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Research Article

Effects of Macro- and Microelements in Soil of Rose Farms in Taif on Essential Oil Production by *Rosa damascena* Mill.

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Rose is one of the most economically important ornamental crops in the world. In this study, we analyzed nine macro- and microelements in soils and petals of *R. damascena* Mill. cultivated in Shafa and Hada mountains. The amounts of the investigated macro- and microelements varied from one soil or petal sample to another and they were generally higher in most soil and petal samples of Shafa compared to Hada. On the other hand, the levels of the investigated elements in petal samples were not dependent on their levels in soil samples. While water extracts of the soil of farms of Shafa were slightly alkaline (pH 7.69), they were moderately alkaline (pH 8.04) in Hada farms. The amounts of oil produced by rose petals of Hada were relatively larger than those of Shafa. Amongst the five investigated constituents of the volatile oil of roses, the amounts of citronellol, geraniol, and eugenol were significantly larger in the volatile oil of rose petals of Hada compared to Shafa. This study suggests that the ecology of roses of both Hada and Shafa mountains is different and this is most likely reflected on the amount of volatile oil and its constituents. Therefore, further integrated multidisciplinary research correlating rose ecology, agronomy, and essential oil yield is highly recommended.

1. Introduction

Rose is one of the most important crops in the floriculture industry [1]. Roses are used as cut flowers, potted plant, and garden plants [2]. They have been also used in the food, perfumery, and cosmetics industries for many years [3, 4]. Roses belong to the genus *Rosa* which contains over 100 species that are widely distributed in Europe, Asia, the Middle East, and North America [5]. Out of 200 species of the genus *Rosa*, only a few have been used for essential oil production, among which *R. damascena* is superior for the production of high value essential oil [6]. The name of the species (*damascene*) is based on Damascus, Syria, where it originally existed as a wild plant. However, it is now cultivated in different countries around the world [7]. *Rosa damascena* has a long history in the Western province of Taif in Saudi Arabia, where a high-quality rose essential oil is produced and a tight traditional culture and strong financial output have been created over time.

Cultivation and processing of the flower of *R. damascena* to get the essential oil have over the years created a central area in the global agribusiness with an estimated annual growth rate of 7–10% [8]. The global demand for high grade natural *R. damascena* essential oil has been increasing for use in pharmaceutical, flavoring, and fragrance industries. In order to meet the rising demand of the rose oil, there is a need to understand how ecological and agronomical factors directly influence the productivity of *R. damascena* essential oil.

The supply of high-quality water has become increasingly limited in many areas of Saudi Arabia, because of the decrease in rains and the increase in the salinity of ground waters (well) that contain relatively high levels of soluble salts [9]. Although *R. damascena* is adapted to a wide range of environmental conditions, the content, relative compositions, and quality of oil are greatly affected by the ecological and agronomical practices [10]. Therefore, studying rose ecology is a central issue to ensure sustainable productivity of essential oil of roses in various environmental conditions and to improve the production of rose essential oil in different farms [11].

In this study we determined the levels of macro- and microelements in soil and their effect on the yield and constituents of *R. damascena* essential oil in farms on two mountains in Taif. It is aimed that this study among other studies in the future would help to understand the ecology and help to set up agronomy of *R. damascena* grown in Taif.

2. Materials and Methods

2.1. Soil Sampling. Samples were collected from two different randomly chosen sites in 9 farms in the mountain of Shafa and 9 farms in the mountain of Hada. The mountains are located Southwest and Northwest of Taif City, respectively. After removing the surface layer, the soil was collected at a depth of about 20 cm avoiding the open slit. Soil samples were dried and sifted through a 2 mm stainless steel sieve to remove the coarse fraction.

2.2. Estimation of pH of Soil. For each sample, five grams of soil was suspended in 25 mL distilled water, shaken for 30 min at room temperature, and filtered before measuring the pH using a calibrated pH meter (Jenway, model 3510).

2.3. Determination of Conductivity and Salinity of Soil. A suspension of 5 g soil in 10 mL of water was prepared for each sample and mechanically shacked for 1 h. The conductivity of supernatant of each sample was measured using calibrated conductivity meter (Jenway, model 4510). The electrode was rinsed in deionized bidistilled water between measurements.

2.4. Estimation of Minerals. Potassium, calcium, magnesium, sodium, manganese, copper, selenium, iron, and zinc were estimated in both soil and rose petals. A microwave-assisted acid digestion procedure was applied to investigate the minerals (closed vessel acid digestion). All vessels were soaked in diluted nitric acid, washed with water, and thoroughly rinsed with deionized water before use. Portions of 0.5 gm of dried samples were deposited onto clean dry Teflon microwave digestion vessels. A total of 10 mL of concentrated nitric acid (69%) was added to each sample which was sealed and digested. Two samples containing only nitric acid were prepared as controls in the same way. The solutions were allowed to cool, quantitatively transferred into a 100 mL volumetric flask, and completed to volume with deionized water before analysis by inductively coupled plasma-optical emission spectroscopy (ICP-OES). Samples were nebulized downstream to the plasma using the autosampler and the concentrations of minerals were automatically determined using standard calibration graphs [12].

2.5. Extraction of Oil from Rose Flowers. Flowers collected in the early morning from 18 farms were used immediately for extraction of essential oil or were immediately frozen in closed containers at −80°C, until further analysis.

The flowers were mixed with agitated hexane to draw out the aromatic compounds. Dissolved organic residues in the hexane were collected by evaporating hexane in a rotary vacuum evaporator. The concrete oil obtained was dried by adding anhydrous Na_2SO_4. The last traces of hexane were removed by bubbling nitrogen gas through the concrete oil.

2.6. GC-MS Analysis of Oil Constituents. Samples and standards were analyzed using Varian 3800 GC/Saturn 2000 GC/MS 2200 and CombiPAL autosampler system, USA. The machine is equipped with a VF-5 fused silica capillary column and an electron ionization system with ionization energy of 70 eV. Helium was used as a carrier gas at a constant low rate of 1 min at 50°C to 260°C at 13°C/min and held for 2 min finally at 260°C. The solvent delayed time was 3 min. Samples were prepared as 20 mg/mL in HPLC grade n-hexane and filtered using membrane filter (0.45 um). The injections of all samples were carried out with autosampler for 1 μL with a split ratio 1/10. Identification of components of samples was based on matching their mass patterns with standards, NIST electronic library [13].

2.7. Statistical Analysis. All measurements were done in triplicate and the mean, standard deviation, and statistical significance were calculated using unpaired t-test, GraphPad software.

3. Results

The mean pH values of the investigated samples of soil indicated they were slightly alkaline in Shafa rose farms and acceptably moderately alkaline in Hada rose farms (Table 1).

The levels of 4 macroelements (Ca, Mg, K, and Na) and 5 microelements (Se, Mn, Cu, Fe, and Zn) in the soil samples of Shafa and Hada mountains were estimated by a microwave-assisted acid digestion procedure. The levels of all elements varied from one sample of soil to another. This was apparent in cases of the macroelements: Na and K in both Shafa and Hada and Ca in case of Shafa soils (Figures 1(a) and 1(b)). As shown in Figures 1(c) and 1(d) apart from Se the level of all microelements varied from one sample to another (data for Fe are not shown in the figure).

The mean levels of the total macro- and microelements in soil samples of Shafa and Hada are shown in Table 2. The mean values indicated that, amongst the macroelements, K and Na were higher in Shafa soils and Ca and Mg were higher in Hada soils (Table 2). On the other hand amongst the microelements, Se, Fe, and Zn were higher in Shafa soils and Mn and Cu were higher in Hada soils (Table 2).

The levels of macro- and microelements in petals of rose flowers of Shafa and Hada were also estimated by a microwave-assisted acid digestion procedure and are shown in Table 3. All macroelements and Mn and Cu microelements were higher in petals of Shafa rose flowers compared to Hada rose petals.

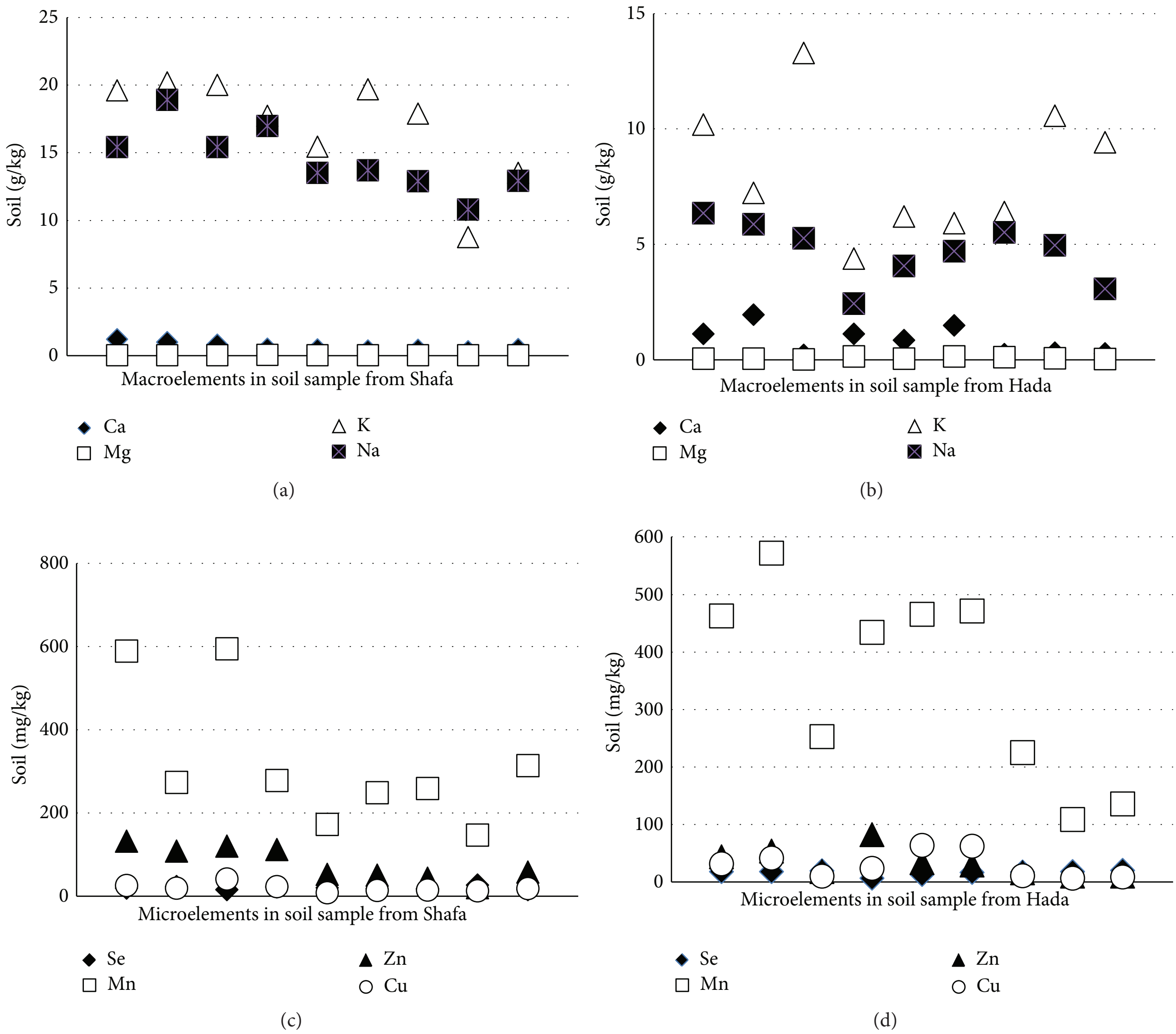

FIGURE 1: Different levels of macroelements (a and b) and microelements (c and d) in soil samples collected from Shafa and Hada.

TABLE 1: pH of soil collected from Shafa and Hada farms.

Location	Range	Mean ± SD	Denomination
Shafa	7.19–8.0	7.69 ± 0.34	Slightly alkaline
Hada	8.08–8.46	8.26 ± 0.16	Moderately alkaline

Figure 2 compares between the mean levels of microelements and macroelements in soils and petals of Shafa and Hada. The increase of Zn and K in soil was associated with increases in their levels in petals (Figure 2). However, the levels of the other tested elements in petals were not always related to their levels in soil. For example, Se level was higher in petals of Hada compared to Shafa, though its level in the soil of the latter was higher (Figure 2).

The conductivity and salinity of soils of Shafa and Hada farms were determined for different soil samples (Table 4). The mean conductivity of water extracts of Hada samples of soil was relatively higher (2.17 dmS) compared to Shafa (1.85 dmS). This might reflect the relative higher salinity of water extracts of Hada soil compared to those of Shafa (Table 4).

The mean levels of five constituents of essential oil of Shafa and Hada are compared in Table 5. The relative amounts of phenylethyl alcohol which is a major component of rose oil were more or less the same in both Shafa and Hada farms. Nonetheless, the relative amounts of the other four estimated constituents, namely, citronellol, geraniol, eugenol, and nonadecane, were higher in Hada essential oil (Table 5).

Figure 3 shows the relationship between the mean levels of total sodium in soils and petals, salinity of soil, and volatile oil contents in Shafa and Hada. While both petal sodium and total soil sodium were higher in Shafa samples compared to Hada, the volatile oil contents were relatively higher in petals of Hada compared to Shafa (Figure 3).

Table 2: Mean levels of macro- and microelements in Shafa and Hada soil samples (g/kg).

Element		Shafa		Hada	
Type	Element	Range	Mean ± SD	Range	Mean ± SD
Macroelements	Ca	0.31–1.19	0.61 ± 0.31	0.19–1.94	0.82 ± 0.631
	Mg	0.01–0.03	0.02 ± 0.01	0.01–0.13	0.058 ± 0.05
	K	8.75–20.18	16.97 ± 3.83	4.37–13.27	8.163 ± 2.85
	Na	10.78–18.90	14.38 ± 2.34	2.42–6.34	4.680 ± 1.291
Microelements	Se	0.015–0.025	0.0189 ± 0.015	0.0066–0.0201	0.0162 ± 0.004
	Mn	0.146–0.594	0.319 ± 0.163	0.1087–0.5712	0.3471 ± 0.17
	Cu	0.0075–0.041	0.018 ± 0.01	0.0066–0.0635	0.0286 ± 0.023
	Fe	1.286–2.0961	11.444 ± 6.17	0.1900–16.776	10.353 ± 5.37
	Zn	0.0195–0.131	0.076 ± 0.04	0.0101–0.0818	0.033 ± 0.024

Table 3: Mean levels of macro- and microelements in Shafa and Hada rose petal samples (mg/kg).

Element		Shafa		Hada	
Type	Element	Range	Mean ± SD	Range	Mean ± SD
Macroelements	Ca	0.305–1.912	0.73 ± 0.575	0.189–0.612	0.3 ± 0.129
	Mg	0.228–0.75	0.361 ± 0.1969	0.125–0.266	0.16 ± 0.04
	K	1.97–4.91	3.028 ± 0.867	1.418–2.739	1.95 ± 0.402
	Na	0.01–0.153	0.0604 ± 0.048	0.011–0.047	0.026 ± 0.015
Microelements	Se	0.015–0.027	0.0189 ± 0.015	0.0066–0.0201	0.01623 ± 0.004
	Mn	0.003–0.006	0.0041 ± 0.001	0.0020–0.0054	0.0034 ± 0.001
	Cu	0.004–0.001	0.008 ± 0.0036	0.0028–0.0071	0.004 ± 0.0014
	Fe	0.005–0.031	0.0166 ± 0.010	0.0026–0.0304	0.0162 ± 0.117
	Zn	ND–0.0023	0.054 ± 0.88	ND	ND

Table 4: Conductivity and salinity of soil collected from Shafa and Hada farms.

Location	Conductivity (dmS)		Salinity (g/L)	
	Range	Mean ± SD	Range	Mean ± SD
Shafa	0.69–3.33	1.85 ± 1.064	0.414–2.02	1.11 ± 0.640
Hada	0.73–4.09	2.17 ± 1235	0.434–2.46	1.30 ± 0.738

4. Discussion

Soil is the storehouse of plant macro- and microessential nutritional elements which play an important role in proper growth and development of plants [14, 15] as well as the quality attributes of their crops [16, 17]. In this study, we determined the levels of macro- and microelements in soils and petals of flowers of *R. damascena* farms, located in two different areas in Taif. One area is located on the Northwest mount of Hada and the other is located on the Southwest mount of Shafa. We also determined the yield of rose oil in petals of roses of farms of both areas.

Roses are known to grow well in slightly acidic to slightly alkaline soils with pH values ranging from 6.0 to 7.5. Generally speaking the plant growth and flower yield are known to be reduced in both acidic and alkaline soils which is probably due to imbalance of micronutrients [15]. Nonetheless, soils with pH range of 8-9 were found to be somewhat suitable for growth of roses in India [18, 19], which is considered one of the major countries producing rose oil [20]. In this study the pH of farm soils tended to be slightly alkaline and moderately alkaline with mean values of pH of 7.69 and 8.26 in Shafa and Hada, respectively. This suggests that Taif *R. damascena* grows better in alkaline soil as the case of roses of India [18, 19]. This also might explain the higher oil content in petals of Hada roses, where the pH of the soil is higher compared to Shafa.

The essential elements have been indeed reported to play an important role in the proper growth and development of roses [14]. *R. damascena* fruits are rich in minerals such as Ca, Fe, K, Mn, Na, P, and Zn [21], a fact that necessitates the availability of these minerals in suitable amounts in the soil. Bud development stage, flower yield, and oil yield of rose are also correlated with the availability of minerals like Na, P, and K [22]. These elements were detected in different amounts in the soil of both Shafa and Hada. In a study by Karlik and Tjosvold [23], it was suggested that the levels of Fe, Mn, and Zn in the soil for the roses should be around 0.3–3.0, 0.2–3.0, and 0.03–3.0 ppm, respectively. In this study the mean values of Mn and Zn were present in the soil of both Shafa and Hada within these previously suggested ranges. On the other hand, Fe was particularly more abundant than what was suggested by Karlik and Tjosvold [23] and existed at mean levels of 11.44 ± 6.17 and 10.35 ± 5.37 g/kg in Shafa and Hada, respectively.

Although the trace element Se in high concentrations is harmful to plants, at low levels, it exerts beneficial effects. Se can increase the tolerance of plants to UV-induced oxidative

Table 5: Levels of some constituents of essential oil in concrete extracted from petals of flowers collected from Shafa and Hada farms.

Constituent of essential oil	Shafa		Hada	
	Range	Mean ± SD	Range	Mean ± SD
Phenylethyl alcohol	14.57–27.88	22.27 ± 4.339	18.45–26.66	21.32 ± 2.97
Citronellol	2.42–4.83	3.878 ± 0.876	5.05–7.15	6.18 ± 0.79
Geraniol	1.27–4.46	2.713 ± 1.194	4.95–8.03	6.39 ± 1.03
Eugenol	0.67–3.06	1.68 ± 0.66	1.25–3.27	2.56 ± 0.72
Nonadecane	13.07–16.06	15.03 ± 1.021	11.57–15.78	14.03 ± 1.61

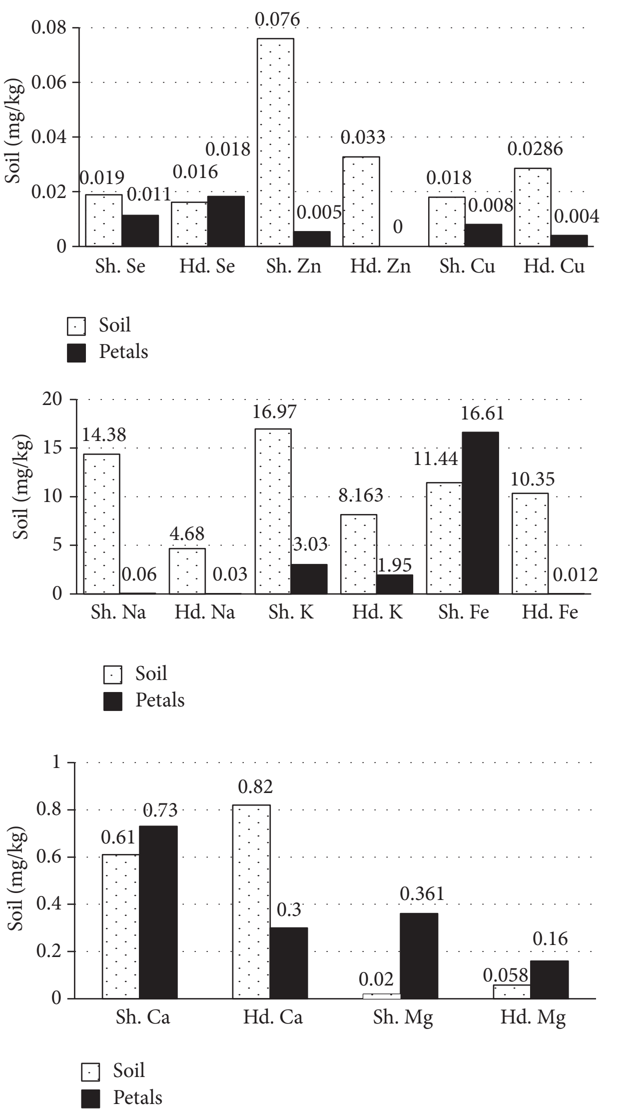

Figure 2: Comparison between the levels of elements in soil and petals.

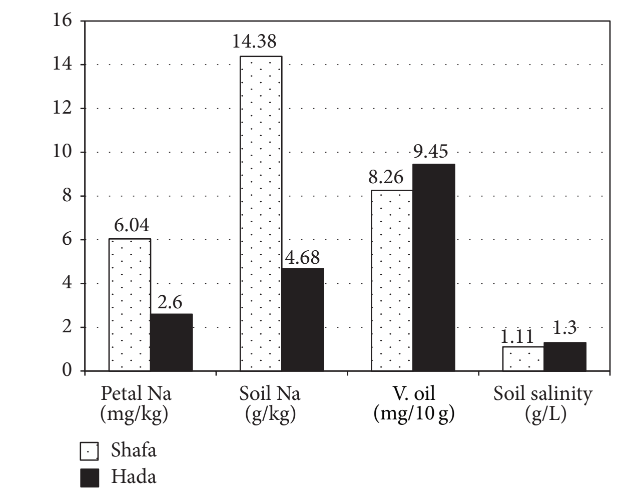

Figure 3: Comparison between the mean levels of total sodium in petals and soil, soil salinity, and the amount of volatile oil in petals of both Shafa and Hada.

stress [24] and promote the growth of ageing seedlings [25]. It was also shown that Se regulates the water status of plants under conditions of drought [26]. In this study Se was available in the soil samples of both Shafa and Hada at mean levels of 0.0189 ± 0.015 and 0.0162 ± 0.004 mg/kg, respectively, which are within the beneficial levels.

Different *Rosa* species are negatively affected by salinity due to NaCl. Salinity was reported to reduce the growth of *R. fortuniana*, *R. odorata*, and *R. multiflora* [27]. Salinity was also reported to reduce the amounts of essential oil produced by herbs like marjoram shoots [28] and mint [29]. As Taif has been suffering in recent years from low rainfall and in the presence of high evaporation rates, the dissolved salts in the ground irrigation water are likely to be high. This might cause the soil of both Shafa and Hada to suffer from salinity. The total amounts of Na were as high as 14.38 ± 2.34 and 4.680 ± 1.291 g/kg, in Shafa and Hada, respectively, with the level of Na in the former significantly ($P < 0.001$) higher than the latter. However, conductivity measurements in this study demonstrated that the levels of salinity were 1.11 ± 0.640 g/L and 1.30 ± 0.738 g/L in soils of Shafa and Hada, respectively, which suggests nonsaline soils [30].

Organic matters are beneficial to soil. They promote plant growth; improve soil structure; and increase the cation exchange capacity (CEC), organic carbon, and available nutrients. In addition, they reduce the salt content, electrical conductivity (EC), and exchangeable sodium percentage [31, 32]. Therefore, the lower availability of salts in the tested soils could be attributed at least in part to the fact that all inspected farms essentially used organic fertilizers (personal communications).

The mean levels of all macroelements were found to be higher in petals of Shafa than petals of Hada by a factor of 1.6 to 2.4. This does not necessarily reflect their relative amounts in soil samples. For instance, in Hada, Ca and Mg existed in higher amounts in soils compared to Shafa, though their amounts in the petals were lower. On the contrary the amounts of Na were several times higher in both soils and petals of Shafa.

Because elevation of Na ions in plant tissues may affect both the amounts and composition of volatile oil produced by herbs [28, 29] and because of the significantly higher amounts of Na in petals of roses of Shafa compared to Hada, we estimated the amounts of volatile oil in petals of roses of both mounts. Indeed there was a relative decrease in the mean amounts of volatile oil in Shafa rose petals; however, this was statistically not significant. In addition, the relative mean amounts of some of the components of volatile oil were different in both volatile oils. For instance, three oil components, namely, citronellol, geraniol, and eugenol, of the five investigated ones were significantly higher in volatile oils of Hada compared to Shafa.

5. Conclusion

This study suggests that the ecology of both Shafa and Hada farms is different. This is consequently reflected on the mean relative amounts of *R. damascena* essential oil and its constituents in both Shafa and Hada. Therefore, further studies should be done as a part of an integrated multidisciplinary research to correlate rose ecology, agronomy, and essential oil yield in Taif.

Conflict of Interests

The authors declare that there is no conflict of interests regarding the publication of this paper.

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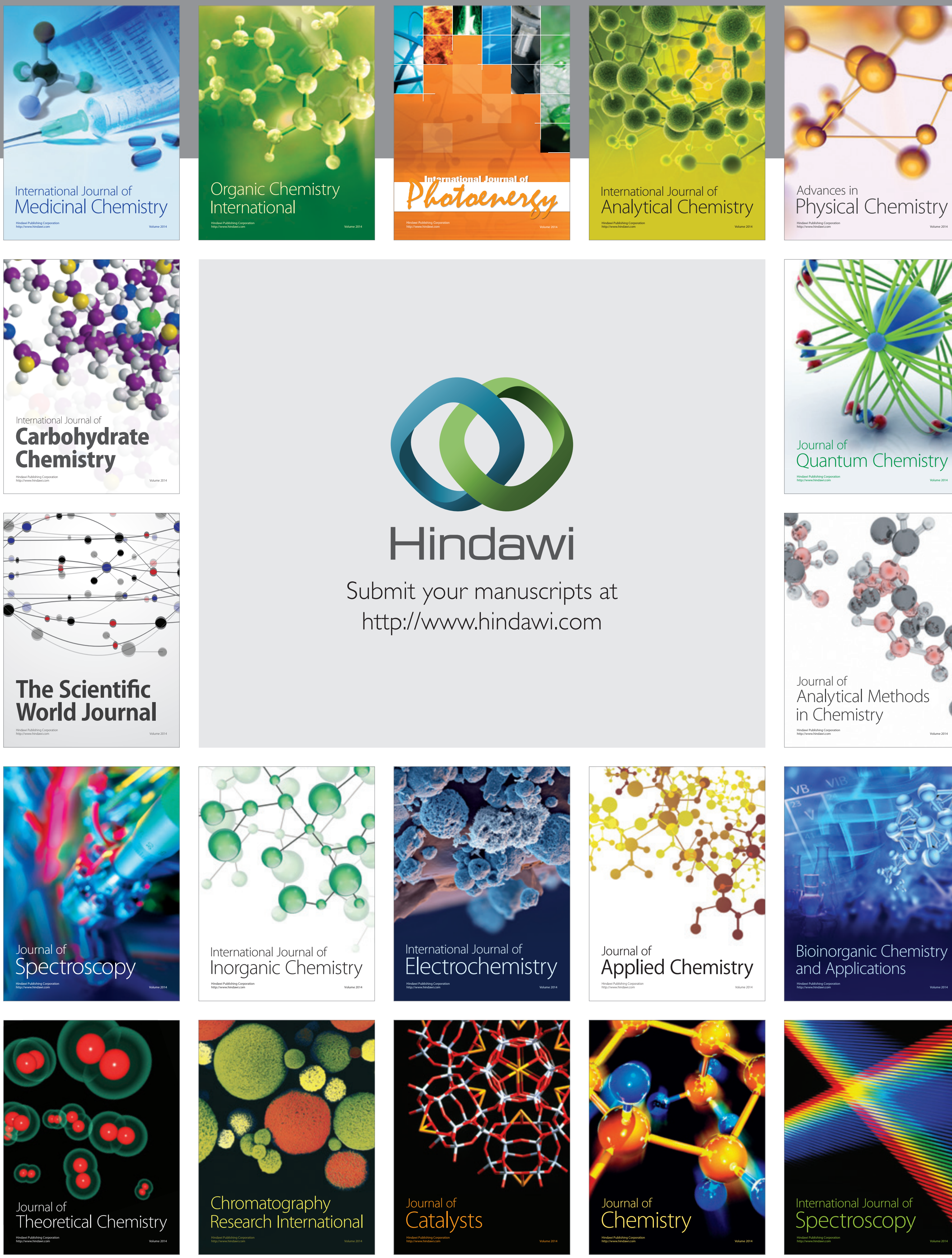
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