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Chemotypes and antibacterial activities of *Inula viscosa* essential oils from Algeria

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Abstract. *Ounoughi A, Ramdani M, Lograda T, Chalard P, Figueredo G. 2020. Chemotypes and antibacterial activities of* Inula viscosa *essential oils from Algeria. Biodiversitas 21: 1504-1517.* The aim of this work is to investigate the chemical composition and the antibacterial activities of the essential oils from *Inula viscosa* (L.) Aiton. Samples were collected in the flowering stage, from different localities in Algeria. The aerial parts of *I. viscosa* were submitted to a hydro distillation. The chemical composition of the essential oil was analyzed by GC and GC/MS. The antibacterial activity of the essential oils was evaluated using the disc diffusion method against fifteen bacterial species. Fifty-eight compounds representing 98.93 ± 2.03% of the total oil was identified in *I. viscosa*. It was found that the chemical composition was dominated by the presence of the following major products: polygodial (19.8 ± 16.97%), phytol (12.3 ± 9.77%), fokienol (6.01 ± 3.43%), intermedeol neo (5.09 ± 2.38%), caryophyllene oxide (4.91 ± 3.03%), nerolidol-Z (4.46 ± 5.46%), nerolidol-E (4.24 ± 8.07%) and α-ionone iso methyl-E (3.72 ± 2.26%). The essential oil of *I. viscosa* has moderate activity against the bacteria tested. In contrast, the *Escherichia coli* ATCC 25922, *Pseudomonon syringae* ATCC 53543 and *Enterococcus faecalis* ATCC 49452 strains are resistant to *I. viscosa* essential oils. The phytochemical study of *I. viscosa* showed that it is rich in terpene compounds, with polygodial and phytol as major components. Three distinct chemotypes are highlighted. The (Polygodial-Intermedeol-neo-Phytol) chemotype of Salah Bey population and two chemotypes with Fokinol-polygodial and Fokinol-phytol. Moderate antibacterial activities of essential oils against the bacteria tested were found.

Keywords: Algeria, antibacterial activity, chemotypes, essential oil, *Inula viscosa*

INTRODUCTION

Inula viscosa (L.) Aiton (Asteraceae) is a herbaceous perennial plant widely spread in the Mediterranean area. The taxonomic revision of the *Dittrichia* genus showed that *I. viscosa* is a synonym of the accepted name *Dittrichia viscosa* (L.) Greuter (Brullo and De Marco 2000; Parolin et al. 2014). This taxonomic change is confirmed in the online "The Plant List" database. It should also be noted that the name *I. viscosa* continues to appear in the literature (Kattouf et al. 2009; Talib et al. 2012; Andolfi et al. 2013; Haoui et al. 2015; Prisa 2019).

Inula viscosa is the most frequently cited among the species of the *Inula* genus, for its vast ethnopharmacological applications (Lev and Amar 2000; Zhao et al. 2006; Merghoub et al. 2009; Al-Qudah et al. 2010; Rajkumar 2012; Amin et al. 2013; Belayachi et al. 2013; Bouyahya et al. 2018; Ozkan et al. 2019). It is used to treat a wide range of disorders, primarily respiratory, gastrointestinal, inflammatory, dermatological, cancer and microbial diseases (Seca et al. 2014; Rhimi et al. 2017, 2018).

Inula viscosa has several biological activities such as: antipyretic and antiseptic (Lauro and Rolih 1990), antifungal (Cohen et al. 2002; Cafarchia et al. 2002; Franco-Mican et al. 2008; Bssaibiss et al. 2009; Al-Masri et al. 2015; Rhimi et al. 2017, 2018; Sriti Eljazi et al. 2018; Mohti et al. 2019; Gharred et al. 2019), antimicrobial (Bssaibiss et al. 2009; Larbi et al. 2016; Rhimi et al. 2017, 2018; Aissa et al. 2019), anti-ulcerogenic (Alkofahi 1999), antioxidant (Schinella et al. 2002; Benseguini-Tounsi 2001; Remli 2013; Chahmi et al. 2015; Sriti Eljazi et al. 2018; Mohti et al. 2019; Gharred et al. 2019), antiviral (Bensassi et al. 2008), anti-tumoral (Rozenblat et al. 2008; Isil et al. 2018; Bar-Shalom et al. 2019; Hepokur et al. 2019), antimalaria (Akkawi et al. 2014), hypolipidemic (Zeggwagh et al. 2006) and anti-tyrosinase (Aissa et al. 2019). *Inula*'s essential oils are also used in the food industry to increase the shelf life of a large number of food products, particularly fats (Boumaza 2011).

The essential oils chemical composition of *I. viscosa* growing in different countries have been investigated; in Island (Pistelli et al. 2018), in Portugal (Miguel et al. 2008); in Spain (Camacho et al. 2000; Blanc et al. 2006); in France (Blanc et al. 2006); in Italy (De Laurentis et al. 2002; Marongiu et al. 2003); in Turkey (Blanc et al. 2006; Sevindik et al. 2017); in Jordan (Al-Qudah et al. 2010); in Syria (Nasser et al. 2014; Alalan et al. 2015), in Lebanon (Assi et al. 2010) in Tunisia (Sriti Eljazi et al. 2018; Aissa et al. 2019) and in Algeria (Madani et al. 2014; Boudouda

et al. 2014; Haoui et al. 2015) (Table 1). β-caryophyllene, tricosane, and isocostic acid characterized the populations of Algeria (Boudouda et al. 2014; Madani et al. 2014). The populations of Italy are characterized by 12-carboxy eudesma-3-11 (13)-diene (De Laurentis et al. 2002). The populations of Island are characterized by 10-epi-γ-eudesmol, α-eudesmol, β-caryophyllene and limonene (Pistelli et al. 2018). The populations of France and Spain contain fokienol, nerolidol-(E) and α-eudesm-6-en-4-ol (Camacho et al. 2000; Blanc et al. 2006). In Italy, the oil of this species is composed of globulol, valerianol and caryophyllene oxide (Chiarlo 1968; De Laurentis et al. 2002; Marongiu et al. 2003); in Turkey, it is composed of borneol, bornyl acetate and iso-bornyl acetate (Perez et al. 1996). *I. viscosa* from Syria is rich in 11-hydroxy-6-ememopheryl (7)-9-(10)-dien-8-one, veridiflorol, cedr-8-en-13-ol, caryophyllene oxide, β-selinene, terpineol and β-bisabolene (Hwija et al. 2018).

The essential oil from Tunisia populations are characterized by the neryle isovalerate-Z, 1,10-di-epi-cubenol and 2,5-dimethoxy-p-cymene (Aissa et al. 2019). The study by Gharred et al. (2019) showed that the chemical composition of the essential oils from different parts of the plant was variable; the flowers contain nerolidol-E, while the leaves were characterized by caryophyllene oxide, isolongifolan-7-α-ol and α-eudesmol.

In another study, the essential oil of *I. viscosa* was tested against *Listeria monocytogenes* which showed high resistance (Silva et al. 2005). In contrast, the essential oil showed an inhibitory effect against *E. coli*, *K. pneumoniae*, *L. innocua*, *S. Aureus*, *P. aeruginosa* strains (Kheyar et al. 2014; Chebouti-Meziou 2016). *Enterobacter* sp., *Bacillus thuringiensis*, *Micrococcus* sp. and *Aspergillus niger* and *Candida albicans* strains, were sensitive to *I. viscosa* oils (Chebouti-Meziou 2016).

The aim of this study is to identify the chemical composition of *I. viscosa* essential oils by GC/MS analysis, to compare the results with the data reported in the literature and to the geographical distribution of chemotypes in Algeria.

Table 1. Chemical composition of *Inula viscosa* essential oil from literature

Localities	**Syria 1**	**Martina**	**Putignano**	**Bari**	**Otranto**	**Sidi Rezine**	**Turkey 1**	**Syria 2**	**France**	**Spain**	**Turkey 2**	**Jordan**	**Lebanon**	**Ain El-Bey**	**Ham Bouziane**	**Portugal**	**Sardinia**
References *	**A**		**B**			**C**	**D**	**E**	**F**	**G**	**H**	**I**	**J**	**K**		**L**	**M**
Fokienol	0.0	0.0	0.0	0.0	0.0	3.4	0.0	0.0	21	39	0.0	30	0.0	4.4	7.2	0.0	0.0
Linolenic acid	0.0	0.0	3.0	0.0	3.8	7.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.1	9.1	0.0	0.0
Pentacosane	7.1	0.0	0.0	0.0	0.0	5.4	0.0	0.0	0.0	0.0	0.3	0.0	0.0	2.0	0.4	0.0	0.0
Heptacosane	0.0	0.0	0.0	0.0	0.0	4.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.3	1.9	0.0	0.0
Nerolidol B	15.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	7.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Caryophyllene Oxide	3.8	2.6	0.6	1.3	2.2	0.2	1.5	1.9	2.5	0.0	3.4	2.6	2.2	5.5	0.1	0.0	8.0
Farnesene-E epoxide	22.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Sellin-6-En-4-ol	2.2	3.3	1.4	2.1	2.0	0.0	0.0	0.0	1.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Octadecanoic Acid	11.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cineol-1-8	0.0	9.6	0.3	2.3	2.3	0.0	0.0	1.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
α-Terpineol	0.0	3.1	3.9	2.6	1.7	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ß-Caryophyllene	0.0	1.7	1.0	1.0	1.9	0.0	0.0	1.3	0.0	0.0	0.0	1.5	0.0	25	9.6	0.0	0.0
Hexahydrofarnesyl Acid	0.0	5.1	0.9	1.8	2.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
12-Carboxyeudesma-3,11 (13)d	0.0	20	42	48	27	29	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Tricosane	0.0	4.6	0.5	0.7	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0
Isocostic acid	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	10	25	59	0.0
Borneol	0.0	0.0	0.0	0.0	0.0	0.0	25	1.7	0.0	0.0	0.0	0.0	0.0	1.6	0.0	0.0	0.0
Bornyl acetate	0.0	0.0	0.0	0.0	0.0	0.0	20	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
lsobornyl acetate	0.0	0.0	0.0	0.0	0.0	0.0	23	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Eugenol	0.0	0.0	7.3	4.0	1.2	0.0	0.0	2.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Intermedeol neo	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.4	7.5	0.0	0.0
2,4-dioxo-3-methyl-6-isopropyl	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	29	0.0	0.0	0.0	0.0	0.0	0.0
Eudesma-5,11 (13)-dien-8,12-	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	25	0.0	0.0	0.0	0.0	0.0	0.0
Bicyclo esquiphellandrene epi	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	17	0.0	0.0	0.0	0.0
Cadinol	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.3	0.0
Globulol	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.8	4.1	0.0	0.0	0.0	17
Nerolidol-E	0.0	6.9	3.4	2.4	2.9	0.0	1.5	1.1	8.6	0.0	0.0	20	0.0	0.0	0.1	1.1	1.9
Valerianol	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	12
1,3-(1,1-dimethylethyl)2Mxy-5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	21	0.0	0.0	0.0	0.0
2,3,5,6,Tetraflouroanisol	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	17	0.0	0.0	0.0	0.0
Azulene	0.0	0.0	0.0	0.0	0.0	0.0	0.0	9.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Eucalyptol	0.0	10	0.3	2.3	2.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Note: *****: A. Nasser et al. (2014); B. De laurentis et al. (2002); C. Haoui et al. (2011); D. Perez-Alonso et al. 1996); E. Alalan et al. (2015); F. Blanc et al. (2006); G. Camacho et al. (2000); H. Sevindik and Paksoy (2017); I. Al Qudah et al. (2010); J. Assi et al. (2014); K. Boudouda et al. (2012); L. Miguel et al. (2008); M. Marongiu et al. (2003)

MATERIALS AND METHODS

Plant material

Inula viscosa L. is an annual herbaceous, viscid and glandular plant with a strong odor. It can reach 50 cm to 1m in height and has many flower heads with yellow flowers at the top of the stem (Quezel and Santa 1963) (Figure 1), locally it is called Magramen.

The essential oil extraction

Samples of *I. viscosa* were collected in the flowering stage from 15 localities in Algeria (Figure 2). The aerial parts were collected in October 2017. The air-dried materials were subjected to hydro-distillation for 3h using a Clevenger apparatus type. Voucher specimens were deposited in the herbarium of the Department of Biology and Ecology, Setif-1 University, Algeria.

The oil obtained was collected and dried over anhydrous sodium sulfate and stored in screw-capped glass vials in a refrigerator at 4-5°C prior to analysis. The Essential oil yield was calculated by the following formula:

$$\text{Yield in essential oil (\%)} = \frac{\text{Weight of the essential oil}}{\text{Weight of the plant used}} x100$$

Essential oil analysis

The essential oils were analyzed using a Hewlett-Packard gas chromatograph (CG/FID 7890), coupled to a gas chromatograph (CG/MS 7890/5975C), equipped with a Column Apolar: DB5 MS: 40 m 0.18 mm 0.18 µm and programming from 50°C for 5min at rate of 5°C/min up to 300°C. Helium was used as the carrier gas (1.0 ml/min); injection in the split mode (1:30), injector and detector temperature of 280°C with split 1/100. The mass spectrometer worked in the EI mode at 70 eV; electron multiplier, 2500 V; ion source temperature, 180°C; the MS data were acquired in the scan mode in the m/z range of 33-450. The identification of the components was based on the comparison of their mass spectra with those of NIST mass spectral library (Masada 1976; NIST 2002) and those described by Adams, and the comparison of their retention indices either with those of authentic compounds or with literature values (Adams 2007).

Antimicrobial Activity

The antimicrobial activities of the essential oil of *I. viscosa* were evaluated against six Gram-positive bacteria (*Staphylococcus aureus* ATCC2592, *S. aureus* SARM, *Listeria innocua* CLIP 74915, *L. Monocytogenes*, *Bacillus cereus* ATCC 11778 and *Enterococcus faecalis*, and nine Gram-negative bacteria (*Pseudomonas aeruginosa* ATCC 27853, *Klebsiella pneumoniae* ATCC700603, *Escherichia coli* ATCC 25922, *Proteus mirabilis* ATCC35659, *Enterobacter cloacae*, *Acetobacter*, *Serratia marcescens*, *S. liquefaciens*, ESBL/BLSE and *Salmonella enterica*. Bacterial inoculums were prepared from overnight broth culture in physiological saline (0.8 % of NaCl) to obtain an optical density ranging from 0.08 to 0.1 at 625 nm. Muller Hinton agar (MH agar) and MH agar supplemented with 5% sheep blood for fastidious bacteria were placed in Petri dishes, solidified, and surface dried before inoculation. Sterile discs (6mm) were placed on inoculated agars, by test bacteria, filled with 10µl of undiluted and diluted essential oil (1/1, 1/2, 1/3 v / v of DMSO). DMSO was used as a negative control, and the antibiotic Gentamicin is used as positive control. The bacterial growth inhibition was determined as the diameter of the inhibition zones around the discs. All the tests were performed in triplicate, and the means were calculated as results. The Petri dishes were incubated at 37°C for 18 to 24h aerobically. After incubation, inhibition zone diameters were measured and documented (Dahiya and Purkayastha 2012). The sensitivity to the essential oil was classified according to the diameter of the inhibition halos as follows: not sensitive (-) for diameters less than 8 mm; sensitive (+) for diameters ranging from 9 to 14 mm; very sensitives (++) for diameters ranging from 15-19 mm and extremely sensitive (+++) for diameters larger than 20 mm (Ponce et al. 2003).

Statistical analysis

The data were first subjected to the Principal Components Analysis (PCA) to examine the relationships among the terpenes compounds and identify the possible structure of the populations. Cluster analysis (UPGMA) was carried out on the original variables and on the Manhattan distance matrix to seek for hierarchical associations among the populations. The cluster analyses were carried out using Statistica v10 software. The antibacterial activity results were analyzed by the ANOVA three-way Completely Randomized (populations, doses, and bacteria) by using the CoStat statistical software package. All analyses were performed at the 5% significance level ($P < 0.05$).

Figure 1. *Inula viscosa* L.

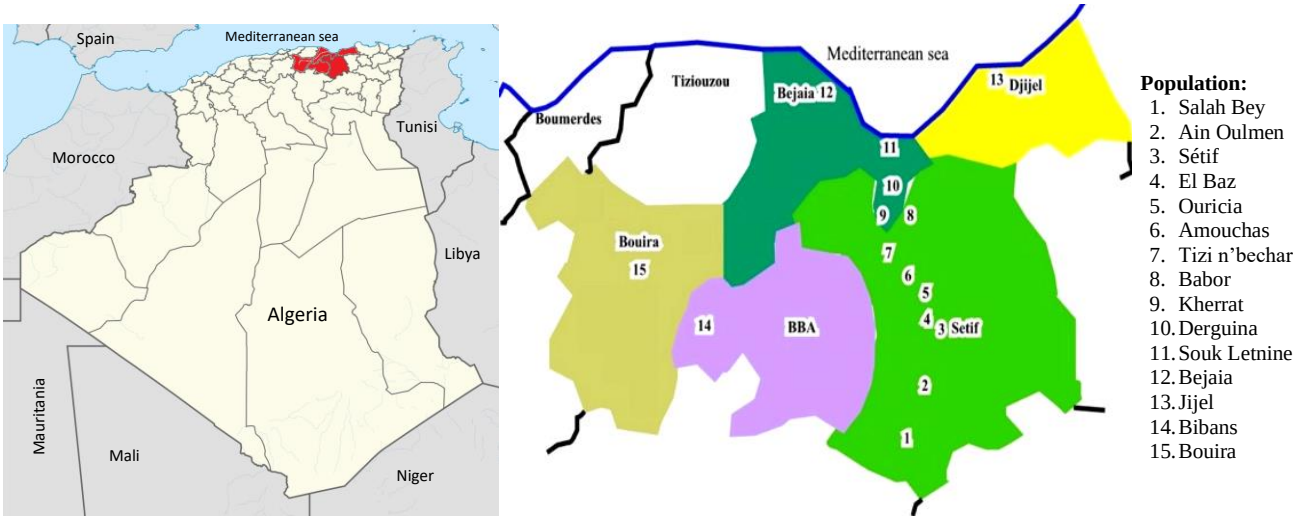

Figure 2. Populations of *Inula viscosa* sampled in Algeria

RESULTS AND DISCUSSION

The hydro-distillation of *Inula viscosa* essential oils gave a yellow-colored viscous liquid. The average yield of the essential oils was 0.23 ± 0.06%. The analysis of the composition of the essential oils was carried out using (GC-MS) (Figure 3).

The identified components and their relative abundances are presented in the order of their appearance (Table 2). Seventy-five chemical compounds, with an average of 38 ± 4, were identified in *I. viscosa* essential oils, representing an average of 98.06 ± 2.03% of the total oils.

The chemical composition of the essential oils of *I. viscosa* populations is very different, but it is dominated by the presence of polygodial (19.8 ± 16.97%), phytol (12.3 ± 9.77%), fokienol (6.01 ± 3.43%), intermedeol neo (5.09 ± 2.38%), caryophyllene oxide (4.91 ± 3.03%), nerolidol-Z (4.46 ± 5.46%), nerolidol-E (4.24 ± 8.07%) and α-ionone iso methyl-E (3.72 ± 2.26%).

The composition of *I. viscosa* essential oils shows significant differences. The concentrations of these components show notable inter-population variability (Figure 4). The compounds that show the largest variation are β-acoradienol (RSD 353), canellal (RSD 339) farnesol (2Z, 2E) (RSD 231) and retene (RSD 214).

The canellal, with an average of 0.51 ± 1.69% is the component that exhibits the greatest variation in this species, followed by retene (0.64 ± 1.38%), γ-ionone iso methyl, nerolidol-Z, Eicosane-1, geranyl acetone, α-muurolene 14-oxy, linoleic acid, aromadrene epoxide allo, nerolidol-E.

Camphor occurs in Biban and El Bez populations with a high content 7.58 and 3.34% respectively. The populations of Bouira and Babor isolate themselves with high levels of aromadrene epoxide-allo (7.1 and 5.33%). Farnesol (2Z, 6E) is present in the oils of three populations Bouira, Bibans and Bejaia with appreciable levels 5.69, 1.67 and 2.36% respectively. The population of Setif is individualized by the presence of β-acoradienol with a concentration of 5.95%. The canellal is present only in Kherrata and Amoucha populations with contents of 1.19 and 6.53%. The populations of Bouira, Ain Oulmen, and Salah Bey contain appreciable levels of retene, 3.73, 4.04 and 1.57% respectively.

I. viscosa populations show very little differences in the total concentrations of the essential oils. To compare profiles with chemical compounds we considered each compound as a quantitative variable. The spatial three-dimensional projection of the 15 populations based on the three main axes from the PCA (Figure 5), shows that the populations of Salah Bey, Ain oulemen, Souk Letnine, Bibans, and Tizi n'Bechar are distinctly separated, but the rest of the populations studied are not clearly distinguished and their separation into homogeneous groups is less clear.

The UPGMA clusters analysis based on the linkage distance, confirms the results of the PCA and separates I. viscosa populations in two distinct clades. This clustration of the populations in small groups indicates differences in the chemical composition of the essential oils (Figure 6). The essential oils of the first cluster, the Salah Bey population, is characterized by a high content of polygodial and important concentrations of phytol and intermedeol-neo.

The second cluster is composed of two subgroups: the first group that includes the populations of Ain Oulemen, Babor, Jijel, Bibans, Bejaia, and Bouira is characterized by a high level of fokienol, Polygodial and Nerolidol-Z.

The second group includes the populations of Ouricia, Derguina, Bibans, Tizi n'Bechar, Setif, Amoucha, El baz, and Kherrata is characterized by the presence of high levels of fokienol, phytol, intermedeol-neo, geranyl acetone, and nerolidol-E. Based on the chemical and statistical results of Inula viscosa populations, several chemotypes can be identified (Table 3).

The Antibacterial activity of the essential oils of I. viscosa is evaluated by the disc method. The diameters of inhibition of the bacterial strains were determined by

measuring the diameter of the inhibition halos after 24 hours of incubation at 37°C (Table 4). The results of the antibacterial assay of I. viscosa essential oils against several bacteria strains showed that P. aeruginosa, K. pneumoniae, S. aureus ESBL and S. enterica bacterial species were extremely sensitive to the essential oils of all the populations tested.

Based on the statistical analyzes, the results showed that the interaction of the sampling sites, dilution levels and strain of the bacteria were highly significant ($P < 0.001$) (Table 5).

The *I. viscosa* essential oils from Setif and Ain Oulmene region exhibits high antimicrobial activity against the bacterial species tested with an average inhibition diameter of 18.72 and 18.55mm respectively (Table 6). The oils of these two populations have the highest inhibitory potency among the populations studied (Figure 7); while the oil of Amoucha population is the least active against the bacterial species. This latter is classified in the last group (g) with an average inhibition diameter of 17.19 mm (Table 6).

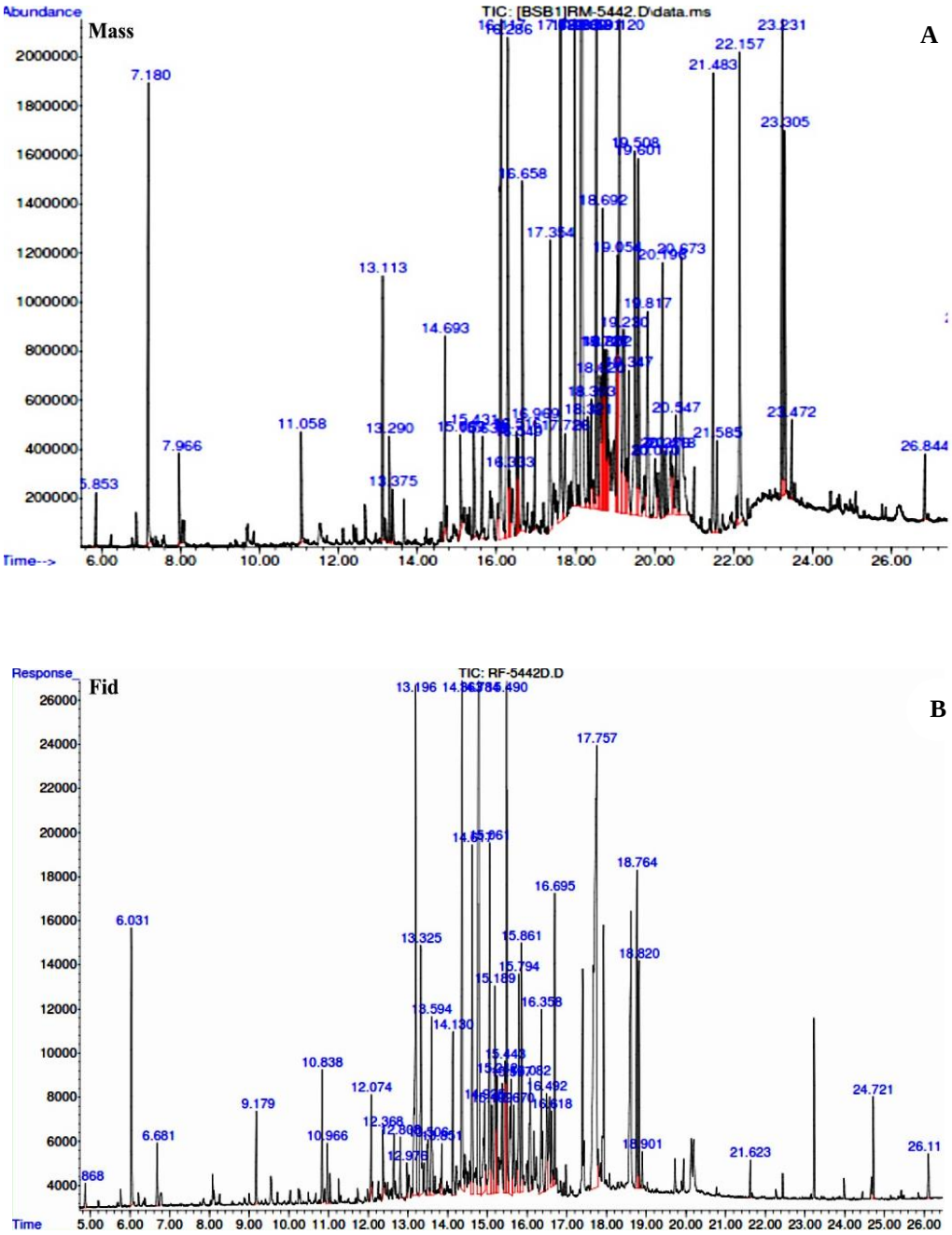

Figure 3. Essential oil chromatogram for Bejaia *Inula viscosa*. A. Mass Spectrophotometer, B. Fid

Table 2. Chemical composition of the essential oils of *Inula viscosa*

		Populations																	
		Salah Bey	Ain Oulmen	Sétif	El Baz	Ouricia	Amouchas	Tizi n' bechar	Babor	Kherrat	Derguina	Souk Letnine	Bejaia	Jijel	Bibans	Bouira	Average (Av)	Stand. deviation SD	Relative SD (RSD)
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15			
Yield %		0.25	0.25	0.19	0.21	0.28	0.25	0.34	0.29	0.18	0.19	0.18	0.29	0.19	0.25	0.11	0.23	0.06	26
Number of compounds	KI	32	41	38	47	37	31	38	38	35	37	37	43	39	35	43	38	4	11
Total %		99.2	99.4	98.1	99.8	97.6	93.3	98.3	99.4	99	98.5	93.3	99.4	98.2	99	98.4	98.06	2.03	2
α-pinene	932	0	0.39	1.14	5.72	0.39	0	0	0.3	0	0	0	0.25	0.3	0	0	0.57	1.46	258
Camphene	939	0	0	0	4.73	0	0	0	0.32	0	0	0	0	0	0	0	0.34	1.22	362
β-pinene	964	0	0	0.38	0.37	0	0	0	0	0	0	0	0	0	0	0	0.05	0.13	264
Pentyl furan-2	990	0	0.63	0	1.08	0.48	0	0	0	0	0.31	0	0	0	0	0	0.17	0.32	195
Cineole dehydro-1,8	977	0.52	3.51	2.65	1.77	0	0	1.1	0.53	0.46	1.56	0.64	2.58	0.81	0.31	0.59	1.14	1.06	93
Cymene-para	1020	0	0.21	0.37	0.74	0.24	0	0	0	0	0	0.25	0.51	0.73	0	0	0.20	0.27	133
γ-terpinene	1058	0.22	1.03	0	0.57	0	0	0	0.54	0	0	0	0	0	0	0	0.16	0.31	198
Linalool	1087	0	0.46	0.53	0	0	0	0	0	0	0	0	0	0	0	0	0.07	0.17	265
Nonanal-n	1092	0	0	0.92	0	0	0	0.59	0	0	0.52	0.19	0	0	0	0	0.15	0.29	196
Camphor	1141	0	0.85	0	3.34	0	0	0	0.39	0	0	0	0.79	0	7.58	0.77	0.91	2.04	223
Menthol iso	1179	0	0	0	0	0	0.13	0	0	0	0	0	0	0	0	0	0.01	0.03	387
α-terpineol	1186	0	0.34	0.91	1.58	0.22	0.4	0	0	0.92	0	0.26	0	0.23	1.09	0.38	0.42	0.48	115
Decanal-n	1201	0.26	0.35	0.49	0.62	0	0	0	0.24	0	0.32	0.5	0	0	0.26	0	0.20	0.22	108
Bornyl acetate	1284	0	0	0	0.42	0	0	0	0.82	0	0	0	1.01	0.62	1.51	0.42	0.32	0.48	149
γ-terpinene-7-al	1290	0.22	0.16	0.23	0	0	0	0.34	0	0	0.29	0.14	0	0.37	0	0	0.12	0.14	121
Menthyl acetate	1294	0.23	0.45	1.52	1.1	0	0	0	0.15	0.86	1.69	0.2	0.77	0.21	0.74	0	0.53	0.56	107
α-copaene	1374	0	0	0.39	0.48	0.12	0	0.19	0.16	0.28	0.38	0.21	0.65	0.14	0.28	0.35	0.24	0.19	77
Methyl eugenol	1403	0	0	0	0.53	0	0.16	0.39	0.22	0	0	0.16	0.56	0	0.63	0.22	0.19	0.23	120
Caryophyllene-Z	1408	0.16	0.58	0	0.85	0	0.43	0.27	0.37	0	0.23	0.2	0.49	0.36	0.41	0.29	0.31	0.23	75
Caryophyllene-E	1417	0.39	0	1.41	0	0.67	0	0.34	0.36	0.37	0.38	0.56	0.3	0.19	0.34	0.37	0.38	0.34	91
Neryl acetone	1434	0.2	0	0	0.8	0	0	0	0	0	0	0	0	0.16	0.39	0.22	0.12	0.22	189
Geranyl acetone	1379	0	0	4.6	0.22	0	2.97	3.34	0.43	0	8.25	0	3.4	1.09	1.81	0.36	1.76	2.37	135
Croweacin	1457	0	0	0.5	0	0.35	0.26	0.43	0	0.22	0.39	0.14	0	0	0	0	0.15	0.19	123
α-ionone iso methyl-E	1478	0	1.45	4.36	3.28	8.86	5.7	5.61	3.35	3.34	4.59	0	4.4	2.8	3.2	4.83	3.72	2.26	61
γ-ionone iso methyl	1480	0.26	0.96	0	1.89	3.78	0	0.1	2.01	1.79	0.53	0.35	2.88	0	0	2.44	1.13	1.24	109
β-selinene	1489	0.57	0.5	0	0	0.2	1.74	0	0.7	0.55	0	0	1.75	0	0.25	0.17	0.43	0.59	137
Calamenene-10-11epoxy	1491	0	0	0	0.39	0	0.23	0	0	0	0	0.65	0	0.52	0	0.77	0.17	0.27	161
α-selinene	1498	1.81	1.24	0.97	0.45	0.68	0.42	0.75	0.99	0.26	1.12	1.64	0.8	1.85	0	0.48	0.90	0.56	62
Δ3-cadinene	1522	0.15	0.28	0	0.4	0.1	0	0.35	0.31	0	0	0.27	0.43	0	0.56	0.94	0.25	0.27	105
Nerolidol-Z	1531	0	4.77	2.67	17.3	0	0	0.64	9.74	0.91	0.94	0	6.15	5.47	14.4	3.9	4.46	5.46	122
Nerolidol-E	1561	0	0	0.39	0	4.05	3.68	21.2	0	24.7	9.68	0	0	0	0	0	4.24	8.07	190
α-copaen-11-ol	1539	0	0.39	0	0.97	1.47	0	0	1.08	0	0	0	1.45	1.1	0.93	2.97	0.69	0.86	124
Longipinanol	1567	0	0	0	0	0.33	1.02	0	0.31	0	0	0.52	1.69	0.74	1.81	0.22	0.44	0.62	139
Sesquisabinene hydrate	1577	0	0	0	0	0	0	0.31	0	0.87	0	0	0	0	0	0	0.08	0.23	296
Caryophyllene oxide	1582	3.01	3	8.58	10.7	2.84	5.62	3.75	4.79	2.18	2.32	0.9	10.9	4.54	4.65	5.8	4.91	3.03	62
Fokienol	1596	0	2.86	6.03	5.08	8.02	6.04	8.97	5.28	7.65	13.8	0.75	3.83	8.41	5.74	7.8	6.01	3.43	57
Ledol	1602	1.28	1.14	1.01	1.79	0	0	2.21	2.75	0	0.98	1.18	2.89	0	1.32	1.53	1.21	0.95	79
Humulene Epoxide II	1608	0	0	0	0	0.55	0	0	0	0	0	0	0	0	0	0	0.04	0.14	387
Cubenol-1-epi	1627	0.74	0.59	1.97	0.78	4.17	0	3.35	0.9	0.89	3.1	0	3.14	0	4.49	0.76	1.66	1.57	95
Caryophylla-4 (12)8 (13)dien5-α-ol	1639	0	0	3.52	2.99	3.46	3.22	0.63	0	2.53	2.14	1.13	1.43	0	3.24	0	1.62	1.45	90
α-cadinol-epi	1638	0	0	0	0	0	0	0	0	0	0	0	1.11	0	0.45	0	0.10	0.30	290
Aromadrene epoxide-allo	1639	0	0	0	0.91	0.34	0	0	5.33	2.3	0	0.4	0.84	0.49	0.33	7.1	1.20	2.15	179
Himachalol	1652	1.96	2.09	2.22	1.33	0.54	2.24	0.78	1.29	1.04	2.98	0.71	2.46	3.85	1.67	4.43	1.97	1.13	57
Himachalol-allo	1652	0	1.29	0	0.88	0	0	0	1.02	0	0	0	2.31	4.7	0	2.55	0.85	1.38	162
Intermedeol-neo	1658	9.04	6.57	4.28	3.07	6.37	3.01	2.8	8.68	3.34	4.6	8.8	6.72	3.17	3.21	2.69	5.09	2.38	47
α-santalol-Z	1674	0	0	1.55	0	0	0	1.07	0	0	1.3	0	0	0	0	0	0.26	0.55	210
Cedranol-5-neo	1684	0	0	0	0	0	0	0	0	0	0	0	0	0.46	0	0	0.03	0.12	387
α-bisabolol	1685	0.18	0.2	0	0	0.58	1.57	0.65	0.41	0	1.2	0	0	0.98	0	0	0.38	0.51	133
Germacra-4 (15)5 (10,14)trien1-α-ol	1685	0	0	0	0	0	1.99	0.79	0	0	0	2.67	0	0	0	0	0.36	0.83	229
Acorenone-B	1697	0.66	0	0	0.33	0	2.69	0	0	0	0	0.22	0	0	0	0	0.26	0.70	268
Farnesol (2Z, 6Z)	1698	0	0.4	0.44	1.36	0	0	0	0	0.95	0	0	1.34	0	0	0	0.30	0.50	168
Amorpha-4,9-dien-14-al	1704	1.02	0	2.23	1.54	0	0	1.46	0	1.29	1.87	0	1.76	1.12	0	0.6	0.86	0.82	95

Thujopsenal	1708	2.05	2.82	1.65	0.76	0.51	1.47	1.23	1.64	0.79	0.56	3.65	2.09	1.98	0	1.74	1.53	0.95	62
Farnesol (2Z, 6E)	1722	0	0.41	0	0	0	0	0	0	0	0	0	2.36	0	1.67	5.69	0.68	1.56	231
α-sinensal	1755	0	0	0	0	0.94	0	0	0	0	1.73	0	0	0	0	0	0.18	0.49	277
β-costal	1766	0.87	1.45	1.32	0.81	1.17	0	1.37	0.77	1.37	0	0.9	1.43	0.72	1	1.35	0.97	0.47	49
β-acoradienol	1762	0	0	5.95	0	0	0.56	0	0	0	0	0	0	0	0	0	0.43	1.53	353
γ-curcumen-15-al	1766	0	0	1.98	1.2	0.72	2	0.8	0.51	1.7	0.64	0	0.66	1.92	0.33	0.9	0.89	0.72	81
α-costol	1773	1.02	3.99	3.23	0.79	1.15	4.5	1.15	1.74	3.06	1.96	7.94	2.57	1.26	1.37	2.36	2.54	1.87	74
α-muurolene 14-oxy	1767	0	0	3.86	0	3	0.41	2.17	0	0.23	0	2.55	0	1.83	0	0	0.94	1.35	144
Isovalencenol-E	1793	0	0	0	1.28	0	0	0	0	0	0	0	1.83	1.85	0	0.3	0.35	0.69	197
Phenyl ethyl acetate	1254	0	0	0	0	0.77	0.27	0	0	1.85	0	0	0	0	0	0	0.19	0.50	261
Eicosane-1	1987	2.01	2.11	0	1.13	0	0	0	3.85	0	0	0	2.78	0.28	0.46	1.14	0.92	1.23	134
Manool oxide	1987	0	1.53	0	0	0	0	0	0	0	0	0	0.3	0	0	0	0.12	0.40	325
Canellal	2045	0	0	0	0	0	6.53	0	0	1.19	0	0	0	0	0	0	0.51	1.69	329
Polygodial	2016	58.7	42.9	3.56	5	11.4	4.31	4.24	31.1	8.66	2.81	26.9	14.2	33.9	31.1	18.3	19.8	16.9	86
Phytol	1942	6.46	0.97	17.6	7.09	24.3	28.9	22.6	5.56	18.7	18.6	21.6	0	8.08	1.01	3.12	12.3	9.77	79
Linoleic acid	2132	0	0.24	0.42	0	1.25	0	0.43	0	0	2.98	3.23	0	0	0	2.54	0.74	1.18	160
Retene	2214	1.57	4.04	0	0	0	0	0	0	0	0	0	0.31	0	0	3.73	0.64	1.38	214
Tricosane	2300	0.34	0.26	0	0	0.29	0	1.2	0	0.36	1.21	0.34	0	0.18	0	0.29	0.30	0.40	133
Tetracosane	2400	0.23	1.34	0	0.67	0	0	0	0	0	0	0	0.87	0.48	0.34	0.22	0.28	0.41	147
Hexacosane	2600	0.7	0	0	0	1.03	0	0	0.49	0.5	0.91	0.61	0	0.32	0	0.93	0.37	0.40	108
Heptacosane	2700	2.04	0	1.74	0	1.86	0.52	0.53	0	1.93	0.32	0.28	0	0	0	1.43	0.71	0.83	117
Untriacontane	3100	0.37	0.62	0.85	0.35	0.51	0.27	0.24	0	1.06	1.39	1.64	0.4	0	0.23	0.44	0.56	0.48	86

Table 3. Chemotypes of *Inula viscosa* populations

Chemotypes	Populations
Polygodial-Intermedeol neo-Phytol	Salah Bey
Fokinol-Polygodial-Nerolidol-Z	Ain Oulemen, Babor, Jijel, Biban, Bejaia, Bouira
Fokinol-Polygodial-Phytol	Souk Letnine
Fokienol-Phytol-Nerolidol-E	Sétif, Derguina, Ouricia, Amouchas, Tizi n'Bechar, kherrata
Fokienol-Phytol-Nerolidol-Z	El-baz

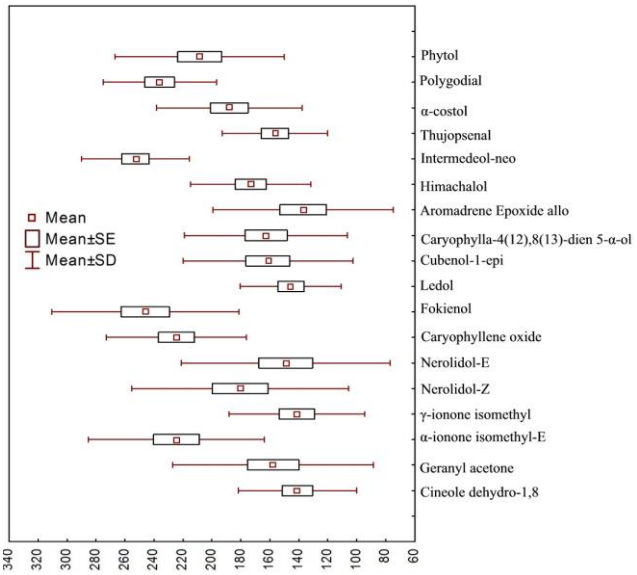

Figure 4. Variability of the essential oils major components of *Inula viscosa*.

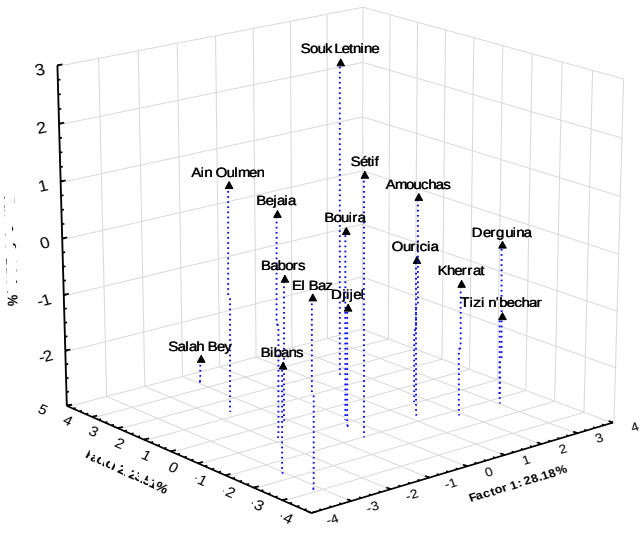

Figure 5. Three-dimensional spatial projection of *Inula viscosa* populations

Table 4. Inhibition diameter (mm) of *Inula viscosa* essential oils

	Dilution	Souk Letenine	Bibans	Saleh Bey	Bouira	Jilel	Bejaia	Ain Olmene	Setif	El Bez	Kherrata	Ouricia	Babor	Amoucha	Derguina	Tizi n' Bechar
P. aeruginosa	1	10.3±0.6	11.3±1.2	10±0	13.3±1.2	10.7±1.2	12±1	22.3±0.6	22±1.7	10.3±0.6	15.7±0.6	13±0	22.3±0.6	14.3±1.2	13±2	10.3±0.6
	1/2	12.3±0.6	12.3±0.6	12±1.7	11.7±0.6	11.3±1.2	11.3±1.2	15±1	14.7±0.6	12.3±1.2	12.3±0.6	10±0	16±1	12.3±0.6	10.7±1.2	12.3±1.2
	1/3	11±1.7	10.7±1.2	10±0	11.7±1.2	11±1	11.7±1.2	13±1.7	13.7±0.6	12±1	10.3±0.6	10±0	12.7±1.2	10±0	12.3±0.6	12±1
	GEN	31.9±0.1	31.9±0.1	31.9±0.1	31.9±0.1	31.9±0.1	31.9±0.1	31.9±0.1	31.9±0.1	31.9±0.1	31.9±0.1	31.9±0.1	31.9±0.1	31.9±0.1	31.9±0.1	31.9±0.1
K. pneumoniae	1	30±0	25±0	22±0	20.3±0.6	20±0	20±0	30±0	25±0	22.7±0.6	23.7±1.5	28±0	28±0	23.3±1.5	23.7±1.2	21.7±2.9
	1/2	20.6±1.2	20.7±1.2	18±0	16.7±0.6	19.7±0.6	25±0	12±0	20.7±1.2	15±0	16±0	17.3±0.6	15.3±0.6	15±0	15±0	13.7±0.6
	1/3	15±0.	16.7±1.2	14±0	13.3±0.6	16.7±1.2	20±0	18±0	15±0	18.3±2.9	15±0	15±0	12.7±1.2	20±0	20±0	13.3±0.6
	GEN	27.9±0.1	27.9±0.1	27.9±0.1	27.9±0.1	27.9±0.1	27.9±0.1	27.9±0.1	27.9±0.1	27.9±0.1	27.9±0.1	27.9 ±0.1	27.9±0.1	27.9±0.1	27.9±0.1	27.9±0.1
E. coli	1	15±0	13.3±4.2	13±0	11.3±0.6	10.3±0.6	10.7±1.2	17.7±2.5	14.3±1.2	14.3±1.2	10.3±0.6	13±1.7	13±1.7	19.3±1.2	11.7±1.2	14.3±0.6
	1/2	13.3±2.9	12±1.7	11.3±1.2	11.7±1.5	14.3±1.2	10±0	14.3±1.2	11.3±1.2	13.3±1.5	10±0	11±0	10.7±0.6	13.7±1.5	10±0	10.7±0.6
	1/3	14.3±1.2	11.3±1.2	10±0	12±1.7	10.7±1.2	10.3±0.6	13.7±1.5	10.7±0.6	11.7±0.6	10.3±0.6	10.30.6	10±0	10.7±1.2	8.7±1.2	10±0
	GEN	39.9±0.1	39.9±0.1	39.9±0.1	39.9±0.1	39.9±0.1	39.9±0.1	39.9±0.1	39.9±0.1	39.9±0.1	39.9±0.1	39.9±0.1	39.9±0.1	39.9±0.1	39.9±0.1	39.9±0.1
B. cereus	1	10.7±1.2	15.7±1.2	13±0	11.3±0.6	10±0	15±0	12.7±0.6	11.7±0.6	15.3±1.5	12.7±0.6	20±0	10.3±0.6	10.7±0.6	13±0	15±0
	1/2	10.7±0.6	10±0	10±0	11±1	10±0	10±0	10±0	10±0	10±0	10.3±0.6	11±0	10±0	10±0	10±0	10.3±0.6
	1/3	10.7±1.2	10.7±1.2	11±0	10.7±0.6	8±0	8.7±1.2	10±0	10±0	11±0	9.3±0.6	10±0	10.7±0.6	10.6±0.6	11.3±0.6	10±0
	GEN	22.9±0.1	22.9±0.1	22.9±0.1	22.9±0.1	22.9±0.1	22.9±0.1	22.9±0.1	22.9±0.1	22.9±0.1	22.9±0.1	22.9±0.1	22.9±0.1	22.9±0.1	22.9±0.1	22.0±0.1
S. aureus	1	15.7±1.2	30±0	29.3±1.2	30±0	30±0	28.7±1.2	30±0	32.7±1.2	32.7±0.6	29.3±1.2	29.3±1.2	29.3±1.2	29.3±1.2	30±0	30±0
	1/2	14.3±1.2	25.3±0.6	21.7±2.9	27±1.7	28.7±1.2	28±0	28±0	28.7±1.2	27.3±1.2	18.7±1.2	26±1.7	26±1.7	26±1.7	28±0	28±0
	1/3	13.3±0.6	22±2	24.7±0.6	25±0	28±0	25.7±1.2	28±0	24.3±1.2	25.3±0.6	15±0	24.7±0.6	22.7±1.2	19.3±1.2	26.7±1.2	19.3±1.2
	GEN	29.9±.1	29.9±0.1	29.9±0.1	29.9±0.1	29.9±0.1	29.9±0.1	29.9±0.1	29.9±0.1	29.9±0.1	29.9±0.1	29.9±0.1	29.9±0.1	29.9±0.1	29.9±0.1	29.9±0.1
S. aureus (SARM)	1	28±0	13.3±0.6	19.3±1.2	19.7±0.6	16.7±1.5	15±1.7	14.±1	23.7±1.2	19.3±1.2	19.3±1.2	20.3±0.6	18.7±1.2	13.3±0.6	16.3±1.2	19.3±1.2
	1/2	25.3±0.6	20±0	18.7±2.3	17.7±2.5	16.3±1.5	13.7±1.5	11.3±1.5	17.7±2.3	12.3±1.2	13.7±1.2	15.3±2.5	17±1	13±0	14.7±1.5	13±1.7
	1/3	20.7±1.2	15±0	15±0	16.7±2.9	14.3±1.2	17.3±2.5	16±1	17.7±0.6	14.3±1.2	12±0	16.7±1.5	11±1	12.7±0.6	10.3±0.6	12±0
	GEN	34.9±0.1	34.9±0.1	34.9±0.1	34.9±0.1	34.9±0.1	34.9±0.1	34.9±0.1	34.9±0.1	34.9±0.1	34.9±0.1	34.9±0.1	34.9±0.1	34.9±0.1	36.2±2.3	34.9±0.1
ESBL	1	12.3±0.6	10.7±1.2	10.3±0.6	11±1	13±0	13.7±1.2	15.7±0.6	20±0	20±0	17.3±1.2	19.3±1.2	18.3±1.2	15. ±0	10±0	17.3±1.2
	1/2	10.7±0.6	11.3±1.2	10±0	10±0	11±0	12.3±0.6	13±1.7	14.7±1.5	14.7±1.5	12.7±0.6	12.7±0.58	10±0	12.7±1.2	11.7±2.9	12.7±0.6
	1/3	9.7±0.6	10.3±0.6	10±0	10.7±0.6	11±1	13.3±1.2	11±0	12.7±1.2	12.7±1.2	11.7±0.6	12.3±0.58	11±1	10.7±0.6	11±0	11.7±0.6
	GEN	39.9±0.1	39.9±0.1	39.9±0.1	39.9±0.1	39.9±0.1	39.9±0.1	39.9±0.1	39.9±0.1	39.9±0.1	39.9±0.1	39.9±0.1	39.9±0.1	39.9±0.1	39.90±0.1	39.9±0.1
L. monocytogenes	1	20±0	12.3±2.5	11.7±2.9	14.3±1.2	21±1.7	10±0	11±1	10.7±1.2	12.7±0.6	11.3±0.6	10.7±1.2	11.33±0.6	10±0	10±0	11.3±0.6
	1/2	17.7±2.5	11±1.7	10±0	12±1	13.3±1.5	10±0	10.7±0.6	10.3±0.6	11.3±1.2	10.3±0.6	10±0	10.3±0.6	10.3±0.6	10±0	10.7±1.2
	1/3	15±0	10±0	10±0	10±0	10±0	10±0	10.3±0.6	10.7±1.2	10±0	10±0	12.3±1.2	12±1.7	10±0	8.7±1.2	10±0
	GEN	34.9±0.1	34.9±0.1	34.9±0.1	34.9±0.1	34.9±0.1	34.9±0.1	34.9±0.1	34.9±0.1	34.9±0.1	34.9±0.1	34.9±0.1	34.9±0.1	34.9±0.1	34.9±0.1	34.9±0.1

E. faecalis	1	13.3±0.6	17.7±0.6	17.7±1.2	20±0	25±0	12±0	19.3±1.2	20.3±0.6	16.3±1.2	18.7±1.2	20.7±1.2	18.7±1.2	16±1.7	13.3±0.6	18±0
	1/2	10±0	12.3±0.6	15.7±1.2	11.7±0.6	11.7±1.5	11.3±0.6	10±0	11.6±0.6	10±0	12±0	15±0	11.3±0.6	12.7±0.6	11±0	10±0
	1/3	10±0	11±1	11±1	11.3±1.2	10±0	10±0	10±0	11±0	12.7±0.6	10.3±0.6	12±0	10.7±0.6	11±0	10±0	10±0
	GEN	12.9±0.1	12.9±0.1	12.9±0.1	12.9±0.1	12.9±0.1	12.9±0.1	12.9±0.1	12.9±0.1	12.9±0.1	12.9±0.1	12.9±0.1	12.9±0.1	12.9±0.1	12.9±0.1	12.9±0.1
S. enterica	1	25±0	29.3±1.2	30±0	25±0	30±0	30±0	30±0	30±0	30±0	30±0	29.3±1.2	25±0	15±0	30±0	27.3±1.2
	1/2	15.3±1.5	26±1.7	25±0	15±0	30±0	28.7±1.2	28.7±1.2	27±1.7	21.3±1.2	22±0	25±0	15.7±1.2	13.7±1.5	24.3±1.2	25.3±0.6
	1/3	15±0	26±1.7	27.7±2.5	17.3±2.1	28±0	28±0	30±2	26±1.7	25±0	25±0	23.7±1.2	15±0	11.3±1.2	11±1.7	25±0
	GEN	26.9±0.1	26.9±0.1	26.9±0.1	26.9±0.1	26.9±0.1	26.9±0.1	26.9±0.1	26.9±0.1	26.9±0.1	26.9±0.1	26.9±0.1	26.9±0.1	26.9±0.1	26.9±0.1	26.9±0.1
Acetobacter sp.	1	15.3±0.6	12.3±2.1	11±0	10.3±0.6	15±0	10±0	13.7±0.6	10±0	11±0	11.7±0.6	13±0	12.3±0.6	10±0	11.3±1.2	13.3±0.6
	1/2	12.7±0.6	10±0	10.3±0.6	11±0	12±0	10.7±0.6	10±0	10.3±0.6	10±0	11.3±0.6	10±0	10±0	10±0	14±0	12.7±0.6
	1/3	11±0	8±0	10.7±0.6	11±1	10.7±0.6	8±0	10±0	10.7±0.6	10±0	11±0	10±0	10±0	10±0	10.7±0.6	10±0
	GEN	24.9±0.1	24.9±0.1	24.9±0.1	24.9±0.1	24.9±0.1	24.9±0.1	24.9±0.1	24.9±0.1	24.9±0.1	24.9±0.1	24.9±0.1	24.9±0.1	24.9±0.1	24.9±0.1	24.8±0.2
P. mirabilis	1	10±0	12.3±0.6	11.3±0.6	10±0	11.3±1.2	10±0	13.3±1.2	12.7±1.2	10.7±1.2	16±1.7	10±0	10.7±1.2	16±0	16.7±1.2	14.7±0.6
	1/2	12.7±0.6	12.3±2.5	10.7±1.2	14.3±1.2	12.3±1.5	17.7±0.6	15±0	15.7±1.2	13±1.7	14.3±1.2	14.7±0.6	13.3±1.2	12±2	13.3±1.5	13±1.7
	1/3	13±1	13.7±0.6	10.3±0.6	13±1.7	12.7±1.2	14±1	17.7±0.6	13.3±0.6	16±1	12±2.7	12.7±1.2	14.3±1.2	13.3±1.5	12±2	14±1
	GEN	27.9±0.1	27.9±0.1	27.9±0.1	27.9±0.1	27.9±0.1	27.9±0.1	27.9±0.1	27.9±0.1	27.9±0.1	27.9±0.1	27.9±0.1	27.9±0.1	27.9±0.1	27.9±0.1	28.5±0.4
S. marcescens	1	15±0	11.3±1.2	11.3±1.2	13±0	10.7±1.2	12±0	11.7±1.5	10.3±0.6	15.7±1.2	11.3±1.2	12±0	11.7±0.6	13.7±1.5	15±0	13±0
	1/2	10±0	10±0	10±0	10.7±1.2	10±0	11±1	10±0	10±0	10±0	10.3±0.6	10.3±0.6	10.7±0.6	10.7±1.2	10.7±1.2	11.7±1.5
	1/3	10.7±1.2	8.3±0.6	8±0	10.3±0.6	10±0	9.3±1.2	10±0	10.3±0.6	11±1	10.8±0.6	10±0	10±0	12±0	10±0	10.7±1.2
	GEN	23.9±0.1	27.9±0.1	23.9±0.1	23.9±0.1	23.9±0.1	23.9±0.1	23.9±0.1	23.9±0.1	23.9±0.1	23.9±0.1	23.9±0.1	23.9±0.1	23.9±0.1	23.9±0.1	24.5±0.5
S. liquefacienes	1	11.3±1.2	11.3±1.2	10.7±1.2	13.3±0.6	13.3±1.2	13±0	12±1	14±1	13.3±1.2	12.3±0.6	12±0	15±0	13.3±1.2	16.7±1.5	10±0
	1/2	10.7±0.6	10±0	10.3±0.6	12.7±0.6	12±0	11±1	11.3±1.2	10±0	12.3±0.6	10±0	10±0	13±0	12.3±0.6	15±0	8±0
	1/3	10.7±1.2	10.7±1.2	10±0	11.3±1.2	10.7±0.6	10.3±0.6	11±0	12.3±0.6	10.7±1.2	10.7±0.6	11.3±1.2	13±0	10±0	11.3±1.2	8±0
	GEN	17.9±0.1	17.9±0.1	17.9±0.1	17.9±0.1	17.9±0.1	17.9±0.1	17.9±0.1	17.9±0.1	17.9±0.1	17.9±0.1	17.9±0.1	17.9±0.1	17.9±0.1	17.9±0.1	17.9±0.1
E. cloacae	1	20±0	15±5	16.7±2.9	18.3±2.9	10±0	25±0	14.3±0.6	14.3±1.2	16.3±1.5	13.7±1.2	19.3±1.2	13.7±1.2	17.3±1.2	10.3±0.	15.7±1.2
	1/2	18.7±1.2	10.3±0.6	11.7±0.6	10±0	14.7±0.6	16.7±2.9	11±0	13.7±1.2	10±0	12.7±0.6	12.3±1.2	11±1	11.7±1.5	12.7±0.	11.3±0.6
	1/3	11.7±2.9	10±0	10.7±1.2	10±0	10.3±0.6	110	10±0	10.3±0.6	8±0	10.7±0.6	10±0	11.3±1.2	10.3±0.6	8.7±1.2	10.3±0.6
	GEN	19.9±0.1	19.9±0.1	19.9±0.1	19.9±0.1	19.9±0.1	19.90.1	19.9±0.1	19.9±0.1	19.9±0.1	19.9±0.1	19.9±0.1	19.9±0.1	19.9±0.1	19.9±0.1	19.9±0.1

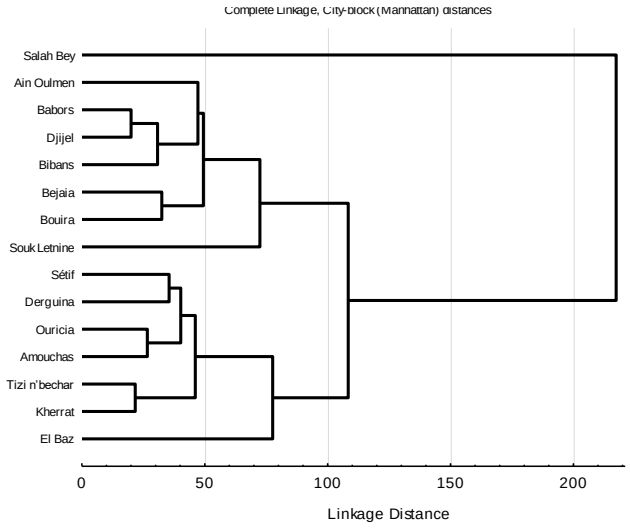

Figure 6. Relationships among *Inula viscosa* populations based on the chemical composition

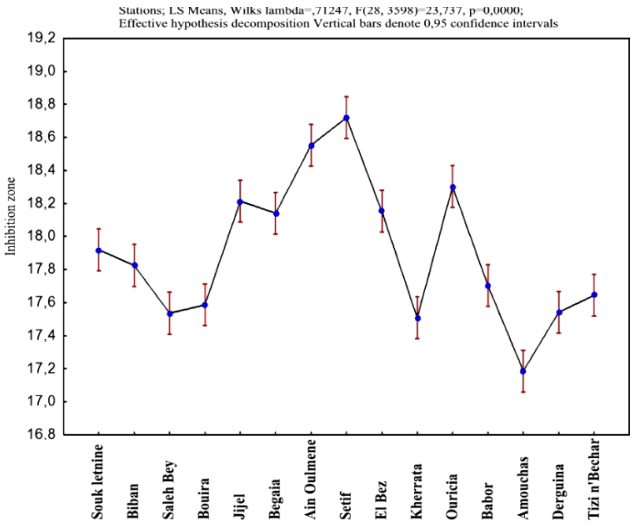

Figure 7. Effective hypothesis decomposition of *Inula viscosa* populations

Table 5. Main effects and interactions of essential oils of *Inula viscosa*

Sources	df	F	p
Main effects			
Sampling locations	14	45	.000 ***
Dilution level	3	41147	.000 ***
Species of bacteria	14	4269	.000 ***
Interaction			
Sampling locations * Dilution level	42	20	.000 ***
Sampling locations * Bacteria	196	45	.000 ***
Dilution level * Bacteria	42	1216	.000 ***
Sampling locations * Dilution level * Bacteria	588	16	.000 ***

Table 6. The effectiveness of *Inula viscosa* essential oils from several sampling locations against eight bacteria species

Rank	Sampling locations	Mean inhibition zone (mm)	n	Significant groups
1	Setif	18.72	180	a
2	Ain Oulmene	18.55	180	a
3	Ouricia	18.30	180	b
4	Jijel	18.21	180	b
5	El Bez	18.15	180	b
6	Bejaia	18.14	180	b
7	Souk Letnine	17.92	180	c
8	Biban	17.83	180	cd
9	Babor	17.70	180	de
10	Tizi n'Bechar	17.64	180	ef
11	Bouira	17.59	180	ef
12	Derguina	17.54	180	ef
13	Saleh Bey	17.53	180	ef
14	Kherrata	17.51	180	f
15	Amouchas	17.19	180	g

Note: LSD 0.05 = 0.17943458234

Table 7. Effect of oil dilutions on the inhibitory zone of bacteria tested

Rank	Dilution level	Mean inhibition zone (mm)	n	Significant groups
1	Gentamicin	27.80	675	a
2	1/1	16.74	675	b
3	1/2	13.99	675	c
4	1/3	13.08	675	d

Note: LSD 0.05 = 0.09265961989

The three-way analysis of variance revealed a very significant difference in the diameters of the inhibitory zones among the essential oils dilutions. Gentamicin has the highest growth inhibition against several bacteria tested with an average inhibitory zone of 27.80 mm. It is classified in group (a) (Table 7). The antibacterial activity of the diluted essential oils (1/2 and 1/3) was a weak activity, with a diameter of growth inhibition of 13.99-13.08mm.

The results reveal that *S. aureus* is highly sensitive to the essential oils of *I. viscosa*. It is classified in group (a), with an average diameter of growth inhibition of 26.84mm (Table 8), while *E. faecalis* and *S. liquefaciens* were the least sensitive to *I. viscosa* oils, with an average diameter of growth inhibition of 13.30 to 13.18 mm.

Desirability test

The relationship between predicted responses on one or more dependent variables and the desirability of responses is called the desirability function. Profiling the desirability of the responses involves first, specifying the desirability function for each dependent variable, by assigning predicted values a score ranging from 0 (very undesirable) to 1 (very desirable). The optimal parameters of this study were located in the exact region of the central point (Figure

8). The desirability profile of *I. viscosa* essential oils against the bacteria tested had a prediction value of 0.28584, which is considered a low value. The oil prediction value of the populations is low, except for the oil of the Souk Letnine population that has a value greater than 0.28584. The dilutions of the oils used in this study have a low activity against the bacteria tested; they have a equal values than the prediction value; on the other hand gentamicin is more effective in inhibiting bacteria than *I. viscosa* essential oils. The desirability test shows that the bacterial species are sensitive to the oils of Inula viscose, with prediction values greater than 0.2584.

Table 8. Sensitivity groups of the bacteria tested to the essential oils of *Inula viscosa*

Rank	Bacteria species	Mean inhibition zone (mm)	n	Significant groups	S*
1	*S. aureus*	26.84	180	a	+++
2	*E. enterica*	24.94	180	b	+++
3	*K. pneumoniae*	21.43	180	c	+++
4	*S. aureus SARM*	21.04	180	d	+++
5	*ESBL/BLSE*	19.54	180	e	++
6	*E. coli*	19.04	180	f	++
7	*P. aeruginosa*	17.47	180	g	++
8	*L. monocytogenes*	17.31	180	g	++
9	*P. mirabilis*	16.85	180	h	++
10	*E. cloacae*	14.67	180	i	+
11	*Acetobacter*	14.51	180	i	+
12	*S. marcescens*	14.32	180	j	+
13	*B. cereus*	14.11	180	k	+
14	*E. faecalis*	13.30	180	l	+
15	*S. liquefaciens*	13.18	180	l	+

LSD 0.05 = 0.17943458234; * S = Sensitivity (+++ extremely sensitive, ++ highly sensitive and + sensitive)

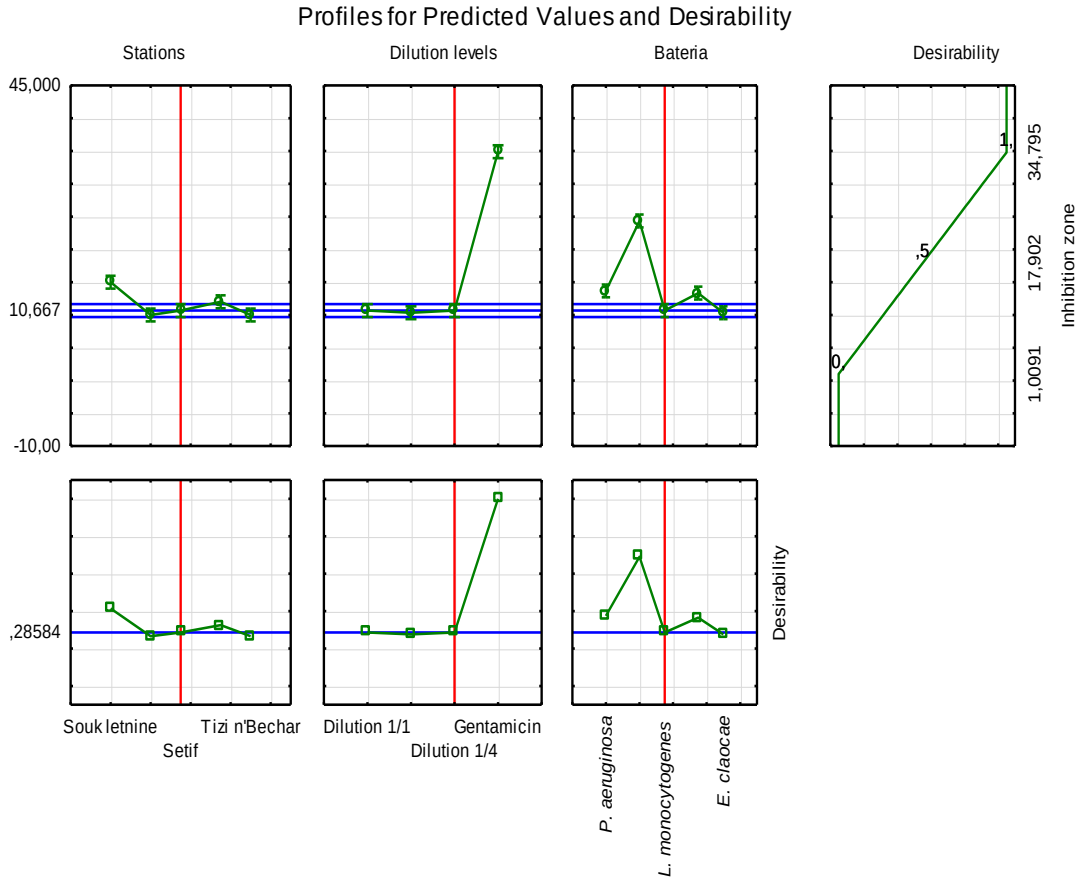

Figure 8. Profile of Predicted Values and Desirability for the inhibition zones induced by *Inula viscosa* essential oils against bacteria

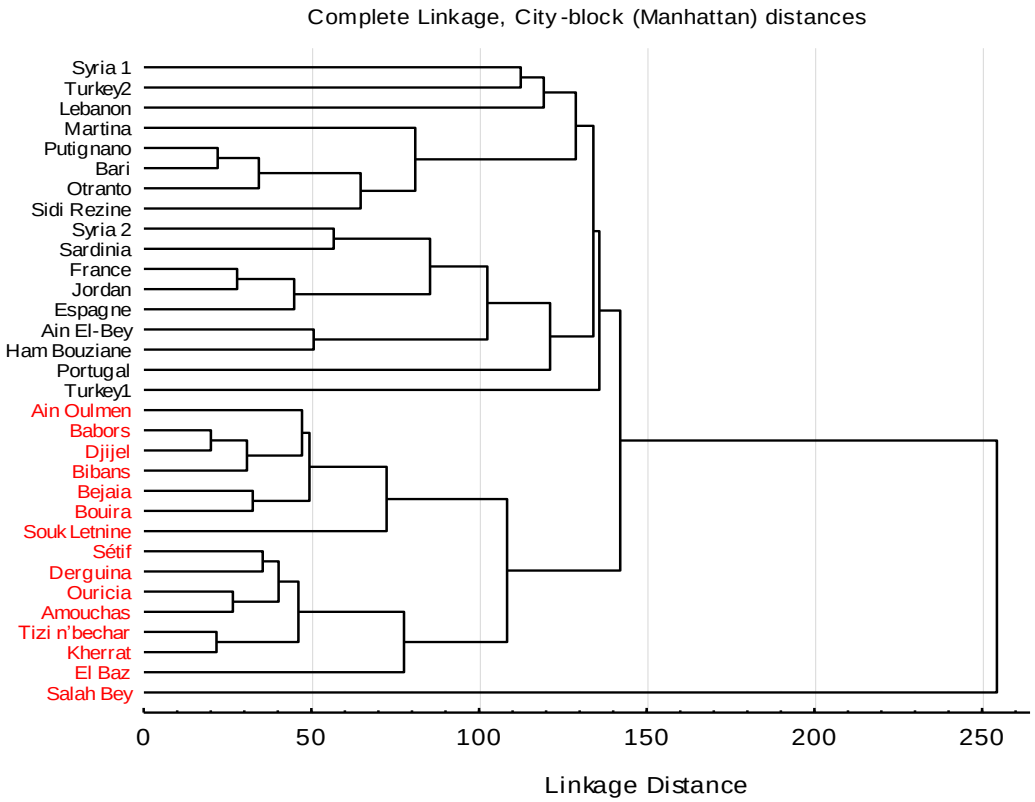

Figure 9. Relationships among *Inula viscosa* populations in the world

Discussion

The essential oils of *Inula viscosa* obtained by hydro-distillation have very low yields with an average of 0.23 ± 0.06%. A study by Boudouda et al. (2012) showed that the yield of *I. viscosa* essential oils ranged from 8 to 10% (obtained by solvant extractions). On the other hand, the yields of *I. viscosa* essential oils obtained from Sidi Rezine (Algeria) was 0.34% (Madani et al. 2014). In the same region, Haoui et al. (2015) found a yield ranging from 0.15 to 0.45%. The yields obtained by De Laurentis et al. (2002) from different regions of Apulia (Italy), vary between 0.35 and 0.37%, depending on the part of the plant.

The aerial parts (Leaves and flowers) of *I. viscosa* growing wild in Al-Qadmous (Syria), gave an essential oil yield of 0.10% and 0.09%, respectively (Nasser et al. 2014). The aerial parts of Kafr Hoor (Syria) gave an essential oil yield of 0.17% (Alalan et al. 2015). The yields of oils from mountainous and coastal regions from Lattakia (Syria) were (0.67-0.55%) (Hwija et al. 2018). The populations from Irbid (Jordan) gave a yield of 0.05% (Al-Qudah et al. 2010).

Chromatographic analysis of *I. viscosa* oils revealed that polygodial and phytol were the major components with an average of 19.8 ± 16.9 and 12.3 ± 9.77% respectively. However, phytol, which is poorly represented in Algiers populations (Haoui et al. 2011) and in Italy (De Laurentiis et al. 2002) is predominant in the oils of Jijel and Setif populations.

The chemical composition of *I. viscosa* essential oils in this study is different from that which has been analyzed previously, from Ain Elbey and Hama Bouziane (Algeria) (Boudouda et al. 2012). These populations are characterized by the presence of β-caryophyllene, intermediol neo and isocostic acid, while the latter compound is absent from the oils of our populations. The Oran population is characterized by the presence of α-terpineol (Boumaza 2011) which is present in our populations at a very low content with an average of 0.42 ± 0.5%. Fokienol, the major component of Jordan populations (Al-Qudah 2010), is present in our populations with an average of 6.01 ± 3.43%. Borneol which is very weakly present in the populations studied, is present with important concentrations in the populations of Turkey (Haoui et al. 2011).

Comparison of the chemical components of *I. viscosa* populations, using the UPGMA analysis (Figure 9), shows that the populations are subdivided into two clades. The first clade is represented by the population of Saleh Bey with a very high polygonal percentage (58.7%). The second clade is subdivided into two groups. The first one brings together the populations studied, while the second group brings together the rest of the world populations, including the Algerian populations, studied by Haoui et al. (2011) and Boudouda et al. (2012).

The differences in the chemical composition of the same species are probably due to various parameters, including the environment, geographic origin, and harvest period (Aboukhalid et al. 2017; Yeddes et al. 2018).

The antibacterial test showed that *S. aureus* was the most sensitive to the essential oil of *I. viscosa*, while *E. faecalis* and *S. liquefaciens* were the most resistant to oils from the 15 populations of this study. These results are consistent with the conclusions of Boudouda et al. (2012)

who have shown that *K. pneumoniae*, *P. aeruginosa* exhibited a good antibacterial activity and that *E. coli* was resistant to methanolic extracts of *I. viscosa*. The *Staphylococcus aureus* and *Enterobacter* sp. strains are rated sensitive, while *Escherichia coli*, *Bacillus thuringiensis*, *Pseudomonas aeruginosa*, *Micrococcus* sp. are mildly sensitive (Chebouti-Meziou 2016).

In conclusion, the essential oils of *I. viscosa* collected from 15 locations in Algeria have chemical compositions different from those described in the literature. GC/MS analysis lead to the identification of 42 components in the essential oil. The main components were polygodial, phytol, fokienol, intermedeol-neo, caryophyllene oxide, nerolidol-Z, nerolidol-E, and α-ionone iso methyl-E. The chemical composition of *I. viscosa* populations showed a notable difference with an abundance of hydrocarbon monoterpenes. This difference allowed us to identify five chemotypes Polygodial-Intermedeol neo-Phytol, two chemotypes with Fokinol-Polygodial and two other with Fokinol-Phytol. The bacterial species tested were sensitive to the essential oils of *I. viscosa*. The optimal inhibition of *I. viscosa* essential oils was obtained with undiluted oils of Setif and Ain Oulmene populations on the S. aureus bacterium. Optimization was confirmed by the desirability parameter, which attained a low value, though acceptable.

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REFERENCES

Aboukhalid K, Al Faiz C, Douaik A, Bakha M, Kursa K, Agacka-Mołdoch M, Machon N, Tomi F, Lamiri A. 2017. Influence of environmental factors on essential oil variability in *Origanum compactum* Benth. growing wild in Morocco. Chem Biodivers 14 (9): e1700158. DOI: 10.1002/cbdv.201700158.

Adams RP. 2007. Identification of essential oils components by Gas Chromatography-Mass spectroscopy. Allured Publishing Corporation Carol Stream, Illinois USA.

Aissa I, Znati M, Zardi Bergaoui A, Flamini G, Ascrizzi R, Ben Jannet H. 2019. GC and GC-MS integrated analyses and in vitro antibacterial, anticholinesterase, anti-tyrosinase, and anti-5-lipoxygenase potential of *Inula viscosa* root fractionated essential oil. S Afr J Bot 125: 386-392. DOI: 10.1016/j.sajb.2019.08.019.

Akkawi M, Abbas I, Jaber S, Aburemeleh Q, Naseredin A, Lutgen P. 2014. Investigation of Traditional Palestinian Medicinal Plant *Inula viscosa* as Potential Anti-malarial Agent. Br J Pharmacol Toxicol 5 (5): 156-162.

Alalan L, AL-Shammaa I, Al-Nouri AS. 2015. Analysis of the chemical composition of essential oil extracted from Syrian *Inula viscosa* (L). J Chem Pharm Res 7 (12): 861-864.

Alkofahi A, Atta AH. 1999. Pharmacological screening of the anti-ulcerogenic effects of some Jordanian medicinal plants in rats. J Ethnopharmacol 67: 341-345. DOI: 10.1016/s0378-8741 (98)00126-3

Al-Masri MI, Sharawi SM, Barakat RM. 2015. Effect of clammy inula (*Inula viscose*) plant extract in combination with a low dose of the fungicide iprodione on *Botrytis cinerea* in vitro and in vivo. Am J Plant Sci 6 (9): 1519.

Al-Qudah MA, Al-Jaber HI, Mayyas AS, Abu-Orabi ST, Abuzarga MH. 2010. Chemical compositions of essential oil from the Jordanian Medicinal plant *Dittrichia viscosa*. Jordan J Chem 5: 343-348.

Amin S, Kaloo ZA, Singh S, Altaf T. 2013. Medicinal importance of genus Inula-A Review. Intl J Curr Res Rev 5 (2): 20-26.

Andolfi A, Zermane N, Cimmino A, Avolio F, Boari A, Vurro M, Evidente A. 2013. Inuloxins A-D, phytotoxic bi-and tri-cyclic sesquiterpene lactones produced by *Inula viscosa*: Potential for broomrapes and field dodder management. Phytochemistry 86: 112-120.

Assi M, Aboul-Ela MA, Ellakany AM, Abdul-Ghani M. 2014. A comparative phytochemical and antimicrobial analysis of *Inula viscosa* and *Inula crithmoides* grown in Lebanon. Acad J Med Plants 2 (4): 057-067. DOI: 10.15413/ajmp.2013.0122.

Bar-Shalom R, Bergman M, Graossman S, Azzam N, Sharvit L, Fares F. 2019. *Inula viscosa* extract inhibits growth of colorectal cancer cells in vitro and in vivo through induction of apoptosis. Front Oncol 9: 227.

Belayachi L, Aceves-Luquero C, Merghoub N, Bakri Y, Fernández de Mattos S, Amzazi Sand PV. 2013. Screening of North African medicinal plant extracts for cytotoxic activity against tumor cell lines. Eur J Med Plants 3 (3): 310-332.

Bensassi A, Harzallah-Skhiri F, Bourgougnon N, Aouni M. 2008. Antiviral activity of some Tunisian medicinal plants against Herpes simplex virus type 1. Nat Prod Res 22 (1): 53-65. DOI: 10.1080/14786410701589790.

Benseguini-Tounsi L. 2001. Etude in vitro de l'effet antibactérien et antifongiques *d'Inula viscosa, Lawsonia inermis, Asphodelus microcarpus*, *Aloe vera* et *Juniperus oxycedrus*. Mémoire de magistère en médecine vétérinaire. Université de Constantine, Algerie. [France]

Blanc MC, Bradesi P, Gonçalves MJ, Salgueiro L, Casanova J. 2006. Essential oil of *Dittrichia viscosa* spp. viscosa: analysis by 168 C-NMR and antimicrobial activity. Flavour Fragr J 21: 324-332. DOI: 10.1002/ffj.1605

Boudouda HB, Benmerache A, Chibani S, Kabouche A, Abuhamdah S, Semra Z, Kabouche Z. 2012. Antibacterial activity and chemical composition of essential oils of *Inula viscosa* (L.) Ait. (Asteraceae) from Constantine, Algeria. Pharm Lett 4: 1863-1867.

Boudouda HB. 2014. Etude phytochimique et biologique des espèces *Biscutella raphanifolia*, *Zilla macroptera*, *Inula graveolens* et *Inula viscosa*. [Thèse Doctorat troisème cycle (LMD)] Université de Constantine 1, Algerie. [France]

Boumaza D. 2011. Séparation et caractérisation chimique de quelque biomolécules actives de deux plantes médicinales : *Inula viscosa* et *Rosmarinus officinalis* de la région d'Oran. [Thèse de Magister] Université d'Oran, Algerie. [France]

Bouyahya A, Et-Touys A, Khouchlaa A, El-Baaboua A, Benjouad A, Amzazi S, Dakka N, Bakri Y. 2018. Ethnobotanical and Phytopharmacological Notes on *Inula viscosa*. Phytotherapy 16 (S1): S263-S268. DOI: 10.3166/s10298-017-1176-2.

Brullo S, De Marco G. 2000. Taxonomical revision of the genus Dittrichia (Asteraceae). Portugaliae Acta Biol 19: 341-354.

Bssaibiss F, Gmira N, Meziane M. 2009. Les plantes médicinales et aromatiques. Rev Microbiol Ind San et Environ 3 (1): 44-55. [France]

Cafarchia C, De Laurentis N, Milillo MA, Losacco V. 2002. Antifungal activity of oils leaves and flowers of *Inula viscosa* (Asteraceae) by Apulian region. Parasitologia 44: 153-156.

Camacho A, Fernández A, Fernández C, Altarejos J, Laurent R. 2000. Composition of the essential oil of *Dittrichia viscosa* (L.). W. Greuter. Riv. Ital. EPPOS. 29: 3-8.

Chahmi N, Anissi J, Jennan S, Farah A, Sendide K, El Hassouni M. 2015. Antioxidant activities and total phenol content of *Inula viscosa* extract selected from three regions of Morocco. Asian Pac J Trop Biomed 5 (3): 228-233.

Chebouti-Meziou N. 2016. Contributions to Study of the Antimicrobial Activity of *Inula viscosa* Harvested in Boumerdes (Algeria). J Adv Chem Eng Biol Sci 3 (1): 159-162. DOI: 10.15242/IJACEBS.C0516204.

Chiarlo B. 1968. Sui costituenti dell'Inula viscosa Ait. Contenuto in azuleni dell'olio essenziale. Boll Chim Farm 107 (6): 370-382.

Cohen Y, Baider A, Ben-Daniel BH, Ben-Daniel Y. 2002. Fungicidal preparations from *Inula viscosa*. Plant Prot Sci 38: 629-630.

Dahiya P, Purkayastha S. 2012. Phytochemical screening and antimicrobial activity of some medicinal plants against multi-drug resistant bacteria from clinical isolates. Indian J Pharm Sci 74 (5): 443-450. DOI: 10.4103/0250-474X.108420.

De Laurentis N, Losacco V, Milillo M, Lai O. 2002. Chemical investigations, of volatile constituents of *Inula viscosa* (L.) Aiton

(Asteraceae) from different areas of Apulia. Southern Italy. Delpinoa, n.s. 44: 115-119.

Franco-Mican SX, Castro J, Campos M. 2008. Observation du complexe parasitaire de l'inule visqueuse en Espagne et ses méthodes de propagation. Le Nouvel Olivier. n°66. Nov. déc. [France]

Gharred N, Dbeibia A, Falconieri D, Hammami S, Piras A, Dridi-Dhaouadi S. 2019. Chemical composition, antibacterial and antioxidant activities of essential oils from flowers, leaves and aerial parts of Tunisian *Dittrichia viscosa*. J Essent Oil Res 31 (6): 582-589.

Haoui IE, Derriche R, Madani L, Oukali Z. 2011. Analysis of the chemical composition of essential oil from Algerian *Inula viscosa* L., Arabian J Chem 21 (14): 587-590 DOI: 10.1016/j.arabjc.2011.05.005

Haoui IE, Derrichea R, Madania L, Oukalib Z. 2015. Analysis of the chemical composition of essential oil from Algerian *Inula viscosa* (L.) Aiton. Arabian J Chem 8 (4): 587-590. DOI: 10.1016/j.arabjc.2011.05.005.

Hepokur C, Budak Y, Karayel HB, Selvi B, Yaylim I. 2019. Investigation of cytotoxic effects of *Inula viscosa* extract. Cumhuriyet Sci J 40 (3): 578-582. DOI: 10.17776/csj.437993.

Hwija E, Yaseer M, Mohannad H. 2018. Chemical composition of essential oils extracted from leaves of taion plant (*Inula viscosa* L.) from two different regions of Lattakia-Syria. Int J Novel Res Phys Chem Math 5 (1): 24-31.

Isil B, Zeynep T, Istemi S, Merve K, Tugba T, Selda M, Munevver A. 2018. The negative effects of *Inula viscosa* L. use on cancer treatment. Acta Sci Med Sci 2 (8): 19-24.

Kattouf J, Belmoukhtar M, Harnafi H, Mekhfi H, Ziyyat A, Aziz M, Bnouham M, Legssyer A. 2009. Effet antihypertenseur des feuilles d'Inula viscosa. Phytothérapie 7: 309-312. DOI: 10.1007/s10298-009-0517-1. [France]

Kheyar N, Meridja D, Belhamel K. 2014. Etude de l'activité antibactérienne des huiles essentielles d'Inula viscosa, Salvia officinalis et Laurus nobilis de la région de Bejaia. Algerian J Nat Prod 2: 18-26.

Larbi KS, Meddah B, Tir Touil Meddah A, Sonnet P. 2016. The antibacterial effect of two plants *Inula viscosa*, *Anacyclus valentinus* (Asteraceae) and their synergistic interaction with antibiotic drugs. J Fundam Appl Sci 8 (2): 244-255. DOI: 10.4314/jfas.v8i2.5.

Lauro L, Rolih C. 1990. Observations and research on an extract of *Inula viscosa* Ait. Bollettino Societa Italiana Biological Sperimentable 66 (9): 829-834.

Lev E, Amar Z. 2000. Ethnopharmacological survey of traditional drugs sold in Israel at the end of the 20th century. J Ethnopharmacol 72 (1-2): 191-205.

Madani L, Derriche R, Haoui IE. 2014. Essential oil of Algerian *Inula viscosa* leaves. J Essen Oil Bearing Plants 17 (1): 164-168.

Marongiu B, Piras A, Pani F, Porcedda S, Ballero M. 2003. Extraction separation and isolation of essential oils from natural matrices by supercritical CO_2. Flavour Fragr J 18 (6): 505-509. DOI: 10.1002/ffj.1258

Masada Y. 1979. Analysis of Essential Oils by Gas Chromatography and Mass Spectrometry. John Wiley & Sons, Inc., New York.

Merghoub N, Benbacer L, Amzazi S, Morjani H, El Mzibri M. 2009. Cytotoxic effect of some Moroccan medicinal plant extracts on human cervical cell lines. J Med Plants Res 3 (12): 1045-1050.

Miguel G, Faleiro L, Cavaleiro C, Salgueiro L, Casanova J. 2008. Susceptibility of *Helicobacter pylori* to essential oil of *Dittrichia viscosa* subsp. revoluta. Phytother Res: Intl J Devoted Pharmacol Toxicol Eval Nat Prod Derivatives 22 (2): 259-263.

Mohti H, Taviano MF, Cacciola F, Dugo P, Mondello L, Marino A, Crisafi G, Benameur Q, Zaid A, Miceli N. 2019. *Inula viscosa* (L.) Aiton leaves and flower buds: effect of extraction solvent/technique on their antioxidant ability, antimicrobial properties and phenolic profile. J Nat Prod Res (Formerly Nat Prod Lett) 1: 1-7. DOI: 10.1080/14786419.2019.1569659.

Nasser M, Housheh S, Kourini A, Maala N. 2014. Chemical composition of essential oil from leaves and flowers of *Inula viscosa* (L.) in Al-qadmous region Syria. Intl J Pharmaceut Sci Res 5 (12): 5177-5182. DOI: 10.13040/IJPSR.0975-8232.5 (12).5177-82.

NIST. 2002. Mass Spectral Search Program for the NIST/EPA/NIH Mass Spectral Library, vers. 2.0. fiveash data, USA.

Ozkan E, Karakas FP, Yildirim AB, Tas D, Eker D, Yavuz MZ, Türker AU. 2019. Promising medicinal plant *Inula viscosa* L.: Antiproliferative, antioxidant, antibacterial and phenolic profiles. Prog Nutr 21 (3): 652-661. DOI: 10.23751/pn.v21i3.7186.

Parolin P, Scotta M, Bresch C. 2014. Biology of *Dittrichia viscosa* a Mediterranean ruderal plant. Int J Exp Bot 83 (2): 251-261.

Perez-Alonso MJ, Velasco-Negueruela A, Emin-Duru M, Garcia Vallejo MC. 1996. Composition of the volatile oil from the Aerial parts of *Inula viscosa* (L.) Aiton. Flavour Fragr J 11: 349-351.

Pistelli L, Bandeira Reidel RV, Parri F, Morelli E, Pistelli L. 2019. Chemical composition of essential oil from plants of abandoned mining sites of Elba island. Nat Prod Res 33 (1): 143-147.

Ponce AG, Fritz R, Del Valle C, Roura SI. 2003. Antimicrobial activity of essential oils on the native microflora of organic Swiss chard. Lebensmittel-Wissenschaft und Technologie 36 (7): 679-684. DOI: 10.1016/S0023-6438 (03)00088-4.

Prisa D. 2019. Possible use of Inula viscosa (*Dittrichia viscosa* L.) for biostimulation of *Oscularia deltoids* and *Corpuscolaria lehmanii* plants and protection against *Aphis nerii*. GSC Biol Pharm Sci 9 (3): 69-75. DOI: 10.30574/gscbps.2019.9.3.0231.

Quézel P, Santa S. 1962. Nouvelle Flore de l'Algérie et des régions désertiques Méridionales. Paris. [France]

Rajkumar R. 2012. Community Based Cancer Screening-The 12 "I"s Strategy for Success. Topics on Cervical Cancer with an Advocacy for Prevention. IntechOpen, London.

Remli B. 2013. Extraction des flavoniodes de la plante Inula viscusa de la région d'Oran et mise en evidence de l'activité microbienne. Mémoire de magistère en chimie. Université d'Oran, Algerie. [France]

Rhimi W, Ben Salem I, Immediato D, Saidi M, Boulila A, Cafarchia C. 2017. Chemical composition, antibacterial and antifungal activities of crude *Dittrichia viscosa* (L.) greuter leaf extracts. Molecules 22 (7): 942.

Rhimi W, Salem IB, Iatta R, Chaabane H, Saidi M, Boulila A, Cafarchia, C. 2018. *Dittrichia viscosa* L. leaves lipid extract: An unexploited source of essential fatty acids and tocopherols with antifungal and anti-inflammatory properties. Ind Crops Prod 113: 196-201.

Rozenblat S, Grossman S, Bergman M, Gottlieb H, Cohen Y, Dovrat S. 2008. Induction of G2/M arrest and apoptosis by sesquiterpene lactones in humain melanoma cell lines. Biochem Pharmacol 75: 369-382. DOI: 10.1016/j.bcp.2007.08.024.

Schinella GR, Tournier HA, Prieto JM, Mordujovich de Buschiazzo P, Rios JL. 2002. Antioxidant activity of anti-inflammatory plant extracts. Life Sci 70 (9): 1023-1033. DOI: 10.1016/s0024-3205 (01)01482-5.

Seca AML, Grigore A, Pinto D, Silva AMS. 2014. The genus Inula and their metabolites: From ethnopharmacological to medicinal uses. J Ethnopharmacol 154 (2): 286-310. DOI: 10.1016/j.jep.2014.04.010.

Sevindik E, Paksoy MY. 2017. Evaluation of essential oil composition Genus *Dittrichia* L. (Asteraceae) Plants in Aydın/Turkey. Türk Tarım ve Doğa Bilimleri Dergisi 4 (4): 456-460.

Silva D, Denham E, Faleiro L, Miguel G, Cavaleiro C, Salgueiro L. 2005. Antimicrobial activity of the essential oils of *Dittrichia viscosa* subsp. viscosa on *Helicobacter pylori*. Acta Hortic 680 (680): 147-151. DOI: 10.17660/ActaHortic.2005.680.22.

Sriti Eljazi J, Selmi S, Zarroug Y, Wesleti I, Aouini B, Jallouli S, Limam F. 2018. Essential oil composition, phenolic compound, and antioxidant potential of *Inula viscosa* as affected by extraction process. Intl J Food Prop 21 (1): 2309-2319.

Talib WH, Abu Zarga MH, Mahasneh AM. 2012. Antiproliferative. antimicrobial and apoptosis inducing effects of compounds isolated from *Inula viscosa*. Molecules 17 (3): 3291-3303. DOI: 10.3390/molecules17033291.

Yeddes W, Wannes WA, Hammami M, Smida M, Chebbi A, Marzouk B, Tounsi MS. 2018. Effect of environmental conditions on the chemical composition and antioxidant activity of essential oils from *Rosmarinus officinalis* L. growing wild in Tunisia. J Essent Oil Bearing Plant 21 (4): 972-986. DOI: 10.1080/0972060X.2018.1533433.

Zeggwagh NA, Ouahidi ML, Lemhadri A, Eddouks M. 2006. Study of hypoglycaemic and hypolipidemic effects of *Inula viscosa* L. aqueous extract in normal and diabetic rats. J Ethnopharmacol 8 (2): 223-227. DOI: 10.1016/j.jep.2006.05.005.

Zhao YM, Zhang ML, Shi QW, Kiyota H. 2006. Chemical constituents of plants from the Genus *Inula*. Chem Biodivers 3 (4): 371-384. DOI: 10.1002/cbdv.200690041.