspects of the plant. Demand for rose oil is increasing in international markets, but damask rose-producing regions have not changed. So, it is necessary to extend damask rose cultivation to larger areas and to promote the technology of rose oil production. Damask roses have a huge diversity in bush habits and plant traits. In this regard, the present work aimed to study some local genotypes of damask roses in different regions and altitudes of the western Sahand Mountain, East Azerbaijan province in terms of morphological characteristics and their essential oil compositions to find out the preferable genotypes with the best compatibility and quantitative and qualitative yield for cultivation and development in these regions.

MATERIALS AND METHODS

Plant materials

The study was carried out in three distinct areas natively covered by damask roses, including the altitudes of Azarshahr (1451 meters above sea level), Osku (1579 meters above sea level), and Maragheh (1477 meters above sea level) located in East Azerbaijan province, Iran. Six landraces of *R. damascena*, three related to thorny species (Kordabad, Majarshin, and Gonbarf) and the other related to thornless species (Qazi Jahan, Nadilu, and Kharaju) were selected from the northwestern slope of Mount Sahand, East Azerbaijan. The geographical characteristics of the studied regions are presented in table 1. Taxonomically verified individuals of each genotype were harvested in the similar phenological stage of fully open flower (FOF) (Schmitzer *et al*., 2010).

Morphological traits

Morphological traits were examined at the harvest time (about May-June). The data were recorded from nine representative samples from each replication of the experiment. The morphological parameters included flower fresh weight (g), yield (kg h^{-1}), number of buds per branch, petal fresh/dry weight (g), bud fresh/dry weight (g), number of petals per flower, leaf length/width (cm), petal length/width (cm), sepal length/width (cm), petiole weight (g), number of branches per area, bud number per branch, and thorn status (thorny/thornless).

Evaluation of the essential oil combinations

The essential oil was analyzed with an Agilent 6890 N GC coupled to a 5973 N mass spectrometer via an HP-5 MS capillary column (30 m length, 0.25 mm i.d., and 0.25 µm film thicknesses). Briefly, the GC oven temperature was managed for 5 min at 50˚C, increased at a rate of 4˚C/min to 240˚C, and then increased at a rate of 10˚C/min to 300 ˚C. The injector r and transfer line temperature were set at 290˚C. Helium was used as the carrier gas at a flow rate of 0.8 ml min^{-1}. Electron-impact (EI) was 70 eV. Mass range acquisition was from 50 to 400 m/z.

The identification and quantitative processes were performed by a combination of MS matching and calculated liner retention indices of peaks with those combined in the WILEY, Adams and NIST05 libraries (Morshedloo *et al*., 2017).

Data analysis

The data were statistically analyzed to find the significant differences between the morphological parameters and essential oil components of the damask rose landraces and related species, and the means were compared by Duncan's multiple range test at the 5% probability level. Correlations among the chemical components were analyzed by Pearson's coefficient. The cluster analysis was performed using Statistica 7, Statsoft. Inc. (19842007). Also, the relationship and correlation between the traits were examined, evaluated, and analyzed.

Table 1. Damask rose landraces collected from the slopes of Mount Sahand in East Azerbaijan province.

Populations	County	Longitude (E)	Latitude (N)	Altitude (m)
Qazi Jahan	Azarshahr	45° 93′	37°77′	1315
Nadilu	Azarshahr	45°96′	37°72′	1428
Kharaju	Maragheh	46°52′	37°31′	1788
Majarshin	Osku	46°15′	37°73′	2044
Kordabad	Osku	46°11′	37°43′	1354
Gonbarf	Azarshahr	46°22′	37°71′	2307

RESULTS AND DISCUSSION

Evaluation of the morphological traits of different damask rose landraces

Table 2 presents the results of the analysis of variance in morphological indices, flower yield, and essential oil percentage of different *Rosa damascena* landraces.

Table 2. Analysis of variance in morphological indices, flower yield, and essential oil percentage of different *Rosa damascena* landraces.

S.o.V	df	MS							
		Flower fresh weight	Petal fresh weight	Petal dry weight	Petiole weight	Bud fresh weight	Bud dry weight	Floweryield	Petal number
Block	2	0.137**	0.23ns	0.014ns	0.030ns	0.001ns	0.001ns	1301.85ns	0.228ns
Landraces	5	366.46**	309.39**	8.682**	3.809**	0.110**	0.003ns	3664601.48**	15.25**
Error	10	0.017	0.147	0.005	0.155	0.002	0.000078	192.22	0.177
CV (%)		0.24	0.96	0.94	2.6	2.85	2.37	0.25	0.79

*, ** and ns: significant at P< 0.05, P< 0.01 and insignificant, respectively.

Table 2 (Continued).

S.o.V	df	MS							
		Petal length	Petal width	Bud number	Essential oil	Leaf length	Leaf width	Sepal length	Sepal width
Block	2	0.001ns	0.002ns	0.5ns	5.741ns	0.067ns	0.075ns	0.045ns	0.001ns
Landraces	5	2.752**	2.763**	5.496**	7.471**	0.514ns	0.205ns	0.663**	0.053**
Error	10	0.001	0.001	0.130	0.00000019	0.336	0.280	0.040	0.007
CV (%)		1.3	1.56	4.21	1.45	16.67	22.1	7.84	12.58

*, ** and ns: significant at P< 0.05, P< 0.01 and insignificant, respectively.

In our results, the landraces Majarshin, Kordabad, and Gonbarf were known as thorny genotypes, and the other three landraces, i.e., Qazi Jahan, Nadilu, and Kharaju, as thornless genotypes (Table 3). Naturally, *Rosa damascena* is known as one of the important species of Old Roses and is important for its prominent place in the pedigree of many other types as it has very prickly (thorny) branches with hooked spines and also prickly bristles, and the hips are pear-shaped and bristle (Gault and Synge, 1971). So, it is suggested that thornless genotypes may be new genotypes that have evolved over time and during adaptation to environmental conditions. This individual property may affect other characteristics of damask roses.

Flower /petal fresh weight

Results of ANOVA for the effect of different regions on flower and petal fresh weight were significant at the 1% probability level (Table 2). The results of means comparison showed that Qazi Jahan had the highest flower fresh weight with significant differences compared with the other landraces. Then, Nadilu and Kharaju had the higher flower fresh weight, respectively. These landraces were identified as thornless genotypes. Local landraces of Gonbarf, Kordabad, and Majarshin (thorny) had the lowest flower fresh weight compared with the other three genotypes (Table 3). The same results were observed in petal fresh weight as illustrated in table 3. In total, thornless damask landraces had higher flower and petal fresh weight than thorny landraces. The phenotype of two different classes of landraces is illustrated in Fig. 1.

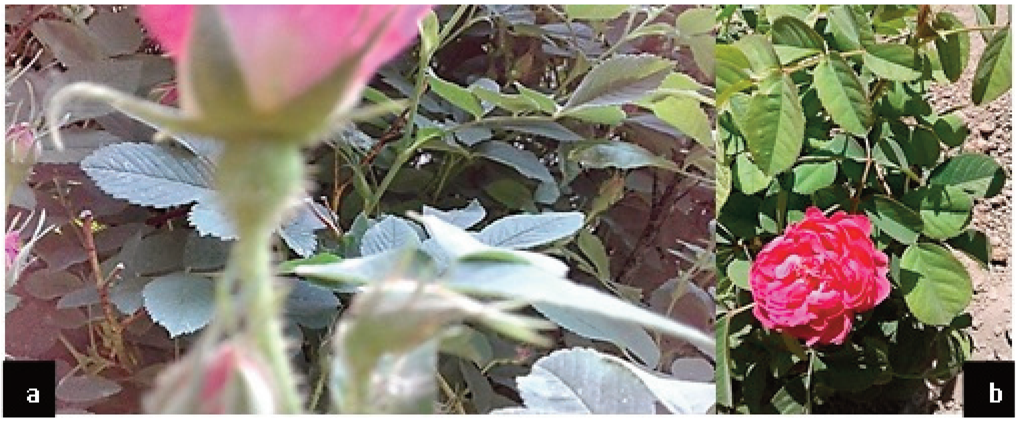

Fig. 1. *Rosa damascenda* a) thorny and b) thornless.

Petal dry weight

The effect of different regions was significant on petal dry weight as the results of means comparison showed. The Qazi Jahan region had the highest petal dry weight with a significant difference compared with the other regions. After that, the Nadilu and Kharaju regions had the highest petal dry weight, respectively (Table 3). The lowest rate of this trait was observed in the Gonbarf, Kordabad, and Majarshin regions covered with thorny genotypes.

Petiole weight

The results in Table 2 demonstrate that the effect of origin was significant on petiole fresh weight at the 1% probability level. According to the results of means comparison in table 3, the Majarshin, Gonbarf, and Kordabad regions covered with thorny genotypes of damask rose had the highest petiole weight with no significant difference with one another. The lowest level of this trait was observed in Qazi Jahan. Also, the Kharaju and Nadilu regions did not have significant differences in thpetiole weight of damask rose (Table 3).

Bud fresh/dry weight

The results of means comparison (Table 3) showed that the Qazi Jahan region had the highest bud fresh and dry weight, differing from the other regions significantly. The Nadilu and Kharaju regions had the second-highest bud fresh/dry weight, respectively. The lowest bud fresh and dry weight was observed in the Gonbarf, Kordabad, and Majarshin regions. In general, thornless genotypes had higher flower weight, petal fresh/dry weight, and bud fresh/ dry weight than thorny genotypes.

Flower yield

The results showed that damask yield was significantly different among regions so that the Qazi Jahan region had the highest flower yield compared with the other regions followed by Nadilu and Kharaju, respectively. The lowest yield was observed in the Gonbarf region. The amount of damask flower yield in the Kordabad and Majarshin regions did not differ significantly. In general, thornless genotypes had higher yields than thorny genotypes (Table 3).

Petal number per flower

The results in Table 2 show that all damask landraces had significant differences in the number of petals at the 1 probability level. According to the comparison of the means illustrated in table 3, the damask rose landraces including Qazi Jahan and Gonbarf had the most and the least number of petals per flower (57.11 vs. 50.77), respectively.

Table 3. Morphological diversity among six *Rosa damascena* landraces from Iran.

Landraces	Thorn	Flower fresh weight (g)	Petalfresh weight (g)	Petaldry weight (g)	Petiole weight (g)	Bud fresh weight (g)	Buddry weight (g)
Qazi Jahan	-	67.41[a]	51.33[a]	9.46[a]	13.2[c]	1.83[a]	0.42[a]
Nadilu	-	64.25[b]	51.33[a]	8.97[b]	14.5[b]	1.73[b]	0.38[b]
Kharaju	-	63.3[c]	47.33[b]	8.66[c]	15.16[b]	1.63[c]	0.37[c]
Majarshin	+	45.21[d]	32[c]	6.17[d]	16.07[a]	1.5[d]	0.36[c]
Kordabad	+	45.05[d]	30.55[d]	5.94[e]	15.92[a]	1.38[e]	0.36[c]
Gonbarf	+	44.63[e]	29.46[e]	5.8[f]	15.96[a]	1.35[e]	0.32[d]

Means with similar letter(s) in each column show the lack of a significant difference at the $P < 0.05$ level based on the LSD test.

Table 3 (Continued).

Landraces	Flower yield (kg h^{-1})	Petal number per flower	Petal length (cm)	Petal width (cm)	Bud number per branch	Sepal length (cm)	Sepal width (cm)	Essential oil (%)
Qazi Jahan	6741.1[a]	57.11[a]	3.33[a]	2.92[a]	10[a]	2.05[b]	0.75[a]	0.034[a]
Nadilu	6425.5[b]	54.44[b]	3.3[a]	2.91[a]	9.6[a]	2.15[b]	0.8[a]	0.034[a]
Kharaju	6330[c]	53.88[b]	3.3[a]	2.86[a]	9.5[a]	2.15[b]	0.8[a]	0.034[a]
Majarshin	4520[d]	53.11[c]	1.54[b]	1.13[b]	7.8[b]	2.97[a]	0.54[b]	0.025[b]
Kordabad	4506.6[d]	51.55[d]	1.56[b]	1.14[b]	7.4[b]	2.97[a]	0.54[b]	0.025[b]
Gonbarf	4463.3[e]	50.77[e]	1.6[b]	1.16[b]	6.7[c]	2.97[a]	0.54[b]	0.025[b]

Means with similar letter(s) in each column show the lack of a significant difference at the $P < 0.05$ level based on the LSD test.

Petal length/width

The results of means comparison (Table 3) showed no significant difference between the Qazi Jahan, Nadilu, and Kharaju regions in petal length, but they had two times as length and width petals as thorny landraces. The lowest amount of this trait was observed in the Majarshin, Gonbarf, and Kordabad regions. These regions did not have significant differences from each other.

Bud number per branch

According to table 2, the effect of treatment on the number of buds in each branch was significant at the 1% probability level. The results of means comparison showed that the highest number of buds in each branch belonged to the Qazi Jahan, Nadilu, and Kharaju landraces, differing from one another insignificantly. The lowest number of bud per branch was observed in the Gonbarf region that were covered with thorny landraces. In general, the thornless landraces had more buds per branch than thorny landraces. The number of buds per branch in Qazi Jahan was 1.4 times as high as that in Gonbarf with the lowest buds per branch (Table 3).

Sepal length/width

The results of ANOVA showed a significant difference in sepal width of different local genotypes at the 1% probability level in sepal length (Table 2). According to table 3, Qazi Jahan, Nadilu, and Kharaju had 31% shorter sepals than the other three local damask roses whereas they had 48% higher sepal width than Majarshin, Kordabad, and Gonbarf.

Essential oil (%)

The results showed a significant difference in the percentage of essential oil among various landraces (Table 2) as the highest essential oil content was observed in the Qazi Jahan, Nadilu, and Kharaju landraces, which was 1.3 times more than that of the other three landraces (Table 3) while no significant difference was observed among them. The lowest amount of this trait was observed in the Majarshin, Gonbarf, and Kordabad genotypes. These regions also did not have any significant differences from each other.

Significant diversity among damask rose populations in different ecological conditions has been reported for many traits such as flower characteristics and yield, as well as the amount of essential oil in Iran. This diversity can provide an effective basis for selecting superior genotypes in terms of functional traits of flowers and essential oil and introducing high-yield genotypes that are compatible with different ecological conditions of Iran (Rezaei *et al*., 2003; Tabaei Aghdaei *et al*., 2005a). Although, most of the morphological characteristics used in determining the genetic diversity of roses are difficult to study (Millan *et al*., 1996). Tabaei Aghdaei *et al*. (2004 a,b; 2005 a,b) investigated damask rose genotypes collected from various parts of Iran and demonstrated a drastic diversity for the evaluated morphological characteristics. Tabaei Aghdaei *et al*. (2003) showed a significant difference in morphological traits of nine genotypes of damask roses collected from three parts of Kashan. The morphological changes of the plant reflect the extent of its adaptation to different environmental conditions. Naturally, under long-term selections, stable variation occurs and produces new traits that can be inherited. Some traits such as leaf length and width were not significantly different among the studied genotypes, and they might be more stable traits. In the present study, the significant differences detected between thorny and thornless landraces for the studied traits can be due to the genetic diversity between genotypes within climatic and geographical areas for flower yield and the amount of flower essential oil or it may be due to differences in the original zone of the genotypes. Also, it might be the result of natural hybridization and mutation among damask roses.

Inter-trait correlation analysis

According to the inter-trait correlation analysis observed in Table 4, there were significant positive and negative correlations among various characteristics. The correlation between flower fresh weights and petal fresh/dry weight was closely significant and positive with a correlation coefficient of 0.997. Also, flower fresh weight was positively correlated with flower yield. The most positive and significant correlation was observed between the percentage of essential oil with petal length and petal width with a correlation coefficient of 0.996. Bud number per branch and yield were also significantly and positively correlated with a correlation coefficient of 0.933. All measured traits had a significant, strong, negative correlation with sepal length. Leaf length and leaf width were not significantly correlated. The most negative correlation was observed between sepal width and flower fresh weight and yield with a correlation coefficient of -0.933. These data indicate that the higher the yield is, the higher the flower fresh weight and the petal fresh and dry weight will be.

Flower yield in damask rose, like other crops and horticultural species, is the result of the activity of a large number of growth conditions. Flower yield is a quantitative trait that is controlled by multi-gene families, so environmental factors have a great influence on it. Therefore, in the first stages of breeding, it is better to use its determining traits instead of plant yield in plant selection (Mahboubi *et al*., 2011) because plant yield is a cumulative effect of its constituent components. Determining the correlations between different traits, especially flower yield and its components, and determining its cause-and-effect relationships allows plant breeding specialists to select the most appropriate combination of components that would lead to a higher yield (Yoosefi *et al*., 2016). As mentioned, flower yield is a quantitative trait greatly influenced by environmental factors. By knowing the relationships between traits and selecting superior and effective traits, we can select optimal genotypes with high yields.

Singh and Kayiyar (2001) suggested that flower yield per plant was positively and directly associated with the number of flowers per plant and the number of branches per plant. In addition, there is a direct and positive relationship between flower yield and flower number per raceme, although it may have a negative relationship with genotype. Considering the major contributors, a multiple selection index for medium plant height and a prolific number of flowers per plant, flowering branches per plant, and flowers/raceme should be considered in developing desired plant types of pink damask rose for high flower yields. Cheng *et al*. (2020) demonstrated that among 16 morphological parameters, style length, sepal width, flower diameter, flower color, and leaflet length and width were the major traits that affected the morphology of *Rosa × odorata*, which is close to the *Rosa damascena* family.

Results of qualitative analysis of damask rose essential oil

The results of essential oil analysis of damask rose from different regions showed that in both thorny and thornless damask roses including Qazi Jahan, Nadilu, and Kharaju a the thorny genotypes and Kordabad, Majarshin, and Gonbarf as the thornless genotypes, more than 85% of the total essential oil consisted of 13 main compounds (Table 5). The results of each landrace are illustrated in table 5. According to the results, 13 compounds were identified in the essential oil of the Qazi Jahan landrace of damask rose, which has a total of 90.91 cases of total plant essential oil. The most important constituents of flower essential oils were citronellol (23.69%), *n*-nonadecane (20.46%), and geraniol (19.59%), respectively. In Nadilu, 13 compounds were identified in essential oil, which in total accounted for 90.89% of the total plant essential oil. The main constituents of flower essential oils were *n*-nonadecane (23.07%), citronellol (22.26%), and geraniol (16.8%), respectively.

According to the results in table 5, 13 compounds in damask essential oil were identified in Kharaju, which in total accounted for 88.31% of the total essential oil of the plant. The most important constituents of flower essential oils were *n*-nonadecane (29.6%), citronellol (17.1%), and geraniol (10.6%), respectively. The 13 compounds identified in the essential oil of Majarshin accounted for 85.13% of its essential oil content and the main compounds included citronellol (45.2%), geraniol (8.64%), and trans-caryophyllene (7.96%), respectively. According to the results in table 5, 13 compounds were identified in the damask essential oil of Kordabad, which in total accounted for 87.68% of the total plant essential oil. The key constituents included citronellol (36.7%), trans-caryophyllene (12.2%), and geraniol (10.4%), respectively. In Gonbarf, the 13 components of essential oil accounted for 84.38% of its content, and the main constituents were citronellol (28.06%), geraniol (11.65%), and trans-caryophyllene (11.06%), respectively.

Damask roses are among the most important flowers of *Rosa* genus mainly known for their odors. It is important that some scented roses are in the gene pool of modern cultivated garden roses, including *R. odorata* Sweet, *R. moschata* Herrm., and *R. damascena* Mill. (Ma *et al*., 1997). The most important products of damask roses are rose water and essential oils. *Rosa damascena* contains various components including terpene, glycoside, flavonoid, and anthocyanin that are useful for human bodies. So far, 400 volatile compounds have been isolated from the essential oil of rose (Kumar Pal, 2013). The extensive application and low oil content of *Rosa damascena* have made it necessary to carry out agro-experiments to increase its oil performance and flower quality. The medicinal effects of damask rose are widespread, such as its hypnotic, analgesic, and anticonvulsant effects. However, these morphological traits are largely depends on environmental conditions, but one of the reasons for the poor quality of *Rosa damascena* essential oil is the abundance of sesquiterpenes and the lack of citronellol, geranium, and phenyl alcohol monoterpenes in the

Table 4. The correlation coefficient between all measured traits of different damask rose landraces.

Trait	Flower fresh weight	Petal fresh weight	Petal dry weight	Petiole weight	Bud fresh weight	Bud dry weight	Flower yield	Petal number in flower	Petal length	Petal width	Bud number per branch	Essential oil percentage	Sepal length	Sepal width
Flower fresh weight	1	0.997**	0.997**	0.784**	0.929**	0.808**	1**	0.855**	0.992**	0.993**	0.993**	0.988**	-0.933**	0.856**
Petal fresh weight		1	0.999**	0.737**	0.941**	0.829**	0.997**	0.875**	0.986**	0.988**	0.947**	0.983**	-0.931**	0.850**
Petal dry weight			1	0.743**	0.944**	0.832**	0.997**	0.881**	0.983**	0.986**	0.942**	0.980**	-0.932**	0.851**
Petiole weight				1	0.599**	0.434ns	0.784**	0.485*	0.809**	0.802**	0.583*	0.792**	-0.724**	0.711**
Bud fresh weight					1	0.914**	0.928**	0.935**	0.892**	0.897**	0.913**	0.885**	-0.829**	0.780**
Bud dry weight						1	0.808**	0.933**	0.746**	0.753**	0.824**	0.738**	-0.750**	0.589**
Flower yield							1	0.855**	0.992**	0.993**	0.933**	0.988**	-0.933**	0.856**
Petal number in flower								1	0.796**	0.803**	0.659**	0.790**	-0.775**	0.658**
Petal length									1	0.999**	0.911**	0.996**	-0.929**	0.883**
Petal width										1	0.913**	0.996**	-0.930**	0.881**
Bud number per branch											1	0.901**	-0.828**	0.824**
Essential oil percentage												1	-0.939**	0.865**
Sepal length													1	-0.678**
Sepal width														1

**, * and ns; significant at $P<0.01$ and $P<0.05$, and non-significant, respectively.

Table 5. Components of different landraces of damask rose essential oil.

N.	Components	% Amount of different components in landraces							
		AI	RT	Qazi Jahan	Nadilu	Kharaju	Majarshin	Kordabad	Gonbarf
1	α.-Pinene	932	17.15	0.96	-	-	-	-	-
2	Linalool	1096	25.49	1.37	1.35	1.04	2.13	0.97	-
3	Citronellol	1223	31.97	23.69	22.26	17.1	45.2	36.7	28.06
4	Neral	1235	32.53	-	-	-	-	-	-
5	Geraniol	1249	33.1	19.59	16.8	10.6	8.64	10.4	11.65
6	Geranial	1264	33.86	-	-	-	-	0.94	2.30
7	Citronellyl acetate	1350	37.27	-	-	-	-	1.17	2.66
8	Neryl acetate	1359	37.46	-	-	-	-	-	-
9	Geranyl acetate	1379	38.54	3.44	3.47	1.91	1.11	3.39	8.17
10	n-tetradecane	1400	39.46	1.91	-	-	-	-	-
11	trans-caryophyllene	1417	41.1	-	-	-	7.96	12.2	11.06
12	α-humulene	1452	42.63	-	-	-	2.79	4.52	4.13
13	β-selinene	1489	43.1	-	-	-	1.67	-	-
14	pentadecane	1500	43.6	1.11	1.19	1.56	1.34	1.29	-
15	8-heptadecene	1676	50.58	2.54	2.70	3.99	-	-	-
16	n-heptadecane	1700	51.38	4.55	5.33	6.63	-	-	-
17	6(E),8(E)-heptadeca-diene		52.33	-	1.18	1.45	0.80	2.85	2.42
18	1-nonadecene	1883	57.55	3.76	4.14	3.55	-	-	-
19	n-nonadecane	1900	58.46	20.46	23.07	29.6	6.81	6.23	4.19
20	Hexadecanoic acid	1959	60.55	-	-		-	-	2.34
21	n-eicosane	2000	61.55	0.97	1.12	1.28	1.03	-	-
22	Heneicosane	2100	64.7	6.56	6.30	7.38	4.19	5.28	4.07
23	n-tricosane	2300	71.99	-	1.98	2.22	1.45	1.74	2.11

essential oil of this plant. Citronellol and geraniol are the most important volatile substances that are widely used in the perfumery, cosmetics, and soap industries and are the main component of the liquid part of *Rosa damascena* essential oil and are one of its most effective compounds in determining the economic value of essential oil (Yoosefi *et al.,* 2016).

In this work, according to the results of qualitative analysis of the essential oils of Qazi-Jahan, Nadilu, and Kharaju regions (thornless damask roses), the main active ingredients include citronellol, geraniol, and *n*-nonadecane. The main constituents of the essential oils of these damask roses were *n*-nonadecane, and the geraniol and citronellol contents were less than this compound, so the essential oil of these genotypes can be used in the pharmaceutical industry, which aims to use waxy and heavy compounds (Rezaei *et al*., 2003). Also, in thorny damask roses including Majarshin, Kordabad, and Gonbarf, the main active ingredients include monoterpenes citronellol, geraniol, and sesquiterpene trans-caryophyllene. The amount of sesquiterpene-trans-caryophyllene was less than the other two compounds. Therefore, due to the pleasant smell of the essential oils of these landraces, their essential oils can be used in pharmaceutical, cosmetic, and health applications that require a high percentage of these two monoterpenes. There was some literature demonstrating that the amount of citronellol and geraniol in the essential oil of some samples of damask is higher than the other compounds. Also, the amount of *n*-nonadecane was more than other compounds in essential oil (Sefidkon *et al*., 2007). Also, some treatments have potential to accumulate citronellol and geraniol as the percentage of citronellol+nerol was increased by using KNO_3 up to 900 ppm while geraniol content was increased by using KNO_3 up to 1200 ppm (Kumar *et al*., 2016).

CONCLUSION

The study aimed to evaluate two types (thorny and thornless) of six damask landraces (Qazi Jahan, Nadilu, Kharaju, Kordabad, Majarshin, and Gonbarf) in Iran. In general, the thornless damask roses had the highest yield, bud and petal number, petal and bud fresh and dry weight, petal length and width, sepal width, flower fresh weight, and essential oil percentage compared to the thorny ones, while petiole weight and sepal length of the thorny genotypes was higher than the thornless ones. The Qazi-Jahan region was the most suitable in terms of yield and other measured traits followed by the Nadilu and Kharaju regions, respectively. The results of correlation between yield and flower components in different regions showed that flower yield had a positive and significant correlation with petal fresh weight (0.997), petal dry weight (0.997), bud fresh weight (0.935), bud dry weight (0.933), flower fresh weight (1), number of petals per flower (0.992), petiole weight, petal width (0.993), number of buds per branch (0.933), and essential oil percentage (0.988). Sepal length had no positive correlation with any trait.

According to the results of the qualitative analysis of the essential oils of different landraces, the main constituents of the damask active ingredients in Qazi Jahan, Nadilu, and Kharaju were citronellol, geraniol, and *n*-nonadecane while in thorny genotypes of Majarshin, Kordabad, and Gonbarf, the main constituents of damask active ingredients were citronellol, geraniol, and trans-caryophyllene. Citronellol and geraniol are the most important active ingredients of damask rose having medicinal properties. They were observed to be in high quantities in both groups. The most abundant active ingredients detected in thorny and thornless genotypes were citronellol and geraniol, respectively.

Considering the results, especially the significant differences between different morphological traits and their correlations with flower yield, they can be considered in increasing yield in breeding programs. Although the results of the morphological analysis are comprehensive and practical and provide information related to vital adaptive and evolutionary significance, we will be able to provide more precise data on the origin, classification, and evolution of germplasm resources if modern molecular technology is combined with investigations on morphological diversity.

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