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Composition of Essential Oil Compounds from Different Syrian Populations of *Origanum syriacum* L. (Lamiaceae)

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The chemical compositions of the essential oil compounds of 117 individual plants belonging to 11 Syrian populations of *Origanum syriacum* L. (Lamiaceae) were studied by GC-FID and GC-MS. The composition was dominated by carvacrol and/or thymol with a high degree of polymorphism in the occurrence of these two compounds between the different populations. In three populations carvacrol was dominating, with thymol being present only in minor amounts, whereas in only one population thymol was the main compound, with carvacrol only in traces. In all other populations both carvacrol and thymol were present as major compounds. No geographical pattern could be detected for the occurrence of the chemotypes. Thymoquinone, a promising anticancer candidate, was present in the extracts in a wide range between 0.04 and 23.7%.

KEYWORDS: *Origanum syriacum*; essential oil compounds; carvacrol; thymol; thymoquinone; Syria

INTRODUCTION

The genus *Origanum* (Lamiaceae) consists of 43 species and 18 hybrids arranged in 3 groups and 10 sections (*1*). *Origanum syriacum* L. is placed in the section Majorana, together with *Origanum majorana* L. and *Origanum onites* L (*2*). Within *O. syriacum* three varieties, var. *syriacum*, var. *bevanii* (Holmes) Ietswaart, and var. *sinaicum* (Boissier) Ietswaart, are described (*2*). *O. syriacum* inhabits a large area in the eastern Mediterranean. It can be found in southern Turkey, on Cyprus, in Syria, Lebanon, Israel, Jordan, and on the Sinai Peninsula and grows from nearly sea level up to at least 2000 m in rocky soils, often on limestone (*2*). In Syria the plant is called "soba'a" (whirlwind) in the north of the western mountain range and "za'atar khalil" (meaning not known) on the coast and in the southern part of the coastal mountain range. In Syrian folk medicine *O. syriacum* is used for treating gastrointestinal problems and respiratory diseases (Gadoua, personal communication). Treatment against respiratory diseases is also reported as the main medicinal use of this species from neighboring countries such as Jordan (*3, 4*), Israel (*5*), and Palestine (*6*). In Jordan the plant is reported to be additionally used as a carminative, pectoral, antitussive, aperitif, and antistomachache and against arthritis (*3, 4*). In different historical records from the area of Bilad al-Sham (a historical geographical term by former Arab rulers that included significant parts of present-day Syria, Lebanon, Israel, Palestine, and Jordan) *Origanum* sp. was used against internal diseases, hemorrhoids, sexual diseases, pains, animals bites, and poison (*7*). Because *O. syriacum* is the dominating species of the genus in this region, it is very likely that this species was meant by the historical records. Today the quantitatively predominating use, however, is for human consumption as a basic ingredient in za'atar. Many other species from the Labiatae family are also used as za'atar such as *Satureja thymbra* L., called "za'atar rumi" or "za'atar franji" (Roman or European hyssop), *Thymbra spicata* L., called "za'atar hommar" or "za'atar sahrawi" (donkey or desert hyssop), and *Coridothymus capitatus* (L.) Reichenb., called "za'atar farsi" (Persian hyssop). But za'atar par excellence prevailing in terms of sensorial quality and in market quantities is *O. syriacum* (*8*). The basic mixture of za'atar consists of dried and ground leaves of *O. syriacum* (za'atar), powdered seed coats of sumac (*Rhus coriaria*, Anacardiaceae) as acidulant and responsible for the typical red color, salt, roasted sesame seeds, and olive oil. This mixture is often refined by other spices, walnuts, etc. The large quantities needed for preparing za'atar are exclusively collected from the wild.

The essential oil of *O. syriacum* is dominated by carvacrol and thymol (*8*−*18*). Only in one case the bicyclic *cis*-sabinene hydrate was described as a major compound in this species (*19*). Essential oil chemotypes are frequently occurring in species of the genus *Origanum*, whereas rare chemotypes are often overlooked when pooled plant samples are analyzed. In *O. majorana* L. from Cyprus, for example, two new chemotypes could be found by analyzing individual plants (*20*), whereas previous studies about wild-growing *O. majorana* analyzed only the essential oil distilled from a mixture of plants. Also in *O.*

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Table 1. Geographical Localization of the 11 Populations of *Origanum syriacum* Collected in Syria

population	variety	no. of individuals sampled	elevation (m)	GPS N	GPS E
1	var. *bevanii*	5	600	36° 30′ 04.2″	36° 44′ 46.0″
2	var. *bevanii*	2	235	36° 09′ 27.4″	36° 30′ 10.2″
3	var. *bevanii*	16	525	35° 49′ 53.7″	36° 15′ 51.0″
4	var. *bevanii*	13	347	35° 42′ 40.0″	36° 05′ 58.3″
5	var. *bevanii*	12	523	35° 47′ 16.6″	36° 02′ 12.0″
6	var. *syriacum*	4	283	35° 20′ 48.6″	36° 04′ 27.8″
7	var. *syriacum*	5	538	35° 20′ 06.5″	36° 06′ 38.3″
8	var. *syriacum*	16	860	35° 20′ 57.2″	36° 08′ 55.3″
9	var. *bevanii*	20	937	35° 05′ 49.7″	36° 12′ 16.0″
10	var. *bevanii*	9	575	34° 59′ 46.7″	36° 11′ 45.9″
11	var. *bevanii*	15	270	34° 47′ 09.7″	36° 09′ 28.9″

Table 2. Essential Oil Compounds of 11 Different Populations of *Origanum syriacum* from Syria[a]

		population										
compound	RI	1	2	3	4	5	6	7	8	9	10	11
α-thujene	932	0.9 ± 0.4	0.9 ± 0.0	1.0 ± 0.3	1.0 ± 0.2	1.0 ± 0.1	0.8 ± 0.1	0.8 ± 0.3	0.9 ± 0.2	0.8 ± 0.2	0.9 ± 0.1	0.9 ± 0.6
α-pinene	941	0.7 ± 0.1	0.7 ± 0.0	0.7 ± 0.1	0.7 ± 0.1	0.7 ± 0.1	0.7 ± 0.1	0.6 ± 0.2	0.6 ± 0.1	0.6 ± 0.1	0.6 ± 0.0	0.6 ± 0.1
sabinene + β-pinene	980	0.9 ± 0.5	0.8 ± 0.1	0.9 ± 0.4	1.6 ± 2.1	0.8 ± 0.5	0.4 ± 0.3	1.0 ± 0.4	1.0 ± 0.4	0.9 ± 0.4	1.2 ± 0.4	1.0 ± 0.4
myrcene	992	1.3 ± 0.8	2.0 ± 0.0	1.7 ± 0.6	1.8 ± 0.3	1.7 ± 0.6	1.8 ± 0.4	1.4 ± 0.6	1.6 ± 0.5	1.8 ± 0.3	1.7 ± 0.4	1.5 ± 0.4
α-phellandrene	1008	0.2 ± 0.1	0.3 ± 0.0	0.2 ± 0.1	0.2 ± 0.1	0.2 ± 0.1	0.2 ± 0.0	0.1 ± 0.1	0.2 ± 0.1	0.3 ± 0.1	0.3 ± 0.1	0.2 ± 0.1
α-terpinene	1021	0.9 ± 0.8	1.7 ± 0.7	1.7 ± 0.6	1.5 ± 0.5	1.6 ± 0.9	1.2 ± 0.3	1.1 ± 0.5	1.3 ± 0.4	1.8 ± 0.5	1.5 ± 0.6	1.0 ± 0.4
p-cymene	1029	6.1 ± 2.4	5.3 ± 3.3	9.8 ± 7.5	6.9 ± 7.7	8.0 ± 5.1	6.7 ± 2.5	17.7 ± 20.1	10.0 ± 7.7	8.4 ± 5.4	7.9 ± 5.6	8.0 ± 6.4
limonene	1034	0.4 ± 0.1	0.5 ± 0.1	0.4 ± 0.1	0.4 ± 0.1	0.5 ± 0.1	0.4 ± 0.1	0.3 ± 0.2	0.4 ± 0.1	0.5 ± 0.1	0.4 ± 0.1	0.4 ± 0.1
γ-terpinene	1064	5.4 ± 5.6	11.2 ± 8.7	11.3 ± 5.1	9.8 ± 3.9	8.9 ± 5.5	6.8 ± 1.8	8.0 ± 3.4	9.0 ± 4.0	14.3 ± 6.4	11.8 ± 6.7	6.7 ± 4.0
trans-sabinene hydrate	1072	1.0 ± 0.1	0.9 ± 0.0	1.0 ± 0.2	0.9 ± 0.1	1.0 ± 0.1	1.0 ± 0.1	0.9 ± 0.2	0.9 ± 0.3	0.9 ± 0.1	1.0 ± 0.2	1.0 ± 0.1
cis-sabinene hydrate	1101	0.4 ± 0.0	0.6 ± 0.2	0.4 ± 0.1	0.3 ± 0.1	0.3 ± 0.0	0.4 ± 0.0	0.4 ± 0.1	0.4 ± 0.1	0.4 ± 0.1	0.4 ± 0.1	0.4 ± 0.1
terpinen-4-ol	1183	0.3 ± 0.0	0.3 ± 0.0	0.2 ± 0.1	0.2 ± 0.0	0.3 ± 0.1	0.3 ± 0.1	0.2 ± 0.1	0.2 ± 0.1	0.2 ± 0.0	0.2 ± 0.0	0.2 ± 0.1
thymoquinone	1253	4.3 ± 4.1	1.6 ± 1.4	4.7 ± 5.8	2.5 ± 1.9	6.0 ± 6.1	5.1 ± 3.7	4.5 ± 3.1	5.5 ± 5.6	3.1 ± 3.3	5.6 ± 6.2	5.7 ± 5.7
thymol	1296	0.4 ± 0.1	27.8 ± 38.7	15.4 ± 23.7	0.3 ± 0.1	22.2 ± 28.7	10.6 ± 11.3	0.4 ± 0.2	17.6 ± 25.0	57.6 ± 10.3	14.2 ± 22.2	13.3 ± 21.9
carvacrol	1306	69.8 ± 3.6	40.7 ± 53.6	42.1 ± 23.3	63.8 ± 12.0	41.7 ± 29.8	58.2 ± 5.8	53.9 ± 21.6	44.1 ± 31.8	2.7 ± 0.6	45.1 ± 26.6	52.0 ± 31.7
β-caryophyllene	1431	1.7 ± 0.4	2.4 ± 0.3	2.8 ± 0.8	3.2 ± 0.7	2.1 ± 0.3	2.3 ± 0.4	3.5 ± 1.3	3.2 ± 1.0	3.0 ± 0.9	3.9 ± 0.7	4.1 ± 0.9
α-humulene	1466	0.2 ± 0.0	0.2 ± 0.0	0.3 ± 0.1	0.4 ± 0.2	0.2 ± 0.1	0.2 ± 0.1	0.4 ± 0.3	0.3 ± 0.2	0.2 ± 0.1	0.4 ± 0.2	0.3 ± 0.2
β-bisabolene	1516	0.3 ± 0.3	0.4 ± 0.3	1.2 ± 0.8	1.7 ± 1.1	0.2 ± 0.2	0.9 ± 0.6	1.9 ± 1.8	0.5 ± 0.4	0.6 ± 0.5	0.9 ± 0.4	0.8 ± 0.4
germacrene B	1561	2.8 ± 2.2	0.3 ± 0.2	1.6 ± 2.0	0.5 ± 0.4	1.1 ± 1.1	0.8 ± 0.4	0.4 ± 0.2	0.4 ± 0.4	0.3 ± 0.4	0.3 ± 0.4	0.3 ± 0.3
caryophyllene oxide	1596	0.7 ± 0.5	0.2 ± 0.0	0.6 ± 0.5	0.4 ± 0.2	0.3 ± 0.4	0.3 ± 0.2	0.5 ± 0.4	0.2 ± 0.1	0.2 ± 0.1	0.3 ± 0.2	0.2 ± 0.1

[a] Values are arithmetic mean peak area percentages ± standard deviations.

syriacum so far only the essential oil composition of mixed plant samples is reported. In this work we present an analysis of the essential oil compounds from individual plants of 11 populations of *O. syriacum* from Syria, collected along a north−south transect in its distribution area.

MATERIALS AND METHODS

Plant Material. One hundred and seventeen samples of 11 populations of *O. syriacum* L. (Lamiaceae) were collected in Syria in full bloom following a north−south transect in July 2006 (**Table 1**). The identification of plant material was done according to the method of Ietswaart (*2*). The attribution of sampled plants to one of the two varieties in question (var. *syriacum* or var. *bevanii*) was not always unambiguous due to the subtle morphological differences that are used for their discrimination. Voucher specimens of the populations are kept at the herbarium of the Institute for Applied Botany.

Extraction. Seventy milligrams of dried plant material was extracted in 1 mL of dichloromethane for 30 min in an ultrasonic water bath. The extracts were filtered with cotton pads on a Pasteur pipet. Solvent extraction instead of distillation was chosen for the following reason: some essential oil compounds are labile to temperature and/or water and are rearranged during distillation as it is the case for, for example, *cis*-sabinene hydrate, a compound often present in the genus *Origanum* (*21*). Solvent extraction often avoids this problem and enables the detection of the native plant composition (*22*).

GC and GC-MS Analyses. *Fast-GC-FID.* The quantitative GC analyses were performed on an HP 6890 equipped with a FID and fitted with an Agilent DB-5 narrow-bore capillary column (10 m × 0.1 mm, 0.17 μm film thickness). Helium was used as carrier gas. The front inlet was kept at 260 °C in split mode (split ratio = 100:1); injection volume, 0.2 μL; temperature program, 60 °C for 1 min, from 60 to 85 °C at 8 °C/min, from 85 to 280 °C at 12 °C/min.

GC/MS. Analyses to identify the compounds were performed on an HP 6890 coupled with an HP 5972 MSD (mass range *m*/*z* 50−550) and an Agilent DB-5MS narrow-bore capillary column (30 m × 0.25 mm, 0.25 μm film thickness). Helium was used as carrier gas. The inlet was kept at 260 °C in split mode (split ratio = 100:1); injection volume, 1 μL; temperature program, 60 °C for 4 min, from 60 to 100 °C at 5 °C/min, from 100 to 280 °C at 9 °C/min.

Retention indices (RI) of the sample components were determined on the basis of homologous *n*-alkane hydrocarbons under the same conditions. Fenchone was used as internal standard at a concentration of 0.1 mg/mL dichloromethane. The quantitative composition was obtained by peak area normalization, and the response factor for each component was considered to equal 1. The compounds were identified by comparing their retention indices and mass spectra with published data (*23, 24*).

RESULTS AND DISCUSSION

O. syriacum is an important "cash crop" in western Syria, collected exclusively from the wild. In this study the composition of essential oil compounds is dominated by carvacrol and thymol followed by their precursors γ-terpinene and *p*-cymene as well as thymoquinone (**Table 2**).

With regard to its main compounds carvacrol and thymol the species is highly polymorphic in Syria. In our samples the population average values for carvacrol are in a range of

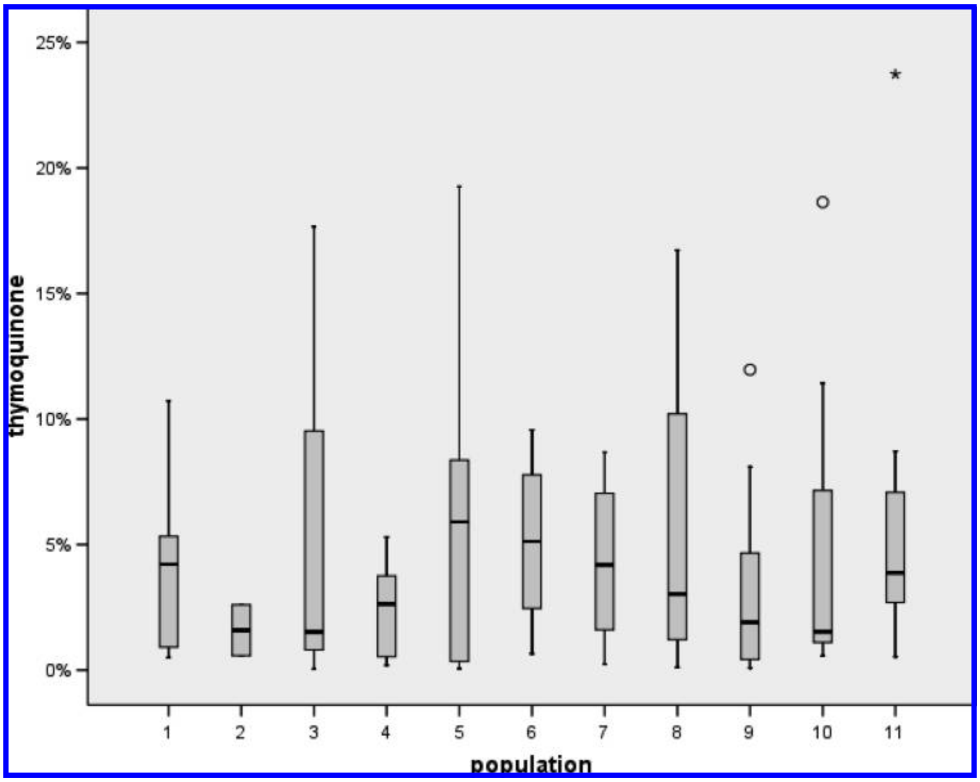

Figure 1. Box plot of thymoquinone contents in the different populations of *Origanum syriacum*.

2.7−69.8%, whereas thymol values were between 0.3 and 57.6%. In Syria 4 of 11 populations were dominated by carvacrol (populations 1, 4, and 7) or thymol (population 9); in the remaining 7 populations both compounds occurred at higher levels. Comparable results were found in previous studies about *O. syriacum* sampled in Turkey, Lebanon, Israel, and Egypt where sometimes one of the two main compounds was over dominating (*9*, *14*, *15*) or both were present in higher amounts (*8*, *10*, *11*). The ratio between the main compounds, however, may change during the vegetation period (*16*). The only deviating essential oil composition was reported by Baser et al. (*19*), who found besides thymol as main compound also *cis*-sabinene hydrate at approximately the same quantity as thymol. In our samples no geographical pattern could be observed regarding the distribution of the two compositional types. Carvacrol and thymol are compounds with remarkable antioxidant activity. In *O. syriacum*, however, the essential oil as well as the pure compounds carvacrol and thymol exhibit lower antioxidant activities than the dichloromethane and methanol/water extracts. Therefore, the major effect of the high antioxidant activity of *O. syriacum* is due to other polar and nonpolar phenolics (*25*).

The average population values of γ-terpinene and *p*-cymene varied between 5.4 and 14.3% and between 5.3 and 17.7%, respectively. The value of 17.7% for *p*-cymene in population 7 was an extreme value based on one sample with an extraordinarily high value of 52%; all other samples showed a continuous variation for *p*-cymene of up to 30%.

Thymoquinone was present in the samples in a wide range between 0.04 and 24%. The average mean of 4.5% together with a median of 3% already indicates a high positive skewness (1.57) of the distribution of thymoquinone. The populations themselves showed mean values for thymoquinone between 1.6 and 6% with very high variability within the populations (**Figure 1**). Especially populations 3, 5, and 8 showed a wide range with values of up to almost 20%. The highest value of 24% was found as an extreme outlier in population 11, where the rest of the population has thymoquinone contents of below 10%.

Thymoquinone is a bioactive compound with interesting properties such as antioxidant effects and anti-inflammatory and analgesic actions (*26*, *27*). Furthermore, the molecule has become a promising anticancer candidate (*28*, *29*). Thymoquinone is often the major aglycone in glycosidically bound volatiles within the genus *Origanum* (*30*−*32*). However, it has been reported as a free (not glycosidically bound) volatile compound only by Economakis et al. (*33*, *34*) for *Origanum dictamnus* and by Johnson et al. (*35*) for *Origanum vulgare* ssp. *hirtum*. First indications for polymorphisms between genotypes of this compound were demonstrated by Economakis et al. (*34*), who found for the two genotypes examined very distinct levels of thymoquinone. Hirobe et al. (*36*) demonstrated the high cytotoxic activity of this compound and published the only report of the presence of low amounts of unbound thymoquinone in the species *O. syriacum*.

Nigella sativa was always propagated as a natural source of thymoquinone (*26*−*29*) and has a 2-fold higher content of thymoquinone in the essential oil (*26*) compared to the best individuals of *O. syriacum*. The >12-fold higher essential oil content in *O. syriacum* together with an 8−9-fold higher yield (*18*), however, demonstrates impressively the higher production potential of *O. syriacum* as a natural source for thymoquinone.

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