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Evaluation of genetic diversity in fifteen *Rosa damascena* Mill. genotypes based on morphologic and yield traits

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ABSTRACT

Damask rose is a valuable oil bearing species whose various products are widely used in food, cosmetics and pharmaceuticals. In this study, fifteen genotypes from different regions of Iran were cultivated in a randomized complete block design with 3 replications and 3 plants per plot. During two crop years, the morphological traits, flower yield and yield components were measured. The essential oils (EOs) extracted using a modified clevenger system according to British Pharmacopoeia (1993). The EO content (percentage) and EO yield were calculated for each of the *R. damascena* (DR) genotypes. The data were analyzed by univariate and multivariate analysis. The results showed a significant difference (p<0.01) between the years and the genotypes for all the traits except the essential oil percentage. The highest flower fresh yields (7383.8 kg.ha^{-1}) were obtained in Fars1 and then 6016 (kg.ha^{-1}) in Isfahan5 and the lowest yield (2566.1 kg) was obtained in LOR1. The highest content of EO (%) was obtained in Kermanshah9 genotype (0.048%) and in Isfahan9 (0.044%), respectively, and the lowest content of EO (%) was obtained in Fars1 (0.024%). The highest EO yields (2.25 kg.ha^{-1}) were observed in Isfahan5 and (2.18 kg.ha^{-1}) in Isfahan9, respectively, and the lowest EO yields was observed in Lorestan1 (0.81 kg.ha^{-1}) and Azarbaijan-e-gharbi1 (0.92 kg.ha^{-1}). The cluster analysis classified the genotypes into four group. The results of PCA showed that Fars1 had the highest flower yield and Isfahan8 had the highest EO yield.

Key words: EO, Genetic diversity, Morphologic traits, *Rosa damascena* Mill., Yield components.

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ABBREVIATIONS

FLOWN (Flower number per plant), EO (Essential oil), LD (Large diameter), SD (Small diameter), CROWN (Canopy cower), FWW (Flower wet weight), FDW (Flower dry weight), PWW (Petal wet weight), PDW (Petal dry weight), WWFPL (Wet weight of flower per plant), DWFPL (Dry weight of flower per plant), WWPPL (Wet weight of petal per plant), DWPPL (Dry weight of petal per plant), WFYIELD (Wet flower yield), DFYIELD (Dry flower yield), WPYIELD (Wet petal yield), DPYIELD (Dry petal yield), ESSYILD (EO yield), ESSPER (Essence percent).

INTRODUCTION

Damask rose (DR) is the most important species used in the production of rose attar and rose water (Farooq *et al.,* 2011). Damask Rose (DR) is a well-recognized high value ornamental and medicinal plant, which can be used in food, perfume, and medicine industries (Jan Ahmadi *et al.,* 2019).

In many parts of the world, such as Turkey, India, Bulgaria, Italy, Iran, and Spain, different varieties of aromatic roses are grown and their aromatic constituents are widely used. Damask rose (*Rosa damascena* Mill.) is among the most precious essential oil (EO) bearing plants in the market (Babu *et al.,* 2002; Nunes and Miguel, 2017). It has been well documented that Damask rose EO is widely used in various pharmaceuticals, foods, perfumes and cosmetics industries. Remarkable antimicrobial, anti-inflammatory, antioxidant, anticancer, protective neuronal, cardiac, gastrointestinal and hepatic effects of this herbal species have been the subjects of some of the previously reported papers in the literature (Nayebi *et al.,* 2017; Nunes and Miguel, 2017). Some varieties of Damask rose are of great importance for rose oil production (Khaleghi and Khadivi, 2020). The EO of rose consists of some valuable natural compounds involving geraniol and citronellol, constituting most of the relevant chemical profiles (Lawrence, 1991).

Some studies indicated the existence of diversity in morphological, yield, and essential oil traits in damask rose such as: flower yield of damask rose from the West of Iran (Tabaei-Aghdaei and Rezaee, 2004), morphological traits and flowering period (Tabaei-Aghdaei *et al.,* 2004a; Tabaei-Aghdaei *et al.,* 2004b; Tabaei-Aghdaei *et al.,* 2004c), also significant differences were observed between different genotypes in terms of flower yield, number of flowers per hectare, flower yield per plant, number of flowers per plant, percentage of flower dry matter, and weight of single flower (Tabaei-Aghdaei *et al.,* 2005), flower yield and yield components (Kodori and Tabaei-Aghdaei, 2007; Yousefi, *et al.,* 2015), The EO content and EO yield (Yousefi *et al.,* 2021), essential oil compounds (Shamspour and Mostafavi, 2011; Batooli and Safaie-Ghomi, 2012; Yousefi and Jaimand, 2018).

Correlation between traits has a special importance in plant breeding. Correlation of yield components is a useful tool for determining valuable genotypes (Li *et al.,* 2006). In the other words, determining the correlation between different traits, especially yields and its components, gives breeders the opportunity to choose the most appropriate combination of components that leads to higher yield (Doffing and Knight, 1992). Pearson's coefficients showed a positive and strong correlation for flower weight with other studied morphological characters in some *Rosa damascena* landraces (Farooq *et al.,* 2011).

Genetic resources constitute the building blocks of crop improvement programs. These provide the basic raw material as well as reservoir of genes for breeding high-quality cultivars (Kiani *et al.,* 2010). Characterization of germplasm is the prerequisite for subsequent utilization of the resources. In a study significant differences were observed for quantitative and qualitative morphological traits and phenotypic variability in twenty six Damask rose genotypes collected from Iran (Kiani *et al.,* 2010).

Genetic distance is usually related to geographical distance. Tabaei-Aghdaei *et al.* (2004b.) showed the greatest genetic distance between the damask rose genotypes of west of Iran. Yousefi (2009) concluded that ecological factors have a significant effect on the characteristics of *Rosa damascena* flower and essential oil.

Collecting different genotypes of damask rose, cultivating and studying them under the same experimental conditions, can be useful in identifying high yield, high oil bearing and compatible genotypes for cultivations. The existence of genetic diversity can be a proper basis for selecting the desired genotypes of damask rose. This study was performed to select compatible RD genotypes with flower and EO high yield for cultivation in the Kermanshah ecological conditions and similar ecological areas.

MATERIALS AND METHODS

Plant materials

In this experiment fifteen accessions of Damask rose (*Rosa damascena* Mill.) were collected from some

Table 1. The name, abbreviations and origin of DR genotypes.

Accession name	Abbrev.	Accession source	no	Accession name	Abbrev.	Accession source	no
Azarbaijan Gharb1i	AZGH1	Khoy	2	Isfahan5	ISFAH5	Chamoo	37
Isfahan9	ISFAH9	Chamoo	4	Isfahan7	ISFAH7	Ardehal	39
Fars1	FARS1	Shiraz	16	Isfahan8	ISFAH8	Chamoo	40
Kermanshah1	KERMSH1	Kermanshah	21	Kermanshah3	KERMSH3	Miandarband	42
Khorasan2	KHOR2	Mashhad	23	Kermanshah8	KERMSH8	Javanrood	47
Lorestan1	LOR1	Khoram abad	26	Kermanshah9	KERMANSH9	Mahidasht	48
Arak1	ARAK1	Arak	28	Kermanshah10	KERMSH10	Sahnah	49
Yazd1	YAZD1	Shirkooh	31				

Table 2. Geographical, climatic, soil and water characteristics of the Islamabad-e-gharb research station.

Characteristic	Values	Characteristic	Values
Longitude	47.26°	Climatic condition	Cold temperate climate
Latitude	34.8°	Evaporation rate	1808.5 mm
Elevation	1346 M	Sunshine	2430.2 hours
The average annual rainfall	538 mm	soil texture	clay-silt
The average annual temperature	+10.5 °C	Soil EC	0.57 mM
Absolute maximum temperature	+41 °C	Soil pH	7.5
Absolute minimum temperature	- 21.8 °C	Water class	C2S1

regions of Iran (Table 1).

Experimental condition

The seedlings were planted in Islamabad-e-Gharb research farm of Research and Education Center of Agricultural and Natural Resources of Kermanshah Province with the following characteristics (Table 2) and under a randomized complete blocks design (RCBD) with three replications and 2.5 meter distances in a 1:1:1 mixture of arable soil, sand and rotten cow manure. The plants were irrigated once a week by drip irrigation. No chemical or toxic fertilizers were used during the project and mechanical methods were used to control the weeds.

Morphological and Yield Traits Measurement

In the second and third years after planting (2015-2016) morphological and yield traits including canopy cover, number of flowers per plant, number of flowers per hectare, fresh and dry weights of flowers, fresh and dry weights of petals, fresh and dry flower production per plant, wet petal production per plant, wet and dry flower yield per hectare, wet petal yield per hectare and EO yield were measured and evaluated. During the flowering period, every morning, the number of flower per plant was counted and the flowers were harvested. Flower dry weight was measured by placing 100 flowers in an oven for 48 hours at 70 °C. To measure the dry weight of the petals, the petals of 100 flowers were separated and kept in an oven at 60 °C for 48 h and then weighed. The wet and dry yield of flowers and petals per plant was calculated by multiplying the number of flowers per plant by the average fresh and dry weight of flowers and petals. Flower petal yield per hectare was obtained by formula 1 and petal yield per hectare by formula 2.

(1) Flower yield (Kg)=[flower number (N)×Average weight of Flower (g)×plant number/ha]/1000

(2) Petal yield (Kg)=[flower number (N)×Average weight of petal of a flower (g)×plant number/ha]/1000

EO extraction

The rose flowers were harvested early in the morning and were immediately transferred to the laboratory. Five hundred g of the fresh petals were used for EO isolation. EOs were extracted by water distillation for 3 h, using the Jaimand-Rezaie status based on the Clevenger and British pharmacopoeia (1993) under the same conditions (Jaimand *et al.,* 2005a). The EO samples were dehydrated with sodium sulfate anhydrous (Na_2So_4), weighted and kept in a refrigerator (4 °C). The EO content in 100 g of petals was calculated by Formulas 3 and EO yield (4).

(3) EO%=EO weight in 500 g petals/5

(4) EO yield (Kg)=(EO%×Petal Yield)/100

Data analysis

The data were analyzed by analysis of variance, Duncan test at 5% level, cluster analysis (Euclidean distance between groups), discriminant factor analysis for the confirmation of the results of cluster analysis and determination of cut line in cluster analysis diagram, principal component analysis (PCA) and Pearson's correlation coefficients by SPSS Ver. (16) and Minitab ver. (16) software's.

RESULTS

Univariate analysis

The results of analysis of variance (Table 3) showed that there was a significant difference between the years for all the studied traits except essential oil percentage, flower dry weight, and petal dry weight and between genotypes for all the studied traits except flower dry weight and petal dry weight. The year/genotype interaction was significant for all the traits except essential oil percentage, flower dry weight, petal dry weight, and large plant diameter (Table 3). The descriptive statistics for traits presented in Table 4.

The results of comparison of means (Table 5) by Duncan method (p<5%) showed that the highest number of flowers per plant (1606.94±448.0) was obtained in Isfahan5 genotype (no 37) and then number of flowers per plant (1533.1±125.3) in Fars1 genotype (no 16) and the lowest (519.55±125.03 number) in Azarbaijan-e-gharbi1 genotype (no 2). The highest large diameter, small diameter, and canopy cover were observed in Lorestan1 genotype (no 26) and then in Isfahan5 genotype (no 37), respectively, and the lowest of these three factors were observed in Azarbaijan-e-gharbi1 genotype. The highest average of flower fresh weight were found in Fars1 genotype (3.90±0.55 g) and Azarbaijan-e-gharbi1 genotype (3.63±0.44 g), respectively, and the lowest was observed in genotype (no 31) Yazd1 (2.40±0.36 g). The highest averages of dry flower weight were observed in Khorasan2 genotype (0.48±0.03 g) and Azarbaijan-e-gharbi1 (0.47±0.014 g), respectively, and the lowest average was observed in genotype Isfahan7 (0.35±0.001 g).

Azarbaijan-e-gharbi1 showed the highest average of petal fresh weight (2.42±0.12 g) and Isfahan5 showed the lowest one (1.73±0.19 g). The highest fresh weight of flowers per plant were found in Fars1 (4615±566.6 g) and Isfahan5 (3760±830.91 g), respectively, and the lowest one was observed in genotype Azarbaijan-e-gharbi1 (1604±226.18 g). Fars1 showed the maximum average fresh weight of the petals in a flower (3029.02±494.77 g) and Azarbaijan-e-gharbi1 showed the lowest one (1199.65±259.64 g).

The highest fresh yields of flowers (7383.8±970.43 kg.ha^{-1}) were observed in Fars1 and then (6016±1329.45 kg.ha^{-1}) in Isfahan5 and the lowest fresh yields of flowers (2566.1±361.90 kg) was observed in Lorestan1. Fars1 (4846.42±791.63 kg.ha^{-1}) and (no 2) Isfahan8 genotypes (4044.4±612.20 kg.ha^{-1}) had the highest fresh yields of petals per hectare, respectively, and Azarbaijan-e-gharbi1 (1919.44±415.42 kg.ha^{-1}) had the lowest fresh yields of petals per hectare.

The highest content of EO (%) were obtained in the genotypes (no 48) Kermanshah9 (0.048±0.002%) and (no 4) Isfahan9 (0.044±0.002%), respectively, and the lowest content of EO (%) was observed in genotype Fars1 (0.024±0.001%). The highest essential oil yields were observed in ISFAH5 (2.25±0.46 kg.ha^{-1}) and for Isfahan9 (2.18±0.30 kg.ha^{-1}) and the lowest essential oil yields were obtained in Lorestan1 (0.81±0.12 kg.ha^{-1}) and Azarbaijan-e-gharbi1 (0.92±0.10 kg.ha^{-1}), respectively.

Multivariate analysis

The cluster analysis (Figure 1) based on Euclidean distance between groups classified the genotypes into four main groups. The group 1 was composed of six genotypes followed by Kermanshah 1, Kermanshah3, Khorasan2, Isfahan8, Isfahan9, and Yazd1. Five genotypes including Kermanshah8, Kermanshah9, Kermanshah10, Azarbaijan-e-gharbi1, and Esfahan7 were located in the second group (group 2). The genotypes Arak1, Fars1 and Isfahan5 were placed in the third group (group 3) and Lorestan1 genotype alone was placed in group 4. The maximum similarity was shown between Kermanshah1 and Kermanshah3 in the first group. Lorestan1 had the maximum dissimilarity with other studied genotypes. The cut of line in cluster diagram was determined based on the results of discriminant factor analysis which placed the genotypes in four groups and confirmed the results of cluster analysis (results not presented).

In the PC analysis, the three first components had eigen value higher than 1 and were showed 89% of cumulative variance. PC1 showed 0.45% of variance and PC2 showed 0.27% of variance. PC1 and PC2 showed 72% of cumulative variance (Table 5). The traits wet flower yield, dry flower yield, wet petal yield, dry petal yield, and EO yield had the maximum portion in PC1 and the traits EO yield, flower wet

Table 3. Analysis of variance for the morphologic and yield traits for the fifteen studied DR genotypes from Iran.

Source of variations	df	Mean of square								
		Flower number	EO%	Large diameter	Small diameter	Crown (canopy cower)	Flower wet weight	Flower dry weight	Petal wet weight	Petal dry weight
Year	1	29210000**	0.000036^{ns}	6583**	3908**	320200000**	21.43**	0.00^{ns}	4.26**	0.00^{ns}
Year/REP	2	6301.00	0.000006	4.15	14.89	24230.00	0.12	0.00	0.03	0.00
Genotype	14	573800**	0.00**	4667**	4527**	280700000**	1.23**	0.01^{ns}	0.28*	0.003^{ns}
Genotype/REP	28	30720.0	0.00001	793.72	1166.00	54610000	0.08	0.01	0.09	0.002
Year/gen	14	280000**	0.00001^{ns}	13.28^{ns}	7.03	1495000*	0.25**	0.00^{ns}	0.11	0.00^{ns}
Error	28	3.40	0.00004	9.93	11.29	6.02	0.08	0.0 0	0.08	0.001
Coefficient of variation (%)		0.17	16.60	1.88	2.31	0.012	11.07	11.07	14.35	1.62

Source of variations	df	Mean of square								
		Flower wet weight/plant	Flower dry weight/plant	Petal wet weight/plant	Petal dry weight/plant	Wet flower yield	Dry flower yield	Fresh petal yield	Dry petal yield	EO yield
Year	1	101100000**	38220000**	65390000**	802700**	258900000**	11280000**	174300000**	2055000**	30.03**
Year/REP	2	58920.00	115800.00	85450.00	106.81	150800.00	1213.00	112300.00	273.43	0.013
Genotype	14	7148000**	2024000**	1710000**	14030**	18300000**	217100**	4014000**	35910**	1.18**
Genotype/REP	28	292200.00	161800.00	191700.00	2903.00	748100.00	25040.00	563800.00	7431.00	0.12
Year/gen	14	2908000**	634700*	647300**	6380**	7444000**	111000**	1504000**	16330**	0.61**
Error	28	4.03	2.41	1.62	1.65	1.03	2.03	3.23	4.20	0.14
Coefficient of variation (%)		0.082	0.083	0.063	0.69	0.026	0.03	0.056	0.688	25.41

* and **: Significant difference at $p<5\%$ and $p<1\%$.
ns: No significant difference.

Table 4. The minimum, maximum, Mean, and SD for the morphologic and yield traits of the fifteen studied DR genotypes from Iran.

Statistical parameters	Year	FLOWN (number)	ESSPER (%)	LD (cm)	SD (cm)	CROWN (cm^2)	FWW (g)	FDW (g)	PWW (g)	PDW (g)
Min.	2016	228.7	0.02	111.0	76.0	6862	2.61	0.31	1.18	0.17
Max.		1151.7	0.05	236.0	217.0	40272	5.55	0.60	3.21	0.37
Mean		537.1	0.04	176.2	152.3	21998	3.27	0.39	2.19	0.24
SD		251.5	0.01	32.1	33.3	8356	0.63	0.06	0.35	0.04
Coefficient of variation (%)		0.17	16.60	1.88	2.31	0.012	11.07	11.07	14.35	1.62
Min.	2017	669.3	0.02	90.0	62.7	4574	1.18	0.31	1.25	0.17
Max.		2863.7	0.48	223.3	200.0	34618	3.21	0.60	2.59	0.37
Mean		1676.4	0.05	159.1	139.1	18226	2.15	0.39	1.75	0.24
SD		505.8	0.07	31.4	33.0	7431	0.33	0.06	0.34	0.04
Coefficient of variation (%)		0.17	16.60	1.88	2.31	0.012	11.07	11.07	14.35	1.62
Statistical parameters	**Year**	**WWFPL (g)**	**DWFPL (g)**	**WWPPL (g)**	**DWPPL (g)**	**WFYILD (Kg)**	**DFYILD (g)**	**WPYILD (Kg)**	**DPYLD (Kg)**	**ESSYILD (Kg)**
Min.	2016	831	106	590	59.2	1329	170	943	94.7	0.41
Max.		5727	628	2909	319.0	9164	1006	3912	510.3	2.35
Mean		1741	213	1176	130.3	2786	341	1826	208.5	1.06
SD		911	107	564	66.5	1458	172	799	106.3	0.46
Coefficient of variation (%)		0.082	0.083	0.063	0.69	0.026	0.03	0.056	0.688	25.41
Min.	2017	1681	281	1233	168.1	2689	449	1973	269.0	1.68
Max.		6357	1115	4287	643.4	10172	1780	6859	1029.5	3.13
Mean		3584	656	2881	397.5	5735.0	1049	4609	635.9	2.73
SD		1179	202	816	119.9	1886.9	323	1306	191.8	0.44
Coefficient of variation (%)		0.082	0.083	0.063	0.69	0.026	0.03	0.056	0.688	25.41

FLOWN: Flower number per plant, ESSPER: Essence percent, LD: Large diameter, SD: Small diameter, CROWN: Canopy cower, FWW: Flower wet weight, FDW: Flower dry weight, PWW: Petal wet weight, PDW: Petal dry weight, WWFPL: Wet weight of flower per plant, DWFPL: Dry weight of flower per plant, WWPPL: Wet weight of petal per plant, DWPPL: Dry weight of petal per plant, WFYILD: Wet flower yield, DFYILD: Dry flower yield, WPYILD: Wet petal yield, DPYLD: Dry petal yield, ESSYILD: EO yield.

weight, flower dry weight, petal wet weight, and petal dry weight had the maximum portions in PC2. The diagram of principal component analysis (Figure 2) showed that traits flower number, fresh and dry flower yield, fresh and dry petal yield, and EO yield showed a similar trend and had the highest positive contribution in the first component (Table 6). Genotypes Fars1 and Isfahan8 had the highest amounts of these traits. Genotypes Isfahan5, Arak1, Yazd1 and Kermanshah1 were highly correlated with the traits as large diameter, small diameter and canopy cover, which had a moderate positive contribution in the first component and had the high values of fresh and dry flower yield, fresh and dry petal yield and EO yield. Fars 1 showed the highest amounts of fresh flower weight, however, it was not the same for EO yield.

The traits fresh flower weight, dry flower weight, fresh petal weight and dry petal weight had the same trend and showed the most positive share in the first component. The highest values of these traits were obtained for genotypes Fars1, West Azerbaijan1 and Khorasan1. The EO percentage had a negative share in the first and second components and showed a special trend alone. Genotypes, Kermanshah8, Kermanshah9, Kermanshah10, Kermanshah3, and Isfahan7 showed the highest EO percentage.

Table 5. Means comparison for the morphologic and yield traits of the fifteen studied DR genotypes from Iran by Duncan method (p<5%).

Gen.	Mean±SE								
	FLOWN (number)	ESSPER (%)	LD (cm)	SD (cm)	CROWN (cm^2)	FWW (g)	FDW (g)	PWW (g)	PDW (g)
2	519±125^{h}	0.037±0.002^{e}	131.8±3.1^{h}	112±3.6^{j}	11889±688^{i}	3.63±0.44^{a}	0.47±0.01^{a}	2.42±0.12^{a}	0.28±0.0^{a}
4	1009±123^{def}	0.044±0.002^{ab}	165.7±6.7^{de}	155±6.3^{d}	20370±1671^{e}	2.43±0.19^{c}	0.35±0.01^{a}	1.91±0.13^{cd}	0.22±0.01^{cd}
16	1553±349^{a}	0.024±0.001^{g}	183.2±5.6^{c}	166±48^{c}	24065±1374^{c}	3.90±0.55^{a}	0.41±0.01^{b}	2.15±0.20^{abc}	0.25±0.01^{abc}
21	1284±319^{bc}	0.036±0.001^{e}	168.2±3.7^{d}	140±6.6^{fg}	18849±1185^{f}	2.53±0.21^{c}	0.36±0.01^{de}	1.84±0.15^{cd}	0.23±0.01^{c}
23	1013±234^{def}	0.035±0.001^{ef}	163.2±4.7^{e}	137±4.2^{g}	17791±1039^{g}	3.13±0.19^{b}	0.48±0.03^{a}	2.39±0.18^{ab}	0.26±0.01^{abc}
26	683±148^{gh}	0.032±0.002^{g}	220.0±4.9^{a}	200±4.5^{a}	34758±1530^{a}	2.65±0.31^{c}	0.39±0.02^{c}	1.91±0.19^{cd}	0.23±0.03^{c}
28	1241±279^{cd}	0.038±0.001^{de}	199.5±4.7^{b}	182±5.5^{b}	28688±1493^{b}	2.47±0.19^{c}	0.38±0.02^{c}	1.92±0.13^{cd}	0.23±0.01^{c}
31	1251±324^{bcd}	0.041±0.001^{bcd}	181.8±8.5^{c}	150±6.2^{e}	21841±1897^{d}	2.40±0.36^{c}	0.37±0.03^{cd}	1.78±0.14^{cd}	0.24±0.02^{bc}
37	1606±448^{a}	0.038±0.001^{cde}	200.8±5.1^{b}	179±4.7^{b}	28454±1349^{b}	2.66±0.24^{c}	0.37±0.00^{cd}	1.73±0.19^{d}	0.19±0.00^{d}
39	871±222^{efg}	0.039±0.002^{cde}	125.3±10.5^{i}	102±12.2^{k}	10655±2029^{j}	2.57±0.29^{c}	0.35±0.01^{e}	1.80±0.12^{cd}	0.22±0.02^{cd}
40	1479±232^{ab}	0.038±0.002^{cde}	181.3±18.3^{c}	141±24.2^{f}	22217±5393^{d}	2.53±0.21^{c}	0.38±0.01^{c}	1.87±0.11^{cd}	0.25±0.01^{abc}
42	1061±213^{c-f}	0.042±0.002^{bc}	169.6±3.7^{d}	144±3.0^{f}	19322±719^{f}	2.50±0.19^{c}	0.39±0.01^{c}	2.11±0.16^{a-d}	0.27±0.03^{bc}
47	1101±289^{cde}	0.039±0.001^{cde}	130.0±8.6^{h}	116±7.6^{i}	12147±1554^{i}	2.56±0.23^{c}	0.40±0.02^{b}	1.92±0.13^{cd}	0.246±0.01^{abc}
48	1099±322^{cde}	0.048±0.002^{a}	151.7±6.2^{f}	129±6.2^{h}	15645±1376^{h}	2.54±0.18^{c}	0.41±0.03^{b}	2.05±0.16^{bcd}	0.25±0.01^{abc}
49	823±187^{fg}	0.042±0.001^{bc}	142.5±12.2^{h}	129±11.0^{h}	14998±2489^{h}	2.53±0.23^{c}	0.39±0.03^{c}	1.76±0.10^{cd}	0.23±0.01^{c}

Gen.	Mean±SE								
	WWFPL (g)	DWFPL (g)	WWPPL (g)	DWPPL (g)	WFYILD (Kg)	DFYILD (g)	WPYILD (Kg)	DPYLD (Kg)	ESSYILD (Kg)
2	1624±232^{gh}	247±63^{f}	1200±260^{e}	146±37^{e}	2598±371^{gh}	396±101^{f}	1919±415^{f}	234±59^{e}	0.92±0.10^{f}
4	2353±606^{d-h}	354±42^{c-f}	1876±181^{cd}	221±28^{bcd}	3765±257^{d-h}	566±68^{c-f}	3003±290de	364±45^{bcd}	1.65±0.09^{cde}
16	4615±566^{a}	643±149^{a}	3029±495^{a}	388±88^{a}	7384±971^{a}	1029±239^{a}	4846±792^{a}	621±141^{a}	1.73±0.23^{a-d}
21	2766±597^{cde}	461±116^{bc}	2106±454^{c}	298±77^{b}	4426±907^{cde}	738±185^{bc}	3369±727^{bcd}	477±123^{b}	1.56±0.30^{cde}
23	2899±226^{cd}	481±118^{b}	2209±475^{c}	257±60^{bc}	4638±956^{cd}	770±189^{b}	3534±760^{bcd}	412±95^{bc}	1.61±0.31^{cde}
26	1604±226^{h}	267±63^{f}	1238±284^{e}	176±51de	2566±362^{h}	426±101^{f}	1981±455^{f}	281±82de	0.81±0.12^{f}
28	2863±487^{cd}	472±99^{bc}	2246±408^{c}	283±61^{b}	4581±780^{cd}	756±158^{bc}	3594±653^{bcd}	453±97^{b}	1.77±0.32^{a-d}
31	2511±508^{def}	462±118^{bc}	2302±631^{bc}	304±77^{b}	4018±814^{def}	739±189^{bc}	3684±1009^{bcd}	487±123^{b}	1.66±0.34^{b-e}
37	3760±830^{b}	597±167^{a}	2370±482^{bc}	290±82^{b}	6016±1330^{b}	955±267^{a}	3792±772^{bc}	464±132^{b}	2.25±0.46^{a}
39	1950±358^{e-h}	306±79^{ef}	1461±333de	192±52^{cde}	3121±574^{e-h}	490±127^{ef}	2338±533^{ef}	306±84^{cde}	1.15±0.16^{ef}
40	3568±416^{bc}	594±87^{a}	2788±303^{ab}	376±65^{a}	5709±666^{bc}	950±140^{a}	4044±612^{b}	601±103^{a}	2.18±0.30^{ab}
42	2453±373^{d-g}	409±82^{b-e}	2229±464^{c}	282±64^{b}	3925±597^{d-gf}	655±131^{b-e}	3567±742^{bcd}	452±102^{b}	1.63±0.24^{cde}
47	2587±548^{def}	441±116^{bcd}	1937±425^{cd}	268±70^{b}	4139±877^{def}	701±186^{bcd}	3100±680^{cd}	429±113^{b}	1.58±0.32^{cde}
48	2503±622^{def}	447±135^{bcd}	2061±535^{c}	277±83^{b}	4005±995^{def}	717±216^{bcd}	3298±856^{bcd}	443±133^{b}	1.84±0.45^{abc}
49	1885±293^{fgh}	332±83^{def}	1373±265^{e}	193±46^{cde}	3017±468^{fgh}	531±133^{def}	2197±423^{e}	309±74^{cde}	1.26±0.19^{def}

FLOWN: Flower number per plant, ESSPER: Essence percent, LD: Large diameter, SD: Small diameter, CROWN: Canopy cower, FWW: Flower wet weight, FDW: Flower dry weight, PWW: Petal wet weight, PDW: Petal dry weight, WWFPL: Wet weight of flower per plant, DWFPL: Dry weight of flower per plant, WWPPL: Wet weight of petal per plant, DWPPL: Dry weight of petal per plant, WFYILD: Wet flower yield, DFYILD: Dry flower yield, WPYILD: Wet petal yield, DPYLD: Dry petal yield, ESSYILD: EO yield. The common letters have no significant difference.

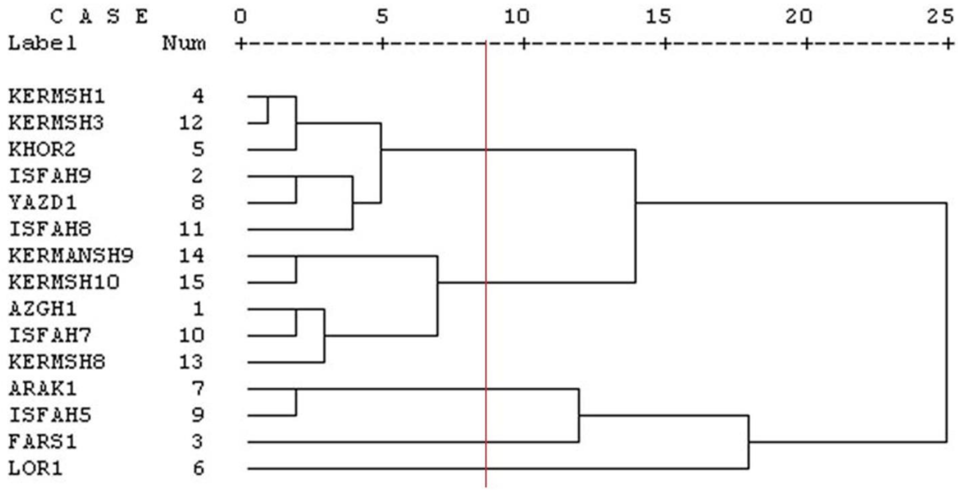

Figure 1. Dendrogram of average linkage (Euclidean distance between groups) between different *R. damascena* genotypes based on morphologic and yield traits.

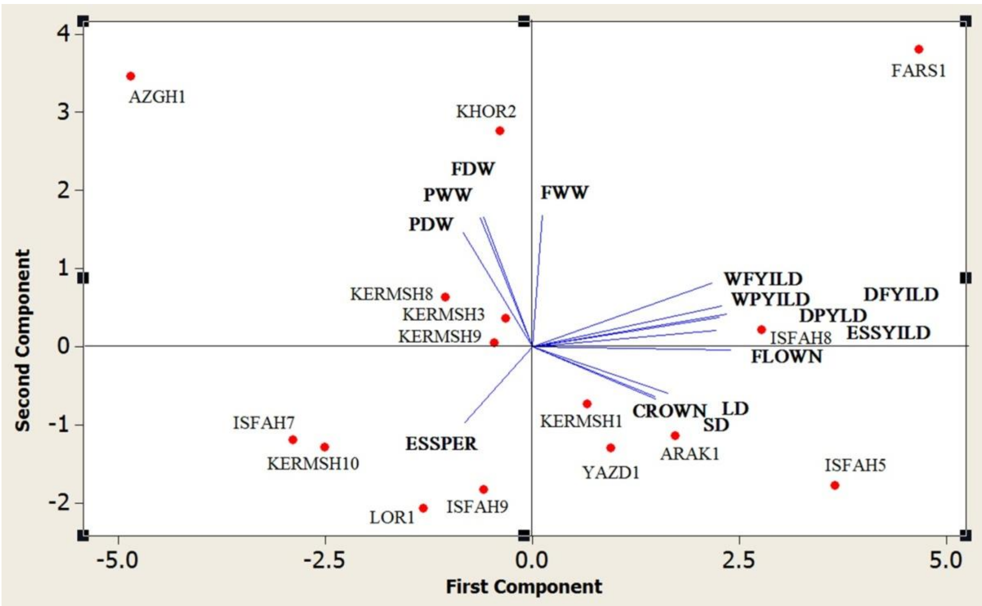

Figure 2. Diagram of PC1 and PC2 biplot for the different *R. damascena* genotypes based on morphologic and yield traits.

Table 6. Amounts of eigen value, variance and cumulative variance for the three first components in principal component analysis.

Variable	PC1	PC2	PC3	Variable	PC1	PC2	PC3
FLOWN (Flower number)	0.38	-0.01	-0.18	PWW (Flower wet weight)	-0.10	0.44	0.14
ESSPER (%EO)	-0.13	-0.03	-0.38	PDW (Flower dry weight)	-0.13	0.39	-0.05
LD (Large diameter)	0.26	-0.16	0.41	WFYILD (Wet flower yield)	0.34	0.22	-0.03
SD (Small diameter)	0.23	-0.17	0.45	DFYILD (Dry flower yield)	0.37	0.113	-0.16
CROWN (Canopy cover)	0.23	-0.18	0.46	WPYILD (Wet petal yield)	0.36	0.14	-0.16
FWW (Flower wet weight)	0.02	0.45	0.21	DPYILD (Dry petal yield)	0.36	0.10	-0.19
FDW (Flower dry weight)	-0.09	0.45	0.16	ESSYILD (EO yield)	0.35	0.07	-0.25
Eigen value	6.343	3.724	2.420				
Variance (%)	0.453	0.266	0.173				
Cumulative variance (%)	0.453	0.719	0.892				

Table 7. Pearson's correlation coefficients for the morphologic and yield traits of DR genotypes.

Traits	FLOWN	ESSPER	LD	SD	CROWN	FWW	FDW	PWW	PDW	WFYILD	DFYILD	WPYILD	DPYLD	ESSYILD
FLOWN	1													
ESSPER	-0.16	1												
LD	0.43	-0.33	1											
SD	0.35	-0.34	0.96**	1										
CROWN	0.36	-0.36	0.99**	0.98**	1									
FWW	-0.05	-0.73**	-0.10	-0.06	-0.09	1								
FDW	-0.29	-0.41	-0.24	-0.23	-0.24	0.76**	1							
PWW	-0.33	-0.30	-0.22	-0.22	-0.25	0.72**	0.89**	1						
PDW	-0.35	-0.10	-0.39	-0.44	-0.45	0.47	0.68**	0.78**	1					
WFYILD	0.82**	-0.55*	0.33	0.31	0.30	0.48	0.09	0.07	-0.05	1				
DFYILD	0.96**	-0.26	0.38	0.29	0.30	0.14	-0.03	-0.10	-0.16	0.89**	1			
WPYILD	0.91**	-0.24	0.38	0.30	0.30	0.16	-0.05	0.01	-0.01	0.88**	0.95**	1		
DPYLD	0.92**	-0.22	0.36	0.25	0.27	0.05	-0.14	-0.12	-0.00	0.83**	0.94**	0.96**	1	
ESSYILD	0.93**	0.00	0.30	0.24	0.23	0.01	-0.16	-0.15	-0.19	0.81**	0.94**	0.92**	0.89**	1

FLOWN: Flower number per plant, ESSPER: Essence percent, LD: Large diameter, SD: Small diameter, CROWN: Canopy cower, FWW: Flower wet weight, FDW: Flower dry weight, PWW: Petal wet weight, PDW: Petal dry weight, WFYILD: Wet flower yield, DFYILD: Dry flower yield, WPYILD: Wet petal yield, DPYLD: Dry petal yield, ESSYILD: EO yield. **, *: Correlation is significant at the 0.01 level and *: at the 0.05 level.

Pearson's correlation coefficient

The results of Pearson's correlation coefficient (Table 7) showed that the trait number of flowers with fresh and dry flower yield, fresh and dry petal yield and essential oil yield had a significant positive correlation. Essential oil percentage did not show a significant correlation with any of the yield and morphological traits. The traits large and small diameter of plant and canopy had a strong positive correlation with each other but did not show a significant correlation with yield traits. The fresh flower weight had a strong positive correlation with dry flower weight, fresh petal weight and dry petal. Fresh flower yield showed a strong positive correlation with dry flower yield, wet and dry petal yields and EO yield. The EO yield showed significant positive correlations with wet and dry petal yields.

DISCUSSION

Conservation and utilization of the native plant resources is essential for long term sustainability of biodiversity (Riaz *et al.,* 2011). Existence of rich genetic diversity for traits can provide the necessary ground for breeding such as different selection methods and hybridization in damask rose. Flower yield and yield components are important factors that should be considered to select superior genotypes of damask rose. For all morphologic and yield traits, there was a great variety between the studied genotypes. The existence of significant differences between the genotypes for these traits indicates the existence of genetic diversity.

In our study, there was a significant difference between the genotypes for all the studied traits except flower dry weight and petal dry weight. The great variety increases the chances of choosing superior genotypes. This high diversity observed in morphologic traits and yield components are consistent with the results of other researchers that have reported a large genetic diversity between different *Rosa damascena* genotypes in terms of morphologic characteristics, flower yield and essential oil yield such as: a great variety for flower yield in different genotype of *R. damascena* (Tabaei-Aghdaei and Rezaee 2004), morphological traits and flowering period (Tabaei-Aghdaei *et al.,* 2004a), yield components (Tabaei-Aghdaei *et al.,* 2005), flower yield and yield components (Kodori and Tabaei-Aghdaei, 2007), flower morphologic traits and EO compounds such as phenylethyl alcohol citronellol and geranial (Baydar *et al.,* 2016), Morphologic and yield traits (Yousefi *et al.,* 2016), EO content and compounds (Yousefi *et al.,* 2021).

Some other studies have shown the diversity and relationship among the rose genotypes for different morphological traits and PCR based random amplified polymorphic DNA (RAPD) technique (Riaz *et al.,* 2011). Khaleghi and Khadivi (2020) concluded that there was a high level of phenotypic variations among 327 wild populations of 21 *R. damascena* genotypes for morphologic and EO traits.

Cluster analysis classified the genotypes into 4 groups but did not show any relationship between geographical origins and these classes. Farooq *et al.* (2011) believed that in cluster analyses for morphological characters of damask rose no relationship was observed between genetic variations with their collection sites to be similar to our results. The lack of relationship between genetic diversity and different growing areas in some DR genotypes cultivated in different regions of Iran may be due to the common origin of seedlings grown in different parts of Iran (Yousefi *et al.,* 2011). In another study, cluster analysis based on morphologic and yield traits have revealed a racial and geographical dependence between some *R. damascena* genotypes (Zeinali *et al.,* 2009). Kian *et al.* (2010) resulted that cluster analysis separated 28 genotypes of *R. damascena* into 7 groups, fourteen genotypes from center of Iran stood in the first group and the Azerbaijan gharbi genotypes formed a separate group. Yousefi *et al.* (2021; 2016) concluded that classification of DR genotypes based on EO chemical compounds showed a relation between the geographical distances and the genetic distances. Yousefi *et al.* (2011) reported that in *R. damasena* landraces a positive correlation was observed between environmental variance (S2) and flower yield and according to dynamic stability, the adaptable genotypes produced a flower yield higher than average.

Also different genotypes of R. damascena based on six main important EO compounds were grouped in three classes and a correlation was shown between the genetic similarities of the groups with the regions these genotypes originate from (Gorji-Chakespari *et al.,* 2017). In a recent study, 15 populations of Damask rose were clustered into 3 groups (Toluei *et al.,* 2019). The results of these researchers are somewhat similar to our findings. Although, it seems that morphological and yield traits are more affected by climatic and ecological factors than the chemical composition of the EO, and perhaps the classification of DR genotypes based on the chemical composition of the essential oil will show clearer results of genetic and geographical similarities.

The PC analysis revealed the trend of traits, and the relationship between the studied traits and genotypes. Georgia - Chekspari *et al.* (2017) have pointed out that the analysis of principal components based on EO chemical compounds can be explained by two first components in DR genotypes. Khaleghi and Khadivi (2020) have identified some of the top DR genotypes in terms of maximum flower weight, petal weight and number of petals by PCA.

Pearson's correlation coefficients showed the significant positive correlations between the most of yield studied traits except EO percentage and crown with others. Jan Ahmadi *et al.* (2019) showed that flower yield significantly and positively correlated with morphological traits and yield components.

Tabaei-Aghdaei *et al.* (2004c) have noted that part of the observed diversity in *R. damascena* accessions is genetic and refers to the real difference between the genotypes collected from different areas with different climatic conditions. Due to the existence of genetic diversity, between the studied different genotypes, breeders can use them to produce new cultivars. Baydar *et al.* (2016) believed that the genetic in DR populations were appropriate for the clonal selection of novel varieties. Our results provided a new insight into the germplasm of Damask rose for the design of constructive breeding programs.

CONCLUSION

It should be noted that although Fars1 had the maximum flower yield but had the little EO yield and was not suitable for recommending to cultivation. The highest percentage of EO was obtained in genotype Kermanshah9 but no EO yield due to lower flower yield. These genotypes can not be recommended for cultivation, either. The highest EO yield (2.25 $kg.ha^{-1}$) was observed in Isfahan5 (37) and then (2.18 $kg.ha^{-1}$) in Isfahan9 (4). These two genotypes are recommended for future breeding programs and also for cultivation under the irrigation and ecological conditions similar to the ones in Kermanshah and other similar regions.

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Conflict of interest

The authors declare that there is no conflict of interest.

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