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Chemical Variation in the Essential Oil of Iranian *Rosa damascena* Landraces under Semi-arid and Cool Conditions

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Abstract
In present study, essential oil content and compositions of 49 Iranian landraces of Damask rose (*Rosa damascena* Mill.) was investigated. Essential oils were isolated with distillation method and component composition was determined with gas chromatography–mass spectrometry (GC/MS). Twenty main compounds were identified in the essential oil representing about 90% of the total oil. The major components were found to be n-nonadecane (with seasonal range of 32.4-36.1%), n-heneicosane (20.3-22.1%), citronellol (6.6-10.3%), n-hexadecanol (6.4-6.7%) and n-tricosane (5.9-7.0%). The percentages of citronellol and geraniol as the two important compounds of the rose oil quality in 2008 were more than their percentages in 2007. Therefore, it can be inferred that dry conditions increased the aliphatic compounds percentages and reduced alcoholic compounds in the rose oil. Despite the differences in origin sites, climates and ecological conditions among landraces, the results of cluster analysis (CA) revealed that all of the landraces of Damask rose with exception of KB1 and AK1 showed more than 90% similarity in their major oil composition. The result of principal component analysis (PCA) revealed that the landraces with the highest percentage of citronellol and geraniol components usually show extreme values (positive or negative) of PC1 and PC2.

Keywords: *Rosa damascena* Mill., essential oil composition, semi-arid conditions, geraniol, citronellol.

Introduction

Rosa genus, belonging to the *Rosaceae* family, includes 200 species and more than 18,000 cultivars (Gudin, 2000). One of the most important *Rosa* species is Damask rose (*Rosa damascena* Mill.), which is a deciduous shrub growing to 2.2 m tall, barbed stem, pinnate leaves with five leaflets, scented pink to light red flowers. Damask rose is one of the most important medicinal, aromatic and ornamental plants which is cultivated for its essential oil and medicinal aspects in many areas of the world e.g. Bulgaria, Turkey, India, Iran etc. (Yousefi et al. 2009; Tabaei-Aghdaei et al., 2007). Damask rose (*R. damascena* Mill.) is used to produce rose oil and water, concrete and absolute which are valuable and important base materials for the perfume and cosmetic industry (Ayci et al., 2005).

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The main producers of rose oil are Bulgaria, Turkey, Iran and India (Rusanov et al., 2009). Different parts of this plant especially flowers are valuable in the medicinal, food and aromatic industries. The essential oil of *R. damascena* is one of the most valuable and important base material in the flavor and fragrance industry. Besides its application in aromatic industries, some valuable characteristics of Damask rose oil such as anti-HIV (Mahmood et al., 1996) antibacterial (Basim and Basim, 2003) and antioxidant (Achuthan et al., 2003; Ozkan et al., 2004), anticancer (Ren et al., 2003), laxative/purgative (Gholamhoseinian et al., 2010 and 2012) activities have been reported. In accordance to this, Boskabady et al. (2011) reviewed literatures related to the pharmacological effects of *R. damascena* and noted that anti-HIV, antibacterial, antioxidant, hypnotic, antidiabetic, and some more are the major pharmacological effects of *R. damascena*. Due to the difficulties for production of rose oil, the low oil content and the lack of natural and synthetic substitutes, rose oil is one of the most expensive essential oils. Natural rose oil is most expensive in the world market as compared to its synthetic substitute, and the global demand of high grade rose oil is likely to increase in near future (Probir and Rakesh, 2013). More than 400 volatile compounds have been identified in the floral scent of various rose cultivars until now, that can be classified into five major groups based on their functions: hydrocarbons, alcohols, esters, aromatic ethers, and some others (including aldehydes, the rose oxides and norisoprenes) (Lavid et al., 2002). A Literature survey on the essential oils of *R. damascena* showed citronellol, nonadecane, geraniol, ethanol, heneicosane, nerol and 1-nonadecene were the major constituents (Bayrak and Akgül, 2006; Verma et el., 2011; Ozel et al., 2006; Loghmani-Khouzani et al., 2007; Koksal et al., 2015; Moein et al., 2010; Shahbazi and Esmaeili, 2012; Javed Naquvi et al., 2014). Literature review showed the considerable effect of environmental factors such as annual rainfall, temperature, humidity, light, soil, pruning, nutrient supply, harvesting time (Topalov, 1964; Prakasa Rao et al., 1995; Sangwan et al., 2001; Mirali et al., 2012; Probir and Rakesh, 2013), years and oil types (Bayrak and Akgül, 2006) on the rose oil. Furthermore, flower ontogeny and growing site (Verma et el., 2011), flower stages, flower parts, harvesting date and fermentation period (Weiss 1997, Verma et al., 2011; Baydar and Baydar, 2005), extraction techniques (Ozel et al., 2006), storing and drying treatments (Koksal et al., 2015), pressure and temperature during distillation (Kiran et al., 2002) can affect the oil content and composition. For example, Kiran et al., 2002 reported that the monoterpene hydrocarbons and esters were found to be in traces, and stearoptene content was found to be higher in the oil distilled under high pressure, as compared to oil produced under atmospheric pressure. Verma et al. (2011) showed that oil content and kind and order of oil compounds can be different among Damask rose cultivars. Essential oil content and composition are complex trait, which are dependent on yield components and is highly influenced by many genetic as well as environmental factors. Therefore evaluation of genotype from different environments is an important step in breeding programs of Damask rose before selecting desirable ones for commercial cultivation.

Iran has been mentioned as one of its origins and in this country, cultivation and consumption of *R. damascena* has a long history (Rusanov et al., 2009). There are limited numbers of publications that have studied the essential oil content and compositions of mainly one or few landraces of *R. damascena* landraces in Iran (Loghmani-Khouzani et al., 2007; Moein et al., 2010; Shahbazi and Esmaeili, 2012). A considerable portion of the *R. damascena* cultivation and appropriate

lands for cultivation development are located in semi-arid and cool areas of Iran including Kurdistan, Azerbaijan and Zanjan provinces.

The aim of this research was to identify the chemical composition of the essential oils of a largepopulations (49 different Damask rose landraces belonged to diverse location of Iran) under semi-arid and cool condition of Sanandaj (Kurdistan province) by GC-MS analysis. Often these landraces such as Kurdistan group of landraces, EA1, QZ1, WA1, AR1, FA2, BC1, GU1, IL1 etc. haven't been previously studied.

Materials and Methods

Location of research

The research was performed in Jalleh research station of Agriculture and Natural Resources Research Center of Kurdistan province (Sanandaj - Iran) during 5 years (2004-2008). The area of research has located in temperate and cool areas of Iran, with 1373.4 m altitude, 47º 00′ Longitude (East), 35 º 20′ Latitude (North), yearly mean optimum temperature about 16 °C (Fig. 2), annual rainfalls and evaporation of 462.4 and 1340 mm respectively and 2860 h total sunny hours.

Plant materials

Plant materials were consisted of 49 Damask rose landraces belonging to diverse parts of Iran (Table 1, Fig. 1). The land preparation and planting holes (with diameter and depth equal to 1 m × 1 m) were conducted in autumn of 2004. After preparing the holes (soil bed with a mixture of soil, sand and manure) and culture conditions, the safe and uniform annual saplings of the landraces were planted in March 2004 using randomized complete block design (RCBD) with three replications. Plant spacing was 3m × 3m (1111 plants per hectare) and every plot was comprised of three plants. Normal cultural practices (drop irrigation 3 times per month, etc.) were carried out and also performedwhen necessary. About 900 g fresh flowers (approximately 250-450 flower and 83-150 flowers per plant related to landrace) of each landrace were collected in early morning in the mid to end of May for each year (2007 and 2008) and were immediately prepared for extraction practices.

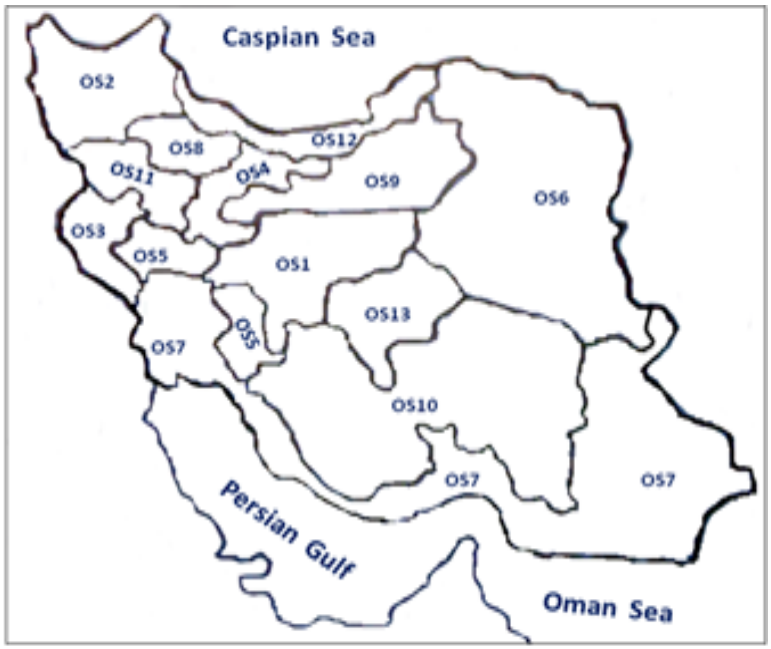

Fig. 1. The origin sites of Damask rose landraces (OS1- Os13) on the map of Iran [34].

Table 1. Origins of Damask rose landraces according to geographical similarities (Tabaei-Aghdaei et al., 2007)

Landraces	Origin site	Province(s) included	Climate*	Landraces	Origin site	Province(s) included	Climate*
IS1- IS10	Os1	Isfahan	T,A	ZA1, QZ1	Os8	Zanjan, Qazvin	C, CT,SA
EA1, WA1, AR1	Os2	East and west Azerbaijan, Ardabil	C, CT, SA	SM1, SM2, QM1	Os9	Semnan, Qom	WT,A
IL1, KS1	Os3	Kermanshah, Illam	T,SA	FA1, FA2, KM1	Os10	Fars, Kerman	T,SA,A
TH1, AK1	Os4	Tehran, Markazi	C T,SA	HA1, KR1-KR12	Os11	Kurdistan, Hamedan	C,SA
CM1, KB1,LO1	Os5	Chaharmahall, Kohkilloyah ,Lorestan	CT,T, SA	GU1, GL1	Os12	Guilan, Gulestan	T,H
KO2	Os6	Razavi Khorasan	T,SA	YZ1, YZ2	Os13	Yazd	WT,A
KZ1, HO1, BC1	Os7	Khuzestan, Hormozgan, Sistan	W,A				

Notes: *T: Temperate, C: Cool, W: Warm, A: Arid, SA: Semi-arid, H: Humid
Yearly mean temperature in warm, temperate and cool climates are 15-25 ºC, 10-15 ºC and 0-5 ºC, respectively. Yearly mean rainfalls in semi-humid, semi-arid and arid climates 600-1400mm, 300-600 and 100-300mm, respectively.

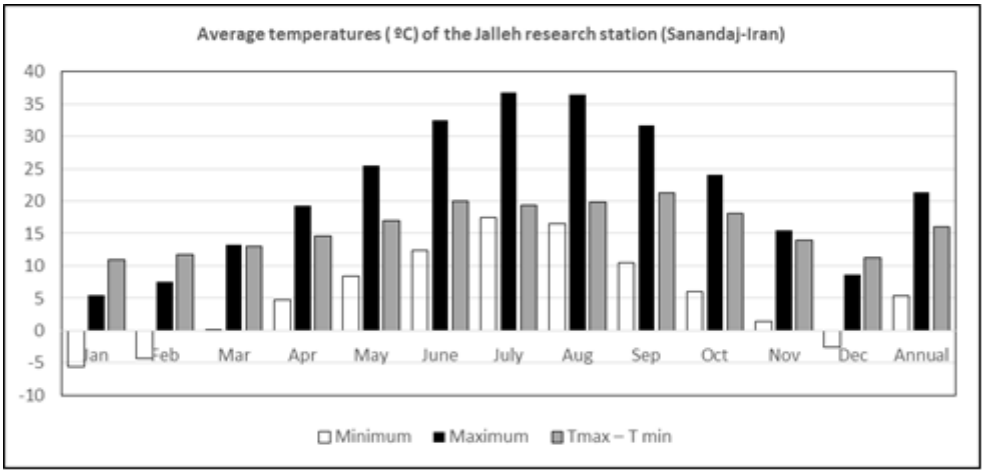

Fig. 2. Average temperatures (ºC) of the Jalleh research station (Sanandaj-Iran).

Isolation Procedure

The extraction of essential oil was performed by hydro distillation (HD). Fresh petals of the plants (500 g) were separately subjected to hydro distillation for every landraces and years (2007 and 2008) for 90 minutes using a hydro distillation (HD) type apparatus for oil extraction. The oils were dried over anhydrous sodium sulfate and stored in sealed vials, at low temperature (4-6 °C), before analysis.

Gas Chromatography

GC analysis was performed using a Thermo-UFM (Ultra Fast Model) (Italy), (Chrom-Card A/D) equipped with a HP-5 (non polar), silica capillary column (dimethylsiloxane phenyl 5%, 10 m × 0.1 mm i.d, film thickness 0.4 µm) with helium with a purity of 99.99 % as the carrier gas with column pressure of 5.1 kg/cm^2 and split ratio, 1:20. Oven temperature was performed as follows: 60 °C (3 minutes) to 210 °C at 3 °C/ minutes; Injector and detector (FID) temperature were 290 °C and 280 °C respectively.

Gas Chromatography- Mass Spectrometry

GC-MS analyses of the essential oil samples were carried out on a Varian 3400 GC- MS system equipped with a DB-5 fused silica column (30m × 0.25mm i.d., film thickness 0.25 µm); Oven temperature was 40 ^{0}C to 250 ^{0}C at a rate of 4 ^{0}C, transfer line temperature 270 ^{0}C, carrier gas helium with a linear velocity of 50 ml/ minute, Ionization energy 70 eV.

Identification of Components

The components of the oils were identified by comparison of their mass spectra with those of computer library (Wiley 5) or with authentic compounds and confirmed by comparison of their retention indices,

either with those of authentic compounds or with data published in the literature (Adams, 1995).

Statistical analyses

Cluster analysis (using an agglomerative hierarchical method with standardized variables by subtracting the means and dividing by the standard deviation and dendrogram with average linkage method and squared Euclidean distance) and principal component analysis (PCA) (using correlation matrix and score plot for first 2 components) were performed for grouping and characterizing of *R. damascena* landraces based on the major oil components (Manly, 2005) using Minitab 14 software.

Results

The results showed that the average essential oil yield of the studied Damask rose landraces was about 0.01% and the landraces of IS2, IS3, IS4 and IS8, from Isfahan province with 0.021%, 0.021%, 0.018% and 0.017% respectively produced the highest oil yield among studied landraces (Table 2).

In this study, twenty major compounds were identified in the essential oil of forty-nine Iranian landraces of Damask rose representing more than 90% of the total oil (Tables 2 & 3). The number of identified components and their percentage in 2007 and 2008 and average of two years are shown in the Table 3. The major components of oil of studied landraces were found in 2007. The following component with their percentages are as the following: n-nonadecane (36.1%), n-heneicosane (22.1%), n-tricosane (7%), n-hexadecanol (6.7%) and citronellol (6.6%), while in 2008; n-nonadecane (32.4%), n-heneicosane (20.3%), citronellol (10.3%), cis-rose oxide (6.8%) and n-heptadecane (6.6%), and average of two years; n-nonadecane (34.2%), n-heneicosane (21.2%), citronellol (8.5%), n-hexadecanol (6.5%) and n-tricosane (6.4%).

The essential oil content of landraces in 2008 (0.012%) was more than that's in 2007 (0.009%). Table 2 shows that drier conditions led to decrease in oil content. In other words, very dry environmental conditions reduce the quality and quantity of oil. The landraces of AK1, IS3, QM1, IS4 and KM1 with 46.5%, 25.5%, 22.3%, 19.8% and 17.9% citronellol and KR3, QZ1, QM1, IS4 and KR12 with 14.2%, 9.0%, 6.0%, 5.0% and 4.1% geraniol produced the highest percentage of citronellol and geraniol among studied Damask rose landraces (Table 2 and Fig. 3). Comparing the oil of the studied Damask rose landraces showed variation between the percentage of major and minor components (Table 2, Fig. 3). For example, the quantity of citronellol and geraniol varied from 46.5% and 14.2% (in the oil of AK1 and KR3) to 0.3% and 0.4% (in the oil of KR7 and KR8). Among major compounds of rose oil cis-rose oxide, geraniol, n-octane, n-tridecane and β-citronellene showed the highest variation while n-heneicosane, n-nonadecane, n-eicosane, n-tricosane and n-hexadecanol showed the lowest variation. Although there were different origin sites, climates and ecological conditions among Iranian Damsk rose landraces, the results of cluster analysis revealed that all of rose landraces with exception of KB1 and AK1 showed more than 90% similarity in the major oil composition. The landrace of AK1 produced the highest citronellol and more than average geranial, geraniol, n-docosane, n-eicosane, n-pentadecanol and n-tricosane while KB1 produced the lowest monoterpene alcohols but a higher amount of alkanes such as n-heneicosane, n-hexadecanol, n-pentadecane, n-tetradecanol and n-tricosane among studied landraces (Fig. 4). The result of principal component analysis (PCA) revealed that 6 first PC with 2.94, 2.37, 1.27, 1.02, 0.83 and 0.58 eigen values respectively cover more than 90% of total variance. Based on the score plot of first 2 components (Fig. 5) the landraces of AK1, IS3, QM1, IS4,

KM1, KR3, QZ1 and KR12 with the highest percentage of citronellol and geraniol components usually show extreme values (positive or negative) of PC1 and PC2. The landraces of QM1 and IS4 with high percentage of citronellol and geraniol components showed negative PC1 but positive PC2.

Table 2. Average percentage of major compounds of the essential oil from fresh petals of 49 landraces of *Rosa damascena*

Landrace Compound	Retention Index (RI)	Year	EA1 1	WA1 2	AR1 3	IS9 4	IS10 5	IL1 6	TH1 7	CM1 8	QM1 10	KZ1 11	ZA1 12	SM1 13	SM2 14	BC1 15	FA1 16	FA2 17	QZ1 18	KR1 19	KM1 20	KS1 21	KB1 22	KO2 23	GL1 24	GU1 25	LO1 26
cis-rose oxide	1104	2007	0.3	0.3	0.3	*	*	*	*	*	0.3	*	*	*	*	*	*	*	0.3	*	*	*	*	*	*	*	*
		2008	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	4.9	*	*	*	*	*	*	*	*	*
		mean	0.3	0.3	0.3	*	*	*	*	*	0.3	*	*	*	*	*	*	4.9	0.3	*	*	*	*	*	*	*	*
citronellol	1234	2007	14.8	12.5	14.7	19.0	5.6	9.6	3.0	1.3	22.3	6.4	7.7	0.8	1.2	25.3	3.7	2.9	20.4	2.1	9.0	15.2	0.9	3.1	1.6	0.9	4.8
		2008	0.6	1.9	0.9	1.9	8.0	5.7	13.6	9.1	*	*	3.8	10.4	17.7	3.2	4.5	4.5	6.0	*	26.9	10.7	*	12.0	2.9	32.0	2.5
		mean	7.7	7.2	7.8	10.5	6.8	7.7	8.3	5.2	22.3	6.4	5.8	5.6	9.5	14.3	4.1	3.7	13.2	2.1	18.0	13.0	0.9	7.6	2.3	16.5	3.7
geranial	1262	2007	8.7	5.0	7.5	0.6	1.7	1.3	1.6	*	9.7	0.9	*	*	*	0.5	1.0	*	14.5	1.3	2.5	1.1	0.5	1.2	1.0	0.7	1.5
		2008	0.5	*	*	*	2.1	0.7	3.7	2.2	0.4	*	*	*	6.1	*	*	*	*	*	9.0	1.1	*	3.6	1.4	8.8	1.8
		mean	4.6	5.0	7.5	0.6	1.9	1.0	2.7	2.2	5.1	0.9	*	*	6.1	0.5	1.0	*	14.5	1.3	5.8	1.1	0.5	2.4	1.2	4.8	1.7
geraniol	1251	2007	4.0	3.3	2.7	*	0.9	0.7	1.0	*	3.3	0.4	1.9	*	*	0.4	0.4	*	9.0	0.8	1.1	0.7	*	0.5	0.6	0.4	0.9
		2008	0.1	*	0.5	0.4	1.0	0.4	1.8	1.0	8.7	5.6	*	0.5	2.2	*	*	4.0	*	*	3.9	0.7	*	1.8	0.6	5.2	0.5
		mean	2.1	3.3	1.6	0.4	1.0	0.6	1.4	1.0	6.0	3.0	1.9	0.5	2.2	0.4	0.4	4.0	9.0	0.8	2.5	0.7	*	1.2	0.6	2.8	0.7
n-docosane	2200	2007	0.6	0.6	*	*	*	*	0.5	0.5	*	0.7	1.0	0.7	0.9	*	*	0.6	*	1.2	*	*	*	0.5	*	*	
		2008	*	0.9	0.9	0.5	0.7	0.5	*	*	*	0.8	0.8	1.4	*	0.8	0.6	*	0.7	1.1	*	0.6	0.5	0.4	0.3	*	0.4
		mean	0.6	0.8	0.9	0.5	0.7	0.5	0.5	0.5	*	0.8	0.9	1.1	0.9	0.8	0.6	0.6	0.7	1.2	*	0.6	0.5	0.4	0.4	*	0.4
n-eicosane	2000	2007	2.5	3.0	2.4	2.6	3.5	3.7	2.9	4.3	2.1	4.1	3.7	4.8	4.6	2.5	3.2	4.3	1.8	4.3	3.0	3.1	2.8	3.4	3.8	3.8	2.4
		2008	2.3	5.3	5.9	4.9	5.1	4.4	3.0	3.9	4.7	4.7	5.0	6.4	2.9	4.4	4.0	3.7	4.6	5.3	1.9	3.8	2.1	3.3	2.3	1.0	2.7
		mean	2.4	4.2	4.2	3.8	4.3	4.1	3.0	4.1	3.4	4.4	4.4	5.6	3.8	3.5	3.6	4.0	3.2	4.8	2.5	3.5	2.5	3.4	3.1	2.4	2.6
n-heneicosane	2100	2007	13.6	15.4	12.7	14.0	21.5	22.0	18.9	26.7	11.8	26.1	17.5	27.4	30.0	11.5	21.7	27.3	9.6	26.0	16.1	17.9	28.2	17.0	25.8	23.8	13.7
		2008	11.2	40.4	22.2	30.2	27.4	25.8	17.0	21.8	31.0	29.3	30.8	26.7	14.9	28.4	23.0	21.2	31.6	24.9	9.8	21.8	17.0	18.6	14.7	5.2	13.1
		mean	12.4	27.9	17.5	22.1	24.5	23.9	18.0	24.3	21.4	27.7	24.2	27.1	22.5	20.0	22.4	24.3	20.6	25.5	13.0	19.9	22.6	17.8	20.3	14.5	13.4
n-heptadecane	1700	2007	1.0	2.6	2.8	*	*	*	*	*	*	*	8.4	1.6	*	2.7	0.9	*	5.1	1.5	0.9	*	1.5	3.1	6.0	4.9	7.3
		2008	11.3	0.3	5.5	0.5	11.7	6.2	6.7	1.8	0.6	4.0	5.0	7.2	9.0	*	1.6	3.3	*	6.4	8.2	6.3	8.9	5.0	5.4	2.7	5.7
		mean	6.2	1.5	4.2	0.5	11.7	6.2	6.7	1.8	0.6	4.0	6.7	4.4	9.0	2.7	1.3	3.3	5.1	4.0	4.6	6.3	5.2	4.1	5.7	3.8	6.5
n-hexadecanol	1878	2007	4.0	2.3	1.8	7.3	7.7	7.1	8.5	8.2	5.4	7.3	4.7	7.8	5.2	8.5	13.4	7.2	2.0	3.9	9.0	6.0	16.0	11.5	5.8	4.6	11.2
		2008	5.0	0.9	7.3	3.5	4.2	9.9	7.5	7.5	3.8	9.1	6.4	*	6.5	7.5	4.3	8.2	4.5	2.2	6.9	8.2	10.0	9.1	10.0	3.1	10.6
		mean	4.5	1.6	4.6	5.4	6.0	8.5	8.0	7.9	4.6	8.2	5.6	7.8	5.9	8.0	8.9	7.7	3.3	3.1	8.0	7.1	13.0	10.3	7.9	3.9	10.9
n-nonadecane	1900	2007	20.4	20.3	15.6	26.9	38.9	41.7	38.3	40.5	23.6	31.8	24.6	42.0	41.0	32.4	32.4	42.3	19.7	33.1	40.9	33.3	*	*	*	*	*
		2008	34.0	36.2	25.9	45.8	23.9	33.4	35.1	39.5	33.6	32.0	36.0	24.3	29.3	39.9	41.5	27.6	37.5	30.6	24.4	36.8	30.4	35.3	52.3	14.5	26.8
		mean	27.2	28.3	20.8	36.4	31.4	37.6	36.7	40.0	28.6	31.9	30.3	33.2	35.2	36.2	37.0	35.0	28.6	31.9	32.7	35.1	30.4	35.3	52.3	14.5	26.8
n-octane	805	2007	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
		2008	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	2.7	*
		mean	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	2.7	*
n-pentadecane	1500	2007	5.7	5.5	2.6	2.7	2.9	0.9	1.7	0.9	1.7	1.1	2.4	*	0.4	1.5	0.4	0.9	2.0	3.7	1.3	2.7	1.0	*	1.0	1.5	1.8
		2008	13.9	*	14.5	*	1.3	0.5	*	*	*	*	*	1.6	0.5	0.3	*	2.5	*	8.5	*	*	8.2	*	0.7	2.3	17.8
		mean	9.8	5.5	8.6	2.7	2.1	0.7	1.7	0.9	1.7	1.1	2.4	1.6	0.5	0.9	0.4	1.7	2.0	6.1	1.3	2.7	4.6	*	0.9	1.9	9.8
n-pentadecanol	1776	2007	4.6	7.6	13.7	6.8	1.3	1.4	2.7	*	2.6	1.4	0.7	0.7	*	1.0	0.4	*	*	*	0.7	*	*	0.7	0.5	*	*
		2008	*	*	2.0	0.5	0.9	*	0.5	0.6	0.5	*	0.5	2.1	*	*	*	*	*	*	*	*	1.3	2.3	0.9	6.9	1.9
		mean	4.6	7.6	7.9	3.7	1.1	1.4	1.6	0.6	1.6	1.4	0.6	1.4	*	1.0	0.4	*	*	*	0.7	*	1.3	1.5	0.7	6.9	1.9
n-tetracosane	2400	2007	*	*	*	*	*	*	*	*	*	*	*	*	*	*	0.8	*	*	0.7	*	*	*	*	*	*	*
		2008	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
		mean	*	*	*	*	*	*	*	*	*	*	*	*	*	*	0.8	*	*	0.7	*	*	*	*	*	*	*
n-tetradecane	1400	2007	1.5	1.5	1.7	2.4	*	*	*	*	1.3	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
		2008	1.1	*	0.6	*	0.6	*	1.2	*	*	*	*	*	*	0.7	*	4.0	*	*	*	*	1.3	*	*	2.6	2.8
		mean	1.3	1.5	1.2	2.4	0.6	*	1.2	*	1.3	*	*	*	*	0.7	*	4.0	*	*	*	*	1.3	*	*	2.6	2.8
n-tetradecanol	1686	2007	2.9	1.8	1.2	3.5	4.0	4.8	6.2	4.7	4.0	3.8	3.6	3.7	2.7	4.8	4.4	3.1	*	2.7	6.9	4.5	2.5	5.5	1.0	1.8	1.9
		2008	10.5	2.3	1.1	4.9	1.0	*	*	5.5	4.0	0.4	*	*	0.5	3.6	3.7	*	3.3	4.1	0.6	*	5.4	*	1.4	2.6	3.8
		mean	6.7	2.1	1.2	4.2	2.5	4.8	6.2	5.1	4.0	2.1	3.6	3.7	1.6	4.2	4.1	3.1	3.3	3.4	3.8	4.5	4.0	5.5	1.2	2.2	2.9
n-tricosane	2300	2007	6.3	6.6	5.5	3.2	5.3	5.3	4.8	7.7	2.9	7.1	8.4	7.5	10.0	2.0	11.8	8.3	3.4	13.1	3.7	4.7	15.2	2.9	5.8	6.9	2.8
		2008	3.2	10.6	7.4	6.6	6.8	7.7	4.0	5.0	8.2	8.8	8.0	13.5	3.5	8.0	6.4	5.9	8.5	9.8	2.0	5.0	7.0	4.4	2.4	*	3.7
		mean	4.8	8.6	6.5	4.9	6.1	6.5	4.4	6.4	5.6	8.0	8.2	10.5	6.8	5.0	9.1	7.1	6.0	11.5	2.9	4.9	11.1	3.7	4.1	6.9	3.3
n-tridecane	1300	2007	*	*	*	*	*	*	*	*	*	*	3.6	*	*	*	0.7	*	0.8	*	0.4	0.7	*	*	*	*	*
		2008	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	1.0	*
		mean	*	*	*	*	*	*	*	*	*	*	3.6	*	*	*	0.7	*	0.8	*	0.4	0.7	*	*	*	1.0	*
trans- rose oxide	1136	2007	0.5	0.6	1.4	2.8	*	*	*	*	1.4	*	0.4	*	*	3.8	*	0.3	2.9	*	1.0	1.7	*	*	*	*	*
		2008	*	*	*	*	0.3	*	0.7	0.9	0.4	*	*	0.6	1.8	*	*	*	0.3	0.3	1.5	*	*	0.6	*	1.1	*
		mean	0.5	0.6	1.4	2.8	0.3	*	0.7	0.9	0.9	*	0.4	0.6	1.8	3.8	*	0.3	1.6	0.3	1.3	1.7	*	0.6	*	1.1	*
β-citronellene	954	2007	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
		2008	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	3.6	*
		mean	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	3.6	*
Total percentage	-	2007	91.4	88.9	86.6	91.8	93.3	98.5	90.1	94.8	92.4	91.1	88.6	97.0	96.0	96.9	95.2	97.2	91.5	94.4	96.5	91.6	68.6	48.9	53.4	49.3	48.3
		2008	93.7	98.8	94.7	99.7	95.0	95.2	94.8	98.8	95.9	94.7	96.3	94.7	94.9	96.8	89.6	89.8	97.0	93.2	95.1	95.0	92.1	96.4	95.3	95.3	94.1
		mean	92.6	93.9	90.7	95.8	94.2	96.9	92.5	96.8	94.2	92.9	92.5	95.9	95.5	96.9	92.4	93.5	94.3	93.8	95.8	93.3	80.4	72.7	74.4	72.3	71.2
Oil content (%)	-	2007	0.006	0.008	0.011	0.006	0.008	0.006	0.016	0.010	0.013	0.010	0.006	0.008	0.012	0.010	0.002	0.014	0.006	0.007	0.019	0.006	0.006	0.012	0.010	0.018	0.002
		2008	0.008	0.013	0.010	0.014	0.010	0.013	0.016	0.015	0.015	0.013	0.008	0.009	0.015	0.012	0.004	0.014	0.005	0.007	0.011	0.007	0.007	0.009	0.006	0.011	0.004
		mean	**0.007**	**0.010**	**0.010**	**0.010**	**0.009**	**0.009**	**0.016**	**0.012**	**0.014**	**0.011**	**0.007**	**0.009**	**0.014**	**0.011**	**0.003**	**0.014**	**0.006**	**0.007**	**0.015**	**0.007**	**0.007**	**0.011**	**0.008**	**0.015**	**0.003**

Landrace Compound	RI	Year	AK1 28	HO1 29	HA1 30	YZ1 31	YZ2 32	IS1 33	IS2 34	IS3 35	IS4 36	IS5 37	IS6 38	IS7 39	IS8 40	KR2 41	KR3 42	KR4 43	KR5 44	KR6 45	KR7 46	KR8 47	KR9 48	KR10 49	KR11 50	KR12 51	EOC Mean
cis-rose oxide	805	2007	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	0.3
		2008	*	*	*	*	*	*	*	*	*	*	*	*	*	14.5	0.9	*	*	*	*	*	*	*	*	*	6.8
		mean	*	*	*	*	*	*	*	*	*	*	*	*	*	14.5	0.9	*	*	*	*	*	*	*	*	*	2.7
citronellol	954	2007	*	3.9	7.6	1.4	0.7	7.0	*	6.3	0.8	6.5	5.0	7.4	12.1	6.0	4.7	3.0	3.1	1.8	0.4	1.9	7.5	1.9	5.7	*	6.6
		2008	46.5	10.5	8.9	3.6	12.0	4.0	11.0	44.7	38.8	7.9	11.5	0.8	17.7	1.5	*	1.3	9.0	0.8	0.2	*	17.7	*	1.9	2.1	10.3
		mean	46.5	7.2	8.3	2.5	6.4	5.5	11.0	25.5	19.8	7.2	8.3	4.1	14.9	3.8	4.7	2.2	6.1	1.3	0.3	1.9	12.6	1.9	3.8	2.1	8.5
geranial	1104	2007	*	0.3	3.2	*	*	*	*	*	*	*	*	*	*	*	*	1.5	0.3	1.0	0.9	0.6	6.2	1.2	2.7	6.0	2.8
		2008	8.5	*	2.3	*	1.4	0.5	*	3.6	16.8	1.0	2.1	*	2.1	12.4	1.3	1.7	0.5	0.9	*	*	6.1	*	2.2	2.3	3.6
		mean	8.5	0.3	2.8	*	1.4	0.5	*	3.6	16.8	1.0	2.1	*	2.1	12.4	1.3	1.6	0.4	1.0	0.9	0.6	6.2	1.2	2.5	4.2	3.3
geraniol	1136	2007	1.5	*	2.0	*	*	*	*	*	*	1.6	*	1.7	*	*	*	0.7	*	0.5	0.4	0.4	3.7	0.7	1.4	7.2	1.8
		2008	4.1	0.4	1.3	*	0.6	0.4	*	1.1	5.0	0.4	1.0	*	0.9	0.7	14.2	0.3	*	*	*	*	3.2	*	0.9	0.9	2.2
		mean	2.8	0.4	1.7	*	0.6	0.4	*	1.1	5.0	1.0	1.0	1.7	0.9	0.7	14.2	0.5	*	0.5	0.4	0.4	3.5	0.7	1.2	4.1	2.0

n-docosane	1234	2007	1.6	*	8.1	0.7	0.8	*	*	*	0.7	*	*	0.6	*	0.3	0.5	*	0.6	0.8	1.4	0.8	0.7	1.4	1.1	0.9	1.1
		2008	*	1.1	0.4	0.4	0.4	0.6	0.7	*	*	0.9	0.4	0.8	0.3	0.4	0.4	0.4	0.5	*	0.5	0.4	0.2	0.4	0.7	0.5	0.6
		mean	1.6	1.1	4.3	0.6	0.6	0.6	0.7	*	0.7	0.9	0.4	0.7	0.3	0.4	0.5	0.4	0.6	0.8	1.0	0.6	0.5	0.9	0.9	0.7	0.8
n-eicosane	1251	2007	6.8	4.1	3.8	4.6	4.5	3.9	4.3	4.1	4.8	4.0	4.2	3.9	3.7	4.0	3.9	3.0	4.3	3.1	3.6	3.7	3.1	4.0	4.1	3.9	3.7
		2008	1.2	6.2	3.6	4.0	3.6	4.3	5.4	1.6	1.1	6.2	3.3	4.7	2.5	2.7	3.8	2.4	4.0	2.0	2.7	2.3	2.3	2.2	3.0	2.6	3.6
		mean	4.0	5.2	3.7	4.3	4.1	4.1	4.9	2.9	3.0	5.1	3.8	4.3	3.1	3.4	3.9	2.7	4.2	2.6	3.2	3.0	2.7	3.1	3.6	3.3	3.6
n-heneicosane	1262	2007	30.8	27.5	21.4	27.7	31.1	29.8	29.7	23.6	32.5	26.0	26.6	24.0	19.8	22.0	23.4	14.7	27.9	22.5	23.0	20.8	19.0	23.3	22.2	19.3	22.1
		2008	6.5	29.5	21.0	22.4	20.6	28.2	22.2	10.2	6.2	26.4	19.6	33.4	15.8	18.3	21.5	13.0	23.9	10.2	17.3	12.7	12.2	12.2	18.4	15.5	20.3
		mean	18.7	28.5	21.2	25.1	25.9	29.0	26.0	16.9	19.4	26.2	23.1	28.7	17.8	20.2	22.5	13.9	25.9	16.4	20.2	16.8	15.6	17.8	20.3	17.4	21.2
n-heptadecane	1300	2007	5.0	4.3	6.4	4.0	*	0.9	2.9	0.5	*	2.2	4.2	3.0	5.1	5.0	4.3	8.5	4.3	5.8	5.7	5.1	10.2	6.7	10.5	10.7	4.5
		2008	1.7	7.0	5.7	5.5	6.4	5.9	14.6	6.6	4.1	10.7	8.4	3.1	6.5	1.0	5.3	11.6	7.2	12.6	9.8	15.0	9.2	12.1	9.1	9.2	6.6
		mean	3.4	5.7	6.1	4.8	6.4	3.4	8.8	3.6	4.1	6.5	6.3	3.1	5.8	3.0	4.8	10.1	5.8	9.2	7.8	10.1	9.7	9.4	9.8	10.0	5.6
n-hexadecanol	1400	2007	*	7.4	5.3	7.5	7.2	8.3	7.5	6.0	5.2	5.0	6.9	4.7	9.2	7.4	6.8	7.2	6.4	6.4	4.7	5.4	3.3	3.4	*	*	6.7
		2008	2.6	*	6.4	10.3	8.5	7.6	*	3.8	3.9	1.6	8.0	6.2	8.4	3.6	7.8	6.0	9.6	7.4	6.6	7.0	8.8	7.1	2.8	3.7	6.4
		mean	2.6	7.4	5.9	8.9	7.9	8.0	7.5	4.9	4.6	3.3	7.5	5.5	8.8	5.5	7.3	6.6	8.0	6.9	5.7	6.2	6.1	5.3	2.8	3.7	6.5
n-nonadecane	1500	2007	*	*	*	*	*	40.5	43.5	45.4	42.8	42.0	45.2	38.0	42.7	46.5	43.8	48.4	42.0	44.7	40.4	42.9	26.0	36.5	28.4	29.7	36.1
		2008	13.0	21.6	39.1	43.1	32.4	37.7	26.8	18.7	14.0	25.7	35.5	33.9	34.1	19.0	31.8	38.1	31.2	38.8	45.7	45.0	31.2	39.3	27.3	36.0	32.4
		mean	13.0	21.6	39.1	43.1	32.4	39.1	35.2	32.1	28.4	33.9	40.4	36.0	38.4	32.8	37.8	43.3	36.6	41.8	43.1	44.0	28.6	37.9	27.9	32.9	34.2
n-octane	1686	2007	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
		2008	0.7	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	1.7
		mean	0.7	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	1.7
n-pentadecane	1700	2007	1.3	0.6	2.8	0.3	0.4	*	*	*	*	*	0.7	1.1	0.9	1.6	*	2.7	0.9	1.4	1.1	2.3	*	*	4.0	3.9	1.9
		2008	*	1.7	0.5	*	1.5	0.4	1.0	*	*	2.3	0.7	3.9	1.5	3.6	0.6	6.2	1.2	10.8	3.9	3.3	0.5	10.1	12.0	11.0	4.5
		mean	1.3	1.2	1.7	0.3	1.0	0.4	1.0	*	*	2.3	0.7	2.5	1.2	2.6	0.6	4.5	1.1	6.1	2.5	2.8	0.5	10.1	8.0	7.5	2.8
n-pentadecanol	1776	2007	*	0.5	0.6	0.5	*	0.5	*	*	*	*	0.5	*	*	0.5	*	*	*	*	*	*	*	*	*	*	2.3
		2008	6.7	*	2.0	0.5	1.6	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	1.9
		mean	6.7	0.5	1.3	0.5	1.6	0.5	*	*	*	*	0.5	*	*	0.5	*	*	*	*	*	*	*	*	*	*	2.1
n-tetracosane	1878	2007	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	0.8
		2008	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
		mean	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	0.8
n-tetradecane	1900	2007	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	0.4	*	3.4	1.7
		2008	*	*	*	*	0.4	*	0.5	*	0.9	0.6	0.4	*	0.4	6.8	0.6	1.6	0.4	1.6	0.6	*	1.4	0.6	2.5	2.2	1.5
		mean	*	*	*	*	0.4	*	0.5	*	0.9	0.6	0.4	*	0.4	6.8	0.6	1.6	0.4	1.6	0.6	*	1.4	0.5	2.5	2.8	1.5
n-tetradecanol	2000	2007	*	*	*	*	2.5	3.2	*	4.0	2.7	1.0	*	0.6	*	*	*	2.3	0.3	1.8	2.0	1.4	1.8	1.6	1.8	*	3.0
		2008	*	*	*	0.9	*	0.5	*	*	2.7	*	*	*	1.0	*	*	5.9	0.7	7.8	3.3	5.9	0.6	6.0	6.3	5.2	3.4
		mean	*	*	*	0.9	2.5	1.9	*	4.0	2.7	1.0	*	0.6	1.0	*	*	4.1	0.5	4.8	2.7	3.7	1.2	3.8	4.1	5.2	3.2
n-tricosane	2100	2007	13.8	7.3	*	7.8	9.9	*	8.3	4.8	8.6	6.7	6.3	6.5	3.8	4.0	5.6	4.2	7.4	6.8	11.0	7.7	7.6	11.7	11.6	7.5	7.0
		2008	1.9	11.8	4.9	4.7	5.3	7.3	7.0	2.3	1.2	8.7	4.5	10.6	3.3	5.2	5.4	4.1	6.5	2.5	5.0	3.4	2.9	3.2	8.4	5.5	5.9
		mean	7.9	9.6	4.9	6.3	7.6	7.3	7.7	3.6	4.9	7.7	5.4	8.6	3.6	4.6	5.5	4.2	7.0	4.7	8.0	5.6	5.3	7.5	10.0	6.5	6.4
n-tridecane	2200	2007	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	1.2
		2008	*	*	*	*	*	*	4.4	*	0.4	*	*	*	*	0.8	*	*	*	*	*	*	*	*	*	*	1.7
		mean	*	*	*	*	*	*	4.4	*	0.4	*	*	*	*	0.8	*	*	*	*	*	*	*	*	*	*	1.4
trans- rose oxide	2300	2007	*	*	*	*	*	2.0	*	3.6	*	0.7	*	1.0	2.0	*	0.9	0.6	*	*	*	*	0.8	*	*	0.4	1.4
		2008	3.7	*	0.3	*	0.5	*	0.7	3.2	2.3	0.4	0.7	*	0.8	0.3	1.0	*	0.4	*	*	*	0.9	*	*	*	1.0
		mean	3.7	*	0.3	*	0.5	2.0	0.7	3.4	2.3	0.6	0.7	1.0	1.4	0.3	1.0	0.6	0.4	*	*	*	0.9	*	*	0.4	1.2
β-citronellene	2400	2007	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
		2008	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	0.5	*	1.4	0.4	0.4	*	1.2	*	*	1.3
		mean	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	0.5	*	1.4	0.4	0.4	*	1.2	*	*	1.3
Total percentage	-	2007	60.8	55.9	61.2	54.5	57.1	96.1	96.2	98.3	98.1	95.7	99.6	92.5	99.3	97.3	93.9	96.8	97.5	96.6	94.6	93.0	89.9	92.8	93.5	92.9	86.5
		2008	97.1	89.8	96.4	95.4	95.2	97.4	94.3	95.8	97.4	92.8	96.1	97.4	95.3	90.8	94.6	93.1	95.1	96.8	96.0	95.4	97.2	94.4	95.5	96.7	95.2
		mean	79.0	72.9	78.8	75.0	76.2	96.8	95.3	97.1	97.8	94.3	97.9	95.0	97.3	94.1	94.3	95.0	96.3	96.7	95.3	94.2	93.6	93.6	94.5	94.8	90.8
Oil content (%)	-	2007	0.008	0.008	0.008	0.010	0.011	0.010	0.025	0.016	0.008	0.011	0.004	0.006	0.013	0.008	0.002	0.006	0.010	0.010	0.010	0.008	0.012	0.011	0.005	0.014	0.009
		2008	0.018	0.010	0.008	0.014	0.012	0.015	0.015	0.026	0.027	0.013	0.018	0.007	0.022	0.016	0.008	0.006	0.009	0.010	0.010	0.006	0.017	0.007	0.007	0.010	0.012
		mean	**0.013**	**0.009**	**0.009**	**0.012**	**0.011**	**0.013**	**0.021**	**0.021**	**0.018**	**0.012**	**0.011**	**0.007**	**0.017**	**0.012**	**0.005**	**0.006**	**0.010**	**0.010**	**0.010**	**0.007**	**0.014**	**0.009**	**0.007**	**0.012**	**0.011**

Note: EOC instead of essential oil content

Table 3. Ranked percentage of compounds of the essential oil from fresh petals of 49 landraces of *Rosa damascena* in 2007-8

2007			2008			Average		
Rows	**Componds**	**%**	**Rows**	**Componds**	**%**	**Rows**	**Componds**	**%**
1	n-nonadecane	36.1	1	n-nonadecane	32.4	1	n-nonadecane	34.2
2	n-heneicosane	22.1	2	n-heneicosane	20.3	2	n-heneicosane	21.2
3	n-tricosane	7	3	citronellol	10.3	3	citronellol	8.5
4	n-hexadecanol	6.7	4	cis-rose oxide	6.8	4	n-hexadecanol	6.5
5	citronellol	6.6	5	n-heptadecane	6.6	5	n-tricosane	6.4
6	n-heptadecane	4.5	6	n-hexadecanol	6.4	6	n-heptadecane	5.6
7	n-eicosane	3.7	7	n-tricosane	5.9	7	n-eicosane	3.6
8	n-tetradecanol	3	8	n-pentadecane	4.5	8	geranial	3.3
9	geranial	2.8	9	geranial	3.6	9	n-tetradecanol	3.2
10	n-pentadecanol	2.3	10	n-eicosane	3.6	10	n-pentadecane	2.8
11	n-pentadecane	1.9	11	n-tetradecanol	3.4	11	cis-rose oxide	2.7
12	geraniol	1.8	12	geraniol	2.2	12	n-pentadecanol	2.1
13	n-tetradecane	1.7	13	n-pentadecanol	1.9	13	geraniol	2
14	trans- rose oxide	1.4	14	n-octane	1.7	14	n-octane	1.7
15	n-tridecane	1.2	15	n-tridecane	1.7	15	n-tetradecane	1.5
16	n-docosane	1.1	16	n-tetradecane	1.5	16	n-tridecane	1.4
17	n-tetracosane	0.8	17	β-citronellene	1.3	17	β-citronellene	1.3
18	cis-rose oxide	0.3	18	trans- rose oxide	1	18	trans- rose oxide	1.2
19	n-octane	*	19	n-docosane	0.6	19	n-docosane	0.8
20	β-citronellene	*	20	n-tetracosane	*	20	n-tetracosane	0.8

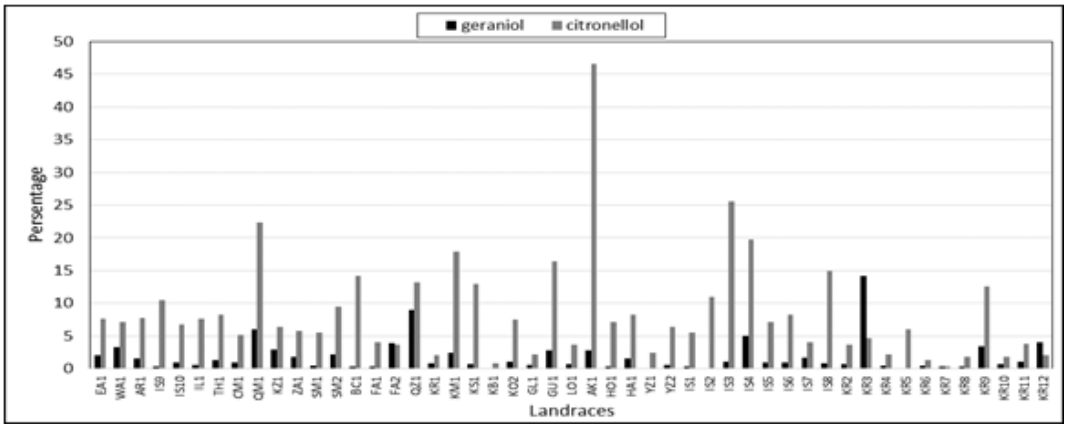

Fig. 3. The percentages of geraniol and citronellol components in the oils of *Rosa damascena* landraces

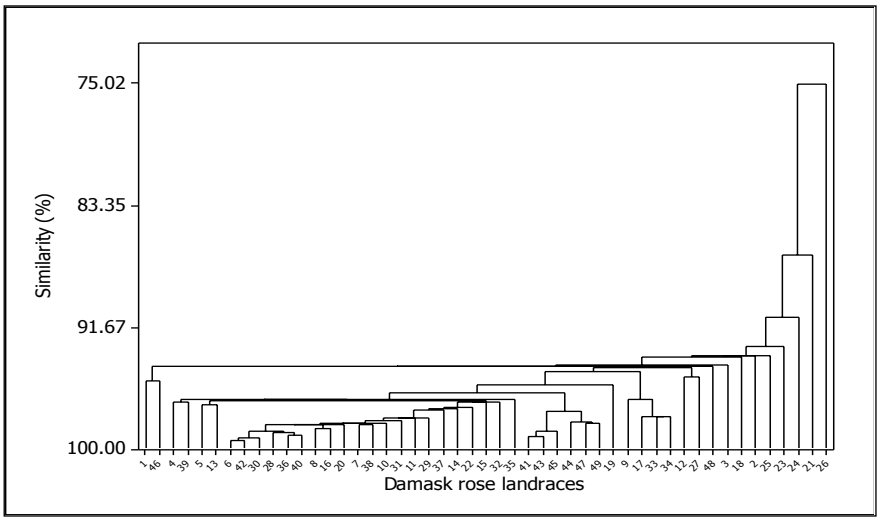

Fig. 4. Dendrogram of cluster analysis of *Rosa damascena* landraces based on the main components of the oil

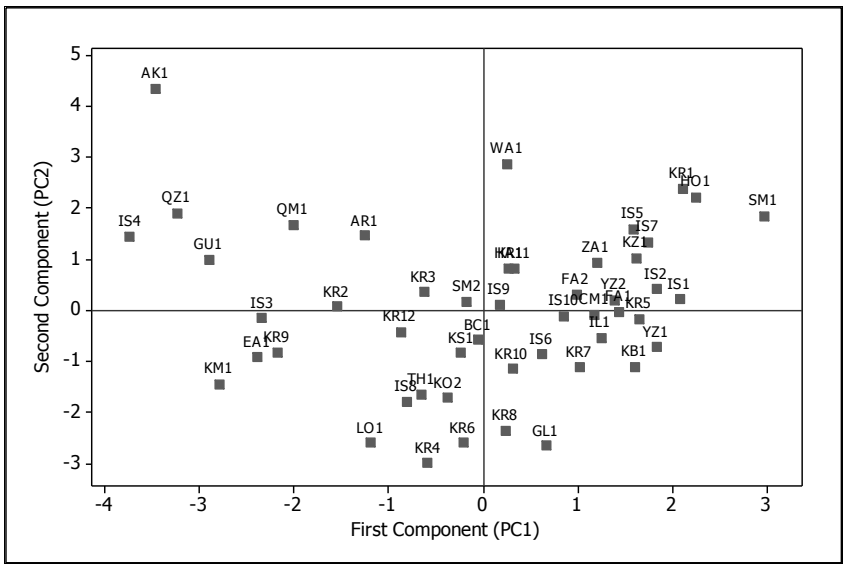

Fig. 5. Score plot for first 2 components of principal component analysis (PCA)

Discussion

The results of present study is in accordance with results obtained by Moein et al., 2010, but there were differences in kinds and percentages of components with some of other reports (Loghmani-Khouzani et al., 2007; Ram Swaroop et al., 2011; Javed Naquvi et al., 2014). For example in this study the percentage of aliphatic compounds such as n-nonadecane, n-heneicosane, n-hexadecanol and n-tricosane were higher than alcoholic compounds and also phenyl ethyl alcohol component wasn't seen in the first twenty major oil compounds.

Based on the results of this study, the average essential oil yield of the studied landraces (0.01%) was less than previous findings (e.g. Baydar and Baydar, 2005 in Turkey (0.03%), Misra et al., 2002 in India (0.05%), Farooq et al., 2011 in Pakistan (0.01-0.03%) and Tabaei Aghdaie et al., 2007 in Iran using a number of Isfahan groups of landraces (0.03%). The variability of the oil content and compounds percentages in present study with others may be due to different factors such as ecological conditions (cool and semi arid climates of Sanandaj on two seasons of 2007 and 2008), kinds and largeness of landraces (49 Damask rose belonging to diverse parts of Iran), extraction method (hydro distillation) and etc. In accordance to this, Younis et al. (2007) reported that both techniques of solvent extraction and steam distillation yielded oil with differences in the percentage composition of each component, but solvent extraction through hexane resulted in better results (i.e. higher yield and more components) than steam distillation for extraction of roses oil. Lawrence (1991) stated that solvent extraction yields about 10 times more than that obtained by steam distillation. The main objective of Damask rose cultivation in many countries such as Turkey, Bulgaria, India and France is the extraction of its flower essential oil (Babu et al., 2002); therefore, the attention towards development essential oil quantity and quality can be considered as an important objective for improving essential oil yield of this species. The percentage of major components is one of the important parameters which determine the quality of rose oil (Boelens and Boelens, 1997; Nikolov et al., 1977). Good quality rose oil should possess a higher amount of monoterpene alcohols and a lower amount of alkanes (Baser, 1992). The percentage of citronellol and geraniol as the two important compounds related to rose oil quality in 2008 were more than their percentages in 2007 (Table 3). The year of 2007 (with maximum, minimum and average annual temperature equal to 22.9°C, 6.3°C and 14.6 °C respectively, 45% annual relative humidity, 244.2 mm annual precipitation) compared with 2008 (with maximum, minimum and average annual temperature equal to 22.4, 6.4 and 14.4 °C respectively, 51% annual relative humidity, 403.1 mm annual precipitation) was a very dry year in Kurdistan province and in Iran. According to this, it can be inferred that very dry conditions (such as 2007) increases the aliphatic compounds percentages and reduces alcoholic compounds in rose oil.

Conclusion

In this study, the essential oil content of Iranian Damask rose landraces (0.01%) was less than the essential oil contents reported in other reports (0.01-0.03%). The landraces of IS2, IS3, IS4 and IS8, from Isfahan (Kashan) province with 0.021%, 0.021%, 0.018% and 0.017% respectively produced the highest oil yield among studied landraces. The main objective of rose cultivation in Iran is production of flower and rose water. Thus, the main attention in long term selections of Iranian landraces by traditional farmers has focused on the genetic improvement of flower yield than the oil content. Twenty main compounds were identified in the

essential oil of studied landraces representing 71.2 to 97.4 % (in different landraces) of the total oil. The major components of all studied oils were found to be n-nonadecane (34.2%), n-heneicosane (21.2%), citronellol (8.5%), n-hexadecanol (6.5%) and n-tricosane (6.4%). In this study we did not find phenyl ethyl alcohol and the percentages of citronellol (8.5%) and geraniol (2.0%) compounds as the two important compounds related to rose oil quality were less than erliear findings (citronellol 2.2-47.5% and geraniol 2.5-33.0%). This can be due to the extraction method (hydro distillation) or ecological conditions (semi-arid and cold conditions, etc.) of the research location. This issue can be the subject of future studies. In 2008, the percentage of citronellol and geraniol as the two important compounds related to rose oil quality were more than their percentages in 2007 with very dry climatic conditions. Therefore, it can be inferred that very dry environmental conditions (such as 2007) increases the aliphatic compounds percentages and reduces alcoholic compounds in rose oil. Although there were different origin sites, climates and ecological conditions among Iranian *R. damascena* landraces, despite of some differences between the percentages of major components and also minor constituents, the results of cluster analysis revealed that all of the rose landraces with exception of KB1 and AK1 showed more than 90% similarity in the major oil composition. The result of principal component analysis (PCA) revealed that the landraces with the highest percentage of citronellol and geraniol components usually showed the extreme values (positive or negative) for PC1 and PC2.

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