Evaluation of various *Rosa damascena* Mill. genotypes grown under rainfed semi-arid condition

Somayeh Jan ahmadi[1], Forough Mortazaeinezhad[1], Hossein Zeinali[2], Omid Askari-Khorasgani[1,3], and Mohammad Pessarakli[*4]

[1]Department of Horticulture, College of Agriculture and Natural Resources, Isfahan (Khorasgan) Branch, Islamic Azad University, Isfahan, Iran

[2]Isfahan Agricultural Research Center, Isfahan, Islamic Republic of Iran

[3]Young Researchers and Elite Club, Department of Horticulture, College of Agriculture and Natural Resources Isfahan (Khorasgan) Branch, Islamic Azad University, Isfahan, Iran ORCID: https://orcid.org/0000-0002-8956-5977

*[4]Professor, School of Plant Sciences, College of Agriculture and Life Sciences, The University of Arizona, Tucson, AZ 85721, USA ORCID: https://orcid.org/0000-0002-7662-2258 * Corresponding Author E-mail: Mohammad Pessarakli pessarak@email.arizona.edu*

ABSTRACT

Rosa damascena Mill L. also known as "Damask Rose" and "Gole Mohammadi" is a well-recognized high value ornamental and medicinal plant, which can be used in food, perfume and medicine industries. This studiy aimed to analyze the genetic diversity of 10 Rosa damascena genotypes by evaluating their morphological traits, flower yield and oil content to find the best genotype with a high productivity under rainfed condition in Lorestan province, Iran. This study was conducted in a completely randomized design trial with three replications. The data analyses, using Pearson's correlation coefficients showed that flower dry yield per hectare was significantly and positively correlated with, flower dry weight per plant, flowering period, plant height, number of flowers per plant, fresh and dry weight of petals, average weight of each flower, and number of flowers per day. Principal component (PC) analysis revealed that the first three PCs, respectively called as flower yield,

receptacle, and flower size components accounted for 88.33% of the total variation. The genotypes were grouped into four clusters in which the highest genetic distance was observed between Kermanshah and Fars1 genotypes. Fars1 and Yazd1 genotypes had the highest productivity in terms of respectively flower yield and oil content and showed the high potential for cultivation under rainfed condition in Lorestan province.

Key words: cluster analysis, essential oil, flower yield, genetic distance, principal component analysis, *Rosa damascene*

CONTACT: Mohammad Pessarakli, Professor pessarak@email.arizona.edu School of Plant Sciences, College of Agriculture & Life Sciences, The University of Arizona, Tucson, Arizona 85721, USA.

Introduction

The flora of the Middle-East is estimated at 15000 species by Heller (1991). Despite the advances in modern medicine, this region is still well-recognized for its medicinal plants with high pharmaceutical values that benefit human health. These medicinal plants have a high potential for treating different diseases as complementary alternative medicine (Azaizeh et al. 2006; Mayzlish-Gati et al. 2018). In the Middle-East, Lorestan Province in the West of Iran along the Zagros Mountains is a rich sourse of native medicinal plants/herbs due to its diverse climate and thus have strong potential of traditional and industrial agriculture (Delfan et al. 2014; Delfan, Kazemeini, and Bahmani 2015).

Rosa damascena Mill L. known as "Damask Rose" (Nayebi et al. 2017) and "Gole Mohammadi" (Mahboubi 2016), a perennial bushy shrub, is a commercially well-known ornamental plant with a worldwide demand in food, perfume and medicine industries due to its fragrance, pharmaceutical and therapeutic properties (Nayebi et al. 2017; Mahboubi 2016).

The orgin of *R. damascene* is the Middle-East and some documents indicate that the origin of rose water is Iran, but the origin of its fragrant oil and extracts is Greece (Zargari 1982). *R. damascene* is largely cultivated in Turky, Bulgaria, Iran, India, China, North African and Europe (Nayebi et al. 2017). *Rosa damascena* is a wild flower normally found in Caucasus, Syria, Morocco, and Andalusia (Chevallier 1996). *R. damascena* is principally cultivated to produce essential oil and rose water and also as an important ornamental flower in Iran. Genetic diversity of 40 *R. damascena* accessions in 28 provinces of Iran demonstrated that *R. damascena* is largely cultivated in Fars, Azarbayjan, and mainly in Isfahan (Kashan city) (Haghighi et al. 2006; Babaei et al. 2007; Mahboubi 2016).

Rosa damascena rose water is used in religious cermonies (Haghighi et al. 2006), beauty products, particularly as the ingredient in cosmetics and skin protection formulations, and also as a precious oil in the perfumery business. Due to its antimicrobial, antifungal, and antioxidant activities, *R. damascena* oil, particularly when it is mixed with other essential oils, can be used as antiseptic agent for eye washing, mouth and wound disinfecting and as antispasmodic agent for alleviating the abdominal pains, and bronchial and chest congestions (Basim et al. 2003; Loghmani Khouzani, Sabzi Fini, and Safari 2007; Mahboubi 2016; Nayebi et al. 2017) and also in aromatherapy (Heydari et al. 2018). *Rosa* petals and receptacles are the most important components in traditional medicine. Flower hydrosol known as *golab* or rose water is traditionally and industrially the main plant product produced by distillation and has widespread applications in Iran (Nikbakht and Kafi 2004; Moein, Zarshenas, and Delnavaz 2014).

Pharmaceutically, plant rose water has many therapeutic effects, such as sedative effects, and healing properties, in terms of digestive and respiratory systems, skin wounds, and healing cold. Vapor therapy with rose oil is helpful for some allergies, headaches, migraine, etc. (Nikbakht and Kafi 2004; Haghighi et al. 2006). *R. damascena* is traditionally

used for treatment of abdominal and chest pains, strengthening the heart, menstrual bleeding, digestive problems and constipation. The antimicrobial, antioxidant, analgesic, antiinflammatory, anti-diabetic, and anti-depressant properties of *R. damascena* have been corroborated (Mahboubi 2016). *R. damascena* oil has moderate antiviral activity against HIV (Mahboubi 2016) and its hip is a rich source of vitamin C (Haghighi et al. 2006).

Since *R. damascena* flower and its oil are the main components in food and pharmaceutical industries, *R. damascena* genotypes with high capacity to produce desirable flower yield and oil yield are commercially beneficial. *R. damascena* has a wide genetic dversity and complex morphological traits in which the number of flowers per plants vary from one genotype to another depending on the environmental conditions (Zeinali, Tabaei-Aghdaei, and Arzani 2009; Farooq et al. 2011). In this context, identifying the elite genotypes with desired traits is an important task in breeding programs. To date, no study has been conducted to demonstrate the *R. damascena* potential for cultivation in rainfed condition in Iran and particularly in Lorestan province. Hence, this study aimed to evaluate yield components and morphological traits of 10 *R. damascena* genotypes by using multivariate analysis method to determine the best genotype with a high flower and oil production capacity under rainfed condition in Lorestan province, Iran.

Materials and methods

Experimental site

To analyze the genetic diversity and the relationships between the morphological traits, 10 R. *damascena* genotypes were collected from different regions of Iran (Table 1). The *R. damascena* uniform hardwood cuttings were cultivated in a completely randomized design trial with a distance of 3 × 3 meter plant spacing in triplicate. Of each genotype, nine plants were cultivated in each replication (27 plants for each genotype and 270 plants for 10 genotypes). The soil physical and chemical properties were as follows: 38% sand, 51% silt,

11% clay, pH = 7.44, EC = 0.8 dS m^{-1}, available K = 500 ppm, available P = 11.8 ppm, organic carbon = 1.55%, and saturation percentage = 53%. The cuttings with at least 4 nodes and 8-10 mm in diameter and 20 cm length were selected from midle parts of plants at the end of summer on 16 September, 2016 and then stored in refrigerator at 4 º C and 80% relative humidity. The cuttings were planted 10 cm deep in the prepared soils (1-meter diameter soils consisted of 38% clay, 20% sand, and 50% manure) at late winter, on 20 March, 2016. Since *Rosa damascena* is a drought tolerant plant, which can grow well in Khorramabad with low annual rainfall (Table 2), the experiment was conducted under rainfed conditions at Agriculture and Natural Resources Research Center of Korramabad City (33° 29" N latitude, 48° 21" E longitude, and 1170 m above sea level), Lorestan province, Iran.

Morphological traits

The measured morphological traits were as followes: number of flowers per day, average weight of each flower (g), fresh weight of petals (g per flower), receptacle fresh weight (g), flower diameter (cm), number of petals per flower, dry weight of petals (g per flower), number of flowers per plant, plant height (cm), flowering period (day), flower dry weight (g per plant), and flower dry yield (kg ha^{-1}), oil yield (kg ha^{-1}). To calculate morphological paraeters, the plants were harvested 3-5 times from 25 April to 5 June, 2017. The flower diameter was determined by a caliper, and weight parameters were determined by a digital precision weighing analytical balance.

Oil extraction

The essential oils of dried petals (100 g) were isolated by hydrodistillation for 90 min using a Clevenger-type apparatus according to the method described in British

Pharmacopoeia (1988). After separating the oil from water by decantation, its content was measured as percentage (w/w).

Statistical analysis

Analysis of the multivariate data and clustering of genotypes were conducted using the SAS software and correlation between morphological traits was estimated by Pearson's test (version 9.4; SAS Inc., Carey, NC). Cluster analysis was performed according to Ward's minimum variance method (Ward 1963) using the cluster procedure of SAS computer software (Version 9.4; SAS Inc., Carey, NC 1996). Variance and relationship between 13 morphological traits of the 10 *R. damscena* genotypes were further studied by using principal component (PC) analysis and cluster analysis. The differences among the means were compared by using Duncan's New Multiple Range Test at 0.05 probability (*P*) level.

Results

In the present study, the morphological traits, flower yeld and oil contents of 10 landraces of *R. damascena* from different origin sites of Iran were determined. As described in Table 3, analysis of variance of 10 genotypes demonstrated that morphological traits, oil yield and flower yield were significantly ($P < 0.01$) affected by genotype variations. The mean comparisons of 10 *R. damascena* genotypes for the 13 morphological traits revealed significant differences among different genotypes, suggesting that genotype selection for superior traits could be possible (Table 4). Comparing the genotypes, genotype 16 (Fars1) exhibited markedly higher flower dry yield (25.11 kg ha^{-1}), flower dry weight (22.6 g per plant), flowering period (23.67 days), plant height (109 cm), number of flowers per plant (286.67), dry weight of petals per flower (0.24 g), fresh weight of petals per flower (1.67 g), average weight of each flower (2.13 g), number of flowers per day (12.28). With respect to

flower size, genotype 21 (Kermanshah) and 31 (Yazd1) had larger flower diameter (6.45 cm), genotype 39 (Isfahan7) had a greater number of petals (31.26 petals per flower), and genotype 37 (Isfahan5) had greater receptacle fresh weight (0.56 g) than other genotypes. Despite having comparatively lower flower yield, the highest oil contents were obtained from genotype 31 (Yazd1) (0.012 kg ha^{-1}) followed by genotype 6 (Ilam) (0.011 kg ha^{-1}) and 37 (Isfahan5) (0.011 kg ha^{-1}) as compared to the other genotypes.

As shown in Table 5, the correlations among the traits indicated that flower dry yield was significantly positively correlated with the number of flowers per day, average weight of each flower, fresh and dry weight of petals per flower, number of flowers per plant, plant height, flowering period, and flower dry weight per plant. In the same way, number of flowers per plant was correlated with average weight of each flower as well as fresh and dry weight of petals per flower. However, there was no correlation between oil yield and other traits. Thus, it can be hypothesized that selection of genotype 31 (Yazd1) for oil yield would be the best option for oil production. Quantitative trait locus (QTL) mapping and marker assisted selection (MAS) (Collard and Mackill 2008) can provide valuable information to identify the genes responsibe for high flower and oil production in these elite genotypes and to design superior plants in the future.

Principal component (PC) analysis revealed the comparative importance of the variables in the clusters. The PC analysis of the traits explained 88.33% of the total variance among the gentypes in the first three PCs, respectively by 64.83, 13.16, and 10.23% of the total variance in PC1 to PC3 (Table 6). The PC1 was associated with the number of flowers per day, average weight of each flower, fresh and dry weight of petals per flower, number of flowers per plant, number of petals per flower, plant height, flowering period, flower dry weight per plant, as well as flower dry yield and, therefor, it was called flower yield component. The PC2 included the receptacle fresh weight and oil yield and, hence, it was

called receptacle component. Considering the PC3, the flower diameter and number of petals were the most important traits and, therefore, it was called the flower size component (Table 6).

According to the cluster analysis, the genotypes were classified into 4 groups. First cluster included genotypes 40, 29, and 21, second cluster included genotypes 37 and 39, and third cluster was divided into 2 sub-groups consisted of genotypes 6, 23, and 31 in the first sub-group and genotype 4 in the second sub-group. Cluster 4 included genotype 16 and, thereby, the highest genetic distance was recorded between the genotypes 21 (Kermanshah) and 16 (Fars1) (Figure 1, Table 7).

Discussion

Comparing the genotypes, significant differences were observed between morphological traits and oil content, indicating that genotype selection for superior traits was possible by using multivariate analysis procedure. With 25.11 g ha^{-1}, genotype 16 (Fars1) had the highest potential to produce flower yield, while the highest oil yield was obtained from genotype 31 (Yazd1) as comared to other genotypes (Table 4). The results are consistent with those reported by Tabaei-Aghdaei et al. (2007) in which the highest flower oil content was obtained from Guilan, Mazandaran, Golestan, followed by Yazd province. It can be hypothesized that the effect of genotype on determining the rose flower yield and oil content was greater than that of environmental conditions. Studies on chemical composition of Guilan, Mazandaran, Golestan, and Yazd landraces can provide more insights for selecting genotypes and engineering Damask Rose with high quality oil.

The Pearson's correlation coefficients showed that the morphological traits could be used in breeding programs for selecting plants with high capacity to produce flower yield. Considering the positive and negative correlations and also mean values between traits, the

data presented in Tables 4 and 5 faciliate the selection of genotypes with high potential for flower yield production. In the same way, Tabaei-Aghdaei et al.'s (2004) findings demostrated a strong positive correlation between flower yield and number of flowers per plant. In this study, pairwise Pearson's correlation coefficients indicated that the flower yield was significantly ($P < 0.01$) positively correlated with the average number of flowers per day, average weight of each flower, fresh and dry weight of petals and the number of flowers per plant (Tables 4 and 5). In agreement with the present study, Zeinali, Tabaei-Aghdaei, and Arzani's (2009) stepwise regression analysis for flower yield per plant demonstrated that the number of flowers per plant was responsible for 90% of the total variation in flower yield and, thus, could be used for selecting plants with high potential for flower production.

In this study, PC analysis revealed that PC1 kown as flower yield component accounted for 64.83% of variation and hence the above-mentioned factors that had positive correlation with flower yield could be used for selecing the genotype with high potential for flower yield production (Tables 4, 5, and 6). Zeinali, Tabaei-Aghdaei, and Arzani's (2009) data demonstated that four main principal components, which explained 86% of the total variation, describing that morphophological variations should be taken into account to select the superior plants. However, in agreement with the present study, their findings demonstrated that number of flowers per plant was markedly positively correlated with flower yield (Zeinali, Tabaei-Aghdaei, and Arzani 2009).

As described by Tabaei-Aghdaei et al. (2004), cluster analysis and principal component analysis of 11 Damask Rose genotypes demonstrated significant differences among the tested genotypes based on their morphological traits, in which the first three components accounted for 68.43% of the total variation and the genotypes were grouped into 3 clusters. In this study, as shown in Figure 1 and Table 7, the genotypes were grouped into four clusters in which genotype 16 (Fars1) with the highest potential for flower yield

production (Table 4) had the greatest genetic distance with the genotype 21 (Kermanshah) (Figure 1) as compared to other genotypes. Similar to the results of Table 4 where Fars1 genotype showed the highest flower yield mean value compared to other genotypes, cluster analyss represented in Table 7 also demonstrated that cluster 4 that included Fars1 genotype (Figure 1) had considerably greater flower yield related parameters (i.e., higher number of flowers per day, average weight of each flower, fresh and dry weight of petals per flower, number of flowers per plant, plant height, flowering period, flower dry weight, and flower dry yield) as comperd to other clusters.

Analysis of variance among clustures revealed the significant differences among all morphological traits as the major source of diversity, except for receptacle fresh weight, flower diameter, and oil yield. Future studies on determining the quality of oil and the genes responsible for oil productivity in Yazd1 genotype can provide insight into desining the super plants with high productivity in terms of producing high oil quality and oil content as well as flower yield. The greater flower yield production of Fars1 in cluster 4 and oil yield of Yazd1 could be the result of their adaptation to the desert-like environmental conditions of their endemic region likely by epigenetic control and human selection. Zeinali, Tabaei-Aghdaei, and Arzani's (2009) study showed that Tehran genotype had the highest potential for flower yield production, which was in positive correlation with the number of flowers per plant, and flowering period as the chief productivity factors, most likely due to plant genetic, adaptation to its environment, as well as irrigation and cultivation management practices. Because the tested genotypes are endemic to Iran and are widely cultivated in Lorestan province for many years, the productivity of the genotypes were mostly affected by genotype variation than the environment and exhibited the high potential for cultivation under rainfed conditions. Future investigation for assessing the oil quality and cultivation practices, particularly regulated deficit rrigation or partial root drying, and also genetic mapping can provide valuable

information for cultivating and engineering Damask Rose species with improved productivity and quality indices.

Conclusions

These findings demonstrated that genetic diversity of Damask Roses had a significant influence on plant productivity possibly due to long-term adaptation to environmental conditions (epigenetic control), natural selection by environment and/or by human interference. The findings also demonstrated that the number of flowers per day and per plant, average weight of each flower, fresh and dry weight of petals, plant height, flowering period, and flower dry weight were the most important morphological traits that should be considered for the selection of Iranian Damask Rose genotypes with desired flower yield under reinfed conditions in Lorestan province. Plant productivity in terms of oil yield and flower yield were affected by plant genetic and their adaptation to hot and dry conditions in their origin sites. In this regard, the highest flower yield was obtained from Fars1 and the greatest oil content was obtained from Yazd1 and hence they can be good candidates to be used in traditional and modern breeding programs. Finally, and more importantly, the results verified that these genotypes had the potential for cultivation under rainfed conditions in Lorestan province. Oil analysis, genetic mapping, and MAS can be used in breeding programs to produce a new generation of plants with superior traits in terms of oil quality and content as well as flower yield in the future.

Acknowledgements

This work was only possible because of the help from Research Center and Natural Resources of Khorramabad. We are especially grateful to officials of these organizations.

References

Azaizeh, H., B. Saad, K. Khalil, and O. Said. 2006. The state of the art of traditional arab herbal medicine in the eastern region of the mediterranean: A review. *Evidence-based Complementary and Alternative Medicine* 3 (2): 229-235. doi: 10.1093/ecam/nel034

Babaei, A., S. R. Tabaei-Aghdaei, M. Khosh-Khui, R. Omidbaigi, M. R. Naghavi, G. D. Esselink, and M. J. M. 2007. Microsatellite analysis of Damask rose (*Rosa damascena* Mill.) accessions from various regions in Iran reveals multiple genotypes. *BMC Plant Biology* 7 (1): 12. doi: 10.1186/1471-2229-7-12

Basim, E., and H. Basim. 2003. Antibacterial activity of *Rosa damascena* essential oil. *Fitoterapia*, 74 (4): 394-396. doi: 10.1016/s0367-326x(03)00044-3

British pharmacopoeia. 1988. British pharmacopoeia, London: HMSO, 2, pp. 137–138.

Chevallier, A. 1996. The encyclopedia of medicinal plants. Dorling Kindersley, London, 336p.

Collard, B. C. Y., and D. J. Mackill. 2008. Marker-assisted selection: an approach for precision plant breeding in the twenty-first century. *Philosophical Transactions of the Royal Society B: Biological Sciences* 363 (1491): 557-572. doi: 10.1098/rstb.2007.2170

Delfan, B., M. Bahmani, H. Hassanzadazar, K. Saki, and M. Rafieian-Kopaei. 2014. Identification of medicinal plants affecting on headaches and migraines in Lorestan Province, West of Iran. *Asian Pacific Journal of Tropical Medicine* 7: 376-379. doi: 10.1016/s1995-7645(14)60261-3

Delfan, B., H. Kazemeini, and M. Bahmani. 2015. Identifying effective medicinal plants for cold in Lorestan province, West of Iran. *Journal of Evidence-Based Complementary & Alternative Medicine* 20 (3): 173-179. doi: 10.1177/2156587214568458

Farooq, A., M. A. Khan, A. Ali, and A. Riaz. 2011. Diversity of morphology and oil content of *Rosa damascena* landraces and related *Rosa* species from pakistan. *Pakistan Journal of Agricultural Sciences* 48 (3): 177-183.

Haghighi, M., A. Tehranifar, A. Nikbakht, and M. Kafi. 2006. Research and current profile of Iranian production of damask rose (*Rosa damascenea* Mill.). *Acta Horticulturae* 769: 449-455. doi: 10.17660/actahortic.2008.769.64

Heller, D. 1991. Conspectus Florae Orientalis. *Botanica Chronica 10***:** *55-61.*

Heydari, N., M. Abootalebi, N. Jamalimoghadam, M. Kasraeian, M. Emamghoreishi, and M. Akbarzaded. 2018. Evaluation of aromatherapy with essential oils of *Rosa damascena* for the management of premenstrual syndrome. *International Journal of Gynecology & Obstetrics* 142 (2): 156-161. doi: 10.1002/ijgo.12534

Loghmani Khouzani, H., O. Sabzi Fini, and J. Safari. 2007. Essential oil composition of *Rosa damascena* Mill. cultivated in central Iran. *Scientia Iranica* 14: 316-319.

Mahboubi, M. 2016. *Rosa damascena* as holy ancient herb with novel applications. *Journal of Traditional and Complementary Medicine* 6 (1): 10-16. doi: 10.1016/j.jtcme.2015.09.005

Mayzlish-Gati, E., M. Fridlender, R. Nallathambi, G. Selvaraj, S. Nadarajan, and H. Koltai. 2018. Review on anti-cancer activity in wild plants of the Middle East. *Current Medicinal Chemistry* 25 (36): 4656-4670. doi: 10.2174/0929867324666170705113129

Moein, M., M. M. Zarshenas, and S. Delnavaz. 2014. Chemical composition analysis of rose water samples from Iran. *Pharmaceutical Biology* 52 (10): 1358-1361. doi: 10.3109/13880209.2014.885062

Nayebi, N., N. Khalili, M. Kamalinejad, and M. Emtiazy. 2017. A systematic review of the efficacy and safety of *Rosa damascena* Mill. with an overview on its

phytopharmacological properties. *Complementary Therapies in Medicine* 34: 129-140. doi: 10.1016/j.ctim.2017.08.014

Nikbakht, A., and M. Kafi. 2004. A study on the relationships between Iranian people and Damask rose (*Rosa damascena*) and its therapeutic and healing properties. *Acta Horticulturae* 790: 251-254. doi: 10.17660/actahortic.2008.790.36

Statistical Analysis System Institute. 1996. *SAS/ STAT User's Guid*. Ver. 6.4, SAS Insititue Inc., Cary, NC.

Tabaei-Aghdaei, S. R., M. Sahebi, A. A. Jafari, and M. B. Rezaee. 2004. Evaluation of flower yield and morphological characteristics of 11 *Rosa damascena* Mill. genotypes using multivariate analysis. *Iranian Journal of Medical and Aromatic Plants* 20 (2): 199-213.

Tabaei-Aghdaei, S. R., A. Babaei, M. Khosh-Khui, K. Jaimand, M. B. Rezaee, M. H. Assareh, M. R. Naghavi. 2007. Morphological and oil content variations amongst Damask rose (*Rosa damascena* Mill.) landraces from different regions of Iran. *Scientia Horticulturae* 113 (1): 44-48.

Ward J. H. J. 1963. Hierarchical grouping to optimize an objective function. *Journal of the American Statistical Association* 58 (301): 236-244. doi: 10.1080/01621459.1963.10500845

Zargari, A. 1982. Medicinal Plants. Vol. 1. Tehran University Press, 951p. Tehran. Iran.

Zeinali, H., S. R. Tabaei-Aghdaei, and A. Arzani. 2009. A study of morphological variations and their relationship with flower yield and yield components in *Rosa damascena. Journal of Agricultural Science and Technology* 11 (4): 439-448.

Table1. Numbers and locations of 10 *Rosa damascena* genotypes.

Province	Genotype	Province	Genotype
Hormozgan	29	Isfahan9	4
Yazd1	31	Ilam	6
Isfahan5	37	Fars1	16
Isfahan7	39	Kermanshah	21
Isfahan8	40	Khorasan2	23

Table 2. Annual average meteorological data in Khorramabad City from 2005 to 2014.

Year	Temperature (°C)	Rainfall (mm per year)	Humidity (%)	Number of frost days (day)
2017	18.1	464.2	41	69
2016	17.5	463.5	42	68
2015	17.9	552.4	47	71
2014	15.7	421.7	47	68
2013	16.9	354.2	45	68
2012	16.3	285.4	40	88
2011	17.6	415.1	41	70
2010	17.0	475.3	46	37
2009	17.6	315.8	45	53
2008	17.0	468.2	47	61
2007	17.0	662.0	46	57
2006	17.5	433.9	43	40
2005	17.1	606.1	45	52

Table 3. Analysis of variance (ANOVA) of morphological traits, oil yield and flower yield among 10 *Rosa damascena* genotypes.

S.O.V.[a]	d.f.[b]	Oil yield	Flower dry yield per hectare	Flower dry weight per plant	Flowering period	Plant height	Number of flowers per plant	Dry weight of petals per flower
Genotype	9	0.1893**	9042.8060**	7326.2870**	15.2592**	430.7740**	14996.3296**	0.0009**
Error	18							

Contd…

	Number of petals	Flower diameter	Receptacle fresh weight	Fresh weight of petals per	Average weight of each	Number of flowers per day

1					flower	flower	
Genotype	9	7.2836**	0.4702**	0.0112**	0.0804**	0.824**	24.6741**
Error	18						

[a] Source of variation; [b] Degrees of freedom; **Significant at 1% Probability level.

Table 4. Mean comparisons of 10 *R. damascena* genotypes for morphological traits, oil yield, and flower yield by using Duncan's Multiple Range test.

Genotype	Oil yield (kg ha^{-1})	Flower dry yield (kg ha^{-1})	Flower dry weight (g per plant)	Flowering period (day)	Plant height (cm)	flowers per plant	petals (g per flower)	petals per flower	Flower diameter (cm)	Receptacle fresh weight (g)	petals (g per flower)	of each flower	Number of flowers per day
4	0.007^{bc}	17.60^{b}	15.84^{b}	19.67^{c}	92.67^{b}	142.00^{bc}	0.22^{b}	26.32^{f}	6.31^{ab}	0.35^{e}	1.47^{b}	1.82^{b}	6.97^{bc}
6	0.011^{ab}	12.62^{c}	11.36^{c}	19.33^{c}	84.33^{cd}	110.00^{d}	0.21^{cd}	27.93^{de}	5.38^{d}	0.41^{cd}	1.26^{cd}	1.67^{cd}	5.69^{de}
16	0.008^{bc}	**25.11^{a}**	**22.60^{a}**	**23.67^{a}**	**109.00^{a}**	**286.67^{a}**	**0.24^{a}**	29.93^{bc}	6.08^{bc}	0.46^{b}	**1.67^{a}**	**2.13^{a}**	**12.28^{a}**
21	0.005^{c}	4.96^{f}	4.47^{f}	15.67^{f}	67.67^{f}	47.00^{f}	0.19^{f}	28.93^{bcd}	**6.45^{a}**	0.44^{bc}	1.20^{de}	1.64^{d}	2.43^{g}
23	0.010^{abc}	12.01^{c}	10.81^{c}	19.67^{c}	84.33^{cd}	109.67^{d}	0.20^{ef}	28.72^{cd}	6.07^{bc}	0.35^{e}	1.29^{cd}	1.64^{d}	5.25^{e}
29	0.005^{c}	6.59^{ef}	5.93^{ef}	17.33^{e}	77.66^{de}	62.67^{ef}	0.19^{f}	28.44^{d}	5.84^{c}	0.44^{bc}	1.19^{de}	1.62^{d}	3.61^{f}
31	**0.012^{a}**	7.17^{e}	6.45^{e}	18.33^{d}	78.67^{de}	66.67^{e}	0.19^{ef}	27.67^{de}	**6.45^{a}**	0.38^{de}	1.21^{de}	1.59^{d}	3.69^{f}
37	0.011^{ab}	9.99^{d}	9.00^{d}	21.00^{b}	90.33^{bc}	133.00^{c}	0.20^{de}	30.19^{ab}	5.97^{c}	**0.56^{a}**	1.18^{e}	1.74^{bc}	6.33^{cd}
39	0.009^{bc}	12.15^{c}	10.93^{c}	21.00^{b}	95.33^{b}	153.33^{b}	0.22^{bc}	**31.26^{a}**	6.03^{bc}	0.40^{cd}	1.38^{bc}	1.78^{b}	7.17^{b}
40	0.008^{bc}	5.87^{ef}	5.28^{ef}	17.67^{de}	73.67^{ef}	59.67^{ef}	0.18^{g}	26.64^{ef}	5.30^{d}	0.43^{bc}	1.15^{e}	1.58^{d}	3.00^{fg}

[a] All values are means. Mean values in each column followed by the same lower-case letters are not significantly different ($p < 0.05$) by Duncan's Multiple Range test.

Table 5. Pairwise Pearson's correlation coefficients for morphological traits, oil yield, and flower yield components of 10 *R. damascena* genotypes.

Number of flowers per day	1												
Average weight of each flower (g)	**0.96	1											
Fresh weight of petals (g per flower)	**0.91	**0.93	1										
Receptacle fresh weight (g)	0.13	0.19	-0.18	1									
Flower diameter (cm)	0.07	0.19	0.26	-0.19	1								
Number of petals per flower	0.43	0.40	0.22	0.47	0.18	1							
Dry weight of petals (g per flower)	**0.94	**0.92	**0.94	-0.06	0.17	0.39	1						
Number of flowers per plant	**1.00	**0.97	**0.91	0.16	0.08	0.44	**0.93	1					
Plant height (cm)	**0.98	**0.90	**0.86	0.10	0.08	0.44	**0.93	**0.96	1				
Flowering period (days)	**0.94	**0.83	*0.76	0.19	-0.02	0.49	**0.84	**0.94	**0.97	1			
Flower dry weight (g per plant)	**0.96	**0.93	**0.95	-0.08	0.10	0.19	**0.94	**0.95	**0.92	**0.85	1		
Flower dry yield (kg ha^{-1})	**0.96	**0.92	**0.95	-0.08	0.10	0.19	**0.94	**0.95	**0.92	**0.85	**1.00	1	
Oil yield (kg ha^{-1})	0.15	-0.08	-0.09	0.01	-0.12	0.11	0.06	0.12	0.23	0.40	0.09	0.09	1

*, **: significant at 5 and 1% Probability levels, respectively.

1

Table 6. Principal components coefficients of the evaluated traits in 10 *R. damascena* genotypes.

Traits	PC1	PC2	PC3
Number of flowers per day	0.99	0.06	-0.02
Average weight of each flower (g)	0.96	-0.01	0.19
Fresh weight of petals per flower (g)	0.93	-0.32	0.08
Receptacle fresh weight (g)	0.07	0.83	0.31
Flower diameter (cm)	0.13	-0.34	0.59
Number of petals	0.41	0.62	0.43
Dry weight of petals per flower (g)	0.96	-0.11	0.02
Number of flowers per plant	0.99	0.07	0.01
Plant height (cm)	0.97	0.09	-0.08
Flowering period (day)	0.92	0.26	-0.19
Flower dry weight per plant (g)	0.96	-0.19	-0.10
Flower dry yield per hectare (kg)	0.96	-0.19	-0.10
Oil yield (kg ha^{-1})	0.12	0.39	-0.69
Variance Proportion percent	64.83	13.16	10.23
The Cumulative Variance percent	64.83	78.00	88.23

Table 7. Analysis of variance of morphological traits, oil yield, and flower yield in addition to mean comparisons between cluster groups in *R. damascena* genotypes**.**

Traits	Mean Squares	Mean of Clusters[a]			
		Cluster1	Cluster2	Cluster3	Cluster4
Number of flowers per day	22.49**	3.01^{c}	6.75^{b}	5.40^{bc}	12.28^{a}
Average weight of each flower (g)	0.07**	1.61^{b}	1.76^{b}	1.68^{b}	2.13^{a}
Fresh weight of petals per flower (g)	0.06*	1.18^{b}	1.28^{b}	1.30^{b}	1.67^{a}
Receptacle fresh weight (g)	0.006^{ns}	0.43^{a}	0.48^{a}	0.37^{a}	0.46^{a}
Flower diameter (cm)	0.02^{ns}	5.86^{a}	6.00^{a}	6.05^{a}	6.08^{a}
Number of petals	5.13*	28.00^{b}	30.72^{a}	27.66^{a}	29.93^{ab}
Dry weight of petals per flower (g)	0.0007*	0.18^{b}	0.21^{b}	0.20^{b}	0.24^{a}
Number of flowers per plant	13850.14**	56.45^{c}	143.17^{b}	107.09^{bc}	286.67^{a}
Plant height (cm)	376.42**	73.00^{c}	92.83^{b}	85.00^{bc}	109.00^{a}
Flowering period (day)	14.09**	16.89^{c}	21.00^{b}	19.25^{b}	23.67^{a}
Flower dry weight per plant (g)	77.12**	5.22^{b}	9.96^{b}	11.11^{b}	22.60^{a}
Flower dry yield per hectare (kg)	95.21**	5.80^{b}	11.07^{b}	12.35^{b}	25.11^{a}
Oil yield (kg ha^{-1})	0.00001^{ns}	0.006^{a}	0.01^{a}	0.01^{a}	0.008^{a}

*, **: Significant at the 5% and 1 % Probability levels, respectively, ns: Non-significant.

[a] All values are means. Mean values in each column followed by the same lower-case letters are not significantly different ($P < 0.05$) by Duncan's Multiple Range test.

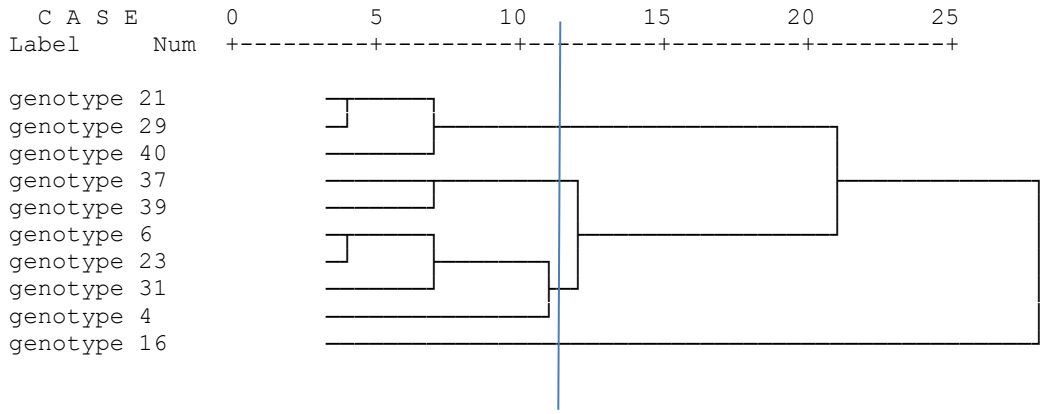

Figure 1. Dendrogram generated by cluster analysis of morphological traits using Ward's clustering procedures.