

Comparative analysis of essential oils and antimicrobial activities of *Scorzonera yildirimlii* and *S. zorkunensis* from Türkiye

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Abstract: The present study aimed to investigate the chemical composition of essential oils (EOs) of two endemic species, *Scorzonera yildirimlii* and *S. zorkunensis*. The EOs were obtained using hydrodistillation (HD) and analyzed by GC-MS. A total of 48 and 37 compounds were identified, accounting for 99.96% and 99.94%, respectively. Aldehydes (56.20% / 34.55%) and terpenoids (17.89% / 25.55%) were the primary chemical classes in the essential oil of both species. Nonanal (18.76%) and phytol (15.58%) in the EO of *S. yildirimlii* and 2-nonadecanone (21.62%) and cedroxide (12.07%) in the EO of *S. zorkunensis* were found to be significant compounds. The antimicrobial activities of the EOs of both species were evaluated against nine microorganisms. They showed the strongest activity against *Mycobacterium smegmatis*, with MIC values of 32.63 µg/mL and 65.81 µg/mL, respectively.

INTRODUCTION

The genus *Scorzonera* L. (Asteraceae) is widely distributed across arid lands in Eurasia and Africa and comprises approximately 180 species worldwide. Although there are only 28 species in the European flora, more than 50 species of the genus *Scorzonera* occur in Türkiye, of which 32 are endemic (Chamberlain, 1975; Çitoğlu *et al.*, 2010; Makbul *et al.*, 2010; Şenol *et al.*, 2014). Türkiye is a significant hub of plant diversity. Many *Scorzonera* species are consumed as vegetables in Türkiye. Some *Scorzonera* species are traditionally used as a manger in Eastern Anatolia. *Scorzonera mollis* Bieb, known as goftigoda; *Scorzonera suberosa* C. Koch, known as wild carrot; *Scorzonera cana* (C.A. Meyer) Hoffm.; *Scorzonera latifolia* (Fisch. et Mey.) DC, commonly known as broadleaf squawroot, are edible plants (Şenol *et al.*, 2014; Tsevegşüren *et al.*, 2007). *Scorzonera cretica* Willd., native to Türkiye, is recognized as an appetizing agent in Greek cuisine (Chamberlain, 1975; Paraschos *et al.*, 2001). *Scorzonera* species are used in traditional medicine in China, Mongolia, Türkiye, and European countries (Wang *et al.*, 2009) for the treatment of hypertension, arteriosclerosis, rheumatism, kidney

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diseases, and diabetes (Baytop, 1999). The roots of *Scorzonera tomentosa* L. contain latex and have wound-healing activity (Sezik *et al.*, 1997). *S. latifolia* is another species that is traditionally used in Turkish folk medicine. A gum called ‘yaki’ is obtained from the latex of this plant and is used for its analgesic and anthelmintic properties, which may help alleviate infertility (Baytop, 1999; Çitoğlu *et al.*, 2010).

Essential oils derived from various plants contain valuable secondary metabolites, predominantly terpenes. These oils are widely used in the cosmetic, pharmaceutical, and food industries. Recent studies have highlighted the biological importance of *Scorzonera* species, prompting increased investigations into their traditional uses (Çitoğlu *et al.*, 2010; Gong *et al.*, 2024; Paraschos *et al.*, 2001; Şenol *et al.*, 2014; Tsevegsuren *et al.*, 2007; Wang *et al.*, 2009). Antimicrobial activity studies against various microorganisms have also been conducted on *Scorzonera* species (Ayromlou *et al.*, 2020; Boussaada *et al.*, 2008; Mohammed *et al.*, 2020; Sarı *et al.*, 2009; Sarı *et al.*, 2019; Şahin *et al.*, 2020; Sweidan *et al.*, 2020; Ugur *et al.*, 2010; Yaylı *et al.*, 2022; Zidorn *et al.*, 2002).

To date, no studies have focused on the EOs and antimicrobial activities of *S. yildirimlii* and *S. zorkunensis*. Therefore, this study aimed to (i) determine the chemical composition of the EOs obtained from *S. yildirimlii* and *S. zorkunensis* species, (ii) analyze the correlation between the chemical composition of EOs obtained by the HD method for both species, and (iii) assess the antimicrobial activities of the EOs of *S. yildirimlii* and *S. zorkunensis*.

METHOD

Study Design and Sampling

This study was designed as an experimental laboratory-based investigation to isolate and characterize essential oils (EOs) from two endemic plant species and evaluate their antimicrobial activities. The plant materials used were *S. yildirimlii* and *S. zorkunensis*, both endemic to Türkiye. *S. yildirimlii* and *S. zorkunensis* plants, including their roots and aerial parts, were collected from Osmaniye, Türkiye: Zorkun Plateau, Keldaz hill (36°58'32" N, 036°24'10.2" E), 2075 m, on 20th August 2023. The plants were classified according to the Flora of Türkiye (Chamberlain, 1975; Coşkunçelebi *et al.*, 2015; Makbul *et al.*, 2010). *S. yildirimlii* and *S. zorkunensis* were stored in the KTU Department of Biology herbarium (KTUB) under the codes KTUB-242 (Coşkunçelebi & Makbul) and KTUB-243 (Coşkunçelebi & Makbul). The whole plants were cleaned, dried in the shade, ground in a mill, and stored in a plastic bag at room temperature until extraction.

Data Collection Tools and Process

Plant material preparation and essential oil extraction

The collected plants were cleaned, shade-dried, and ground into powder. Blended whole parts of *S. yildirimlii* (94 g, dry) and *S. zorkunensis* (95 g, dry) plant materials underwent HD using a modified (double jacketed cooler) Clevenger-type apparatus (7 °C, 3h), yielding (v/w) 0.055% and 0.011% EOs, respectively. The EOs were extracted with *n*-hexane, dried over sodium sulfate (Na₂SO₄), and stored in brown glass bottles at -10 °C until analysis (Yaylı *et al.*, 2022).

Chemical characterization

The chemical composition of the EOs was determined using gas chromatography-mass spectrometry (GC-MS). The analyses were conducted on a Shimadzu QP2010 system equipped with a Restek Rxi-5MS column. The temperature program and other GC-MS parameters were set according to standardized methods (Adams, 2007; Yaylı *et al.*, 2022). Compounds were identified by comparing retention indices and mass spectra with reference data.

Antimicrobial minimal inhibition concentration (MIC) assay

The antimicrobial minimum inhibitory concentration (MIC) values of the essential oils were evaluated using the broth microdilution method, as described by Woods *et al.* (2003). In this

test, 100 μ L of EO solutions at different concentrations were used, and MIC values were defined as the lowest concentration that inhibited visible microbial growth. All microorganisms were purchased from the Hifzissihha Institute of Refik Saydam (Ankara, Türkiye): *Escherichia coli* ATCC35218, *Yersinia pseudotuberculosis* ATCC911, *Pseudomonas aeruginosa* ATCC43288, *Staphylococcus aureus* ATCC25923, *Enterococcus faecalis* ATCC29212, *Bacillus cereus* 709 Roma, *Mycobacterium smegmatis* ATCC607, *Candida albicans* ATCC60193, and *Saccharomyces cerevisiae* RSKK 251. The EOs were dissolved in *n*-hexane to prepare stock solutions (5220 μ g/mL and 10530 μ g/mL). Each well received 100 μ L of Mueller-Hinton Broth (MHB) or Potato Dextrose Broth (PDB) along with a serially diluted extract solution. Test microorganisms were prepared using a McFarland standard of 0.5 (approximately 1×10^8 cfu/mL) and diluted 1:10. The antimicrobial properties of the EOs were investigated quantitatively in respective broth media by using triplicate microdilution, and the MIC values (μ g/mL) were examined (Barry, 1999; Woods *et al.*, 2003; Cansu *et al.*, 2013) (Table 2). We inoculated each well with 5 μ L (equivalent to 5×10^4 cfu) of this dilution. The plates were incubated at 37°C for 24 to 48 h. Brain Heart Infusion broth (BHI) (Difco, Detroit, MI) was used for *M. smegmatis* and incubated at 37°C for 72h. Three independent experiments confirmed the reproducibility of the MIC results. The MIC was defined as the lowest concentration at which no growth was observed. Ampicillin (10 μ g/mL), streptomycin (10 μ g/mL), and fluconazole (5 μ g/mL) were used as the standard antibacterial and antifungal agents. A 1/10 dilution of each solvent was used as the control.

Data Analysis

The chemical composition of the EOs was analyzed by calculating the relative percentage of each compound based on GC peak areas. Antimicrobial activity was evaluated by measuring the diameter of the inhibition zone (mm), and the mean values for each sample were reported. Data analysis was descriptive, comparing EO composition and antimicrobial efficacy against the tested microorganisms.

Gas chromatography-mass spectrometry (GC-MS)

GC-MS analysis was performed using a Shimadzu Ultra QP2010 (Shimadzu Class-5000 Chromatography Workstation software). A Restek Rxi-5MS column (30 mm x 0.25 mm x 0.25 μ m) (USA) was used for the analysis. The sample (1 μ L, in HPLC-grade *n*-hexane) was injected into split mode (1:30) at 230 °C. The initial column temperature was 60 °C for 2 minutes, after which it was increased to 240 °C at a heating rate of 3 °C/min. The final temperature was maintained at 250 °C for 4 min. The carrier gas was Helium (99.999%) with a flow rate of 1 mL/min. MS detection was performed in the electronic impact mode (EI, 70 eV; scan mode 40-450 *m/z*) (Adams, 2007; Üçüncü *et al.*, 2010a,b). The samples were analyzed, and the mean values were reported (Table 1). Retention indices (RI) of the EO components were calculated from a homologous series of *n*-alkanes (C₆-C₃₀) using the same chromatographic conditions as those applied to the samples. Linear retention indices (LRIs) were calculated according to the Van den Dool and Kratz equation under temperature-programmed conditions. The calculated RI values were compared with literature data and reference databases for compound identification.

RESULTS

Chemical Composition

The EOs of *S. yildirimlii* and *S. zorkunensis* were extracted using the HD method and analyzed by GC-MS using an Rxi-5MS capillary column. GC-MS chromatograms of *S. yildirimlii* and *S. zorkunensis* are given in Figures 1 and Figure 2, respectively. Chemical constituents were identified by comparing their RI and MS data with those in the NIST, Wiley7NL, FFNSC1.2, and W9N11 libraries (Adams, 2007). The structures of the compounds, percentages, and retention indices of all compounds in *S. yildirimlii* and *S. zorkunensis* are presented in Table 1.

GC-MS analysis of the EOs yielded 48 and 37 compounds, accounting for 99.96% and 99.94% of the total components, respectively. Nonanal (18.76%), phytol (15.58%), hexanal (9.52%), (*E*)-2-dodecenal (6.48%), (*E*)-2-decenal (5.15%), and octanal (3.63%) were found to be the main components in the EO of *S. yildirimlii*. Whereas 2-nonadecanone (21.62%), cedroxyde (12.07%), nonanal (8.73%), hexanal (8.62%), D-germacrene (3.49%), γ -gurjuene (3.10%), and (2*E*)-decen-1-ol (3.04%) were detected as the main compounds in the EO of *S. zorkunensis*.

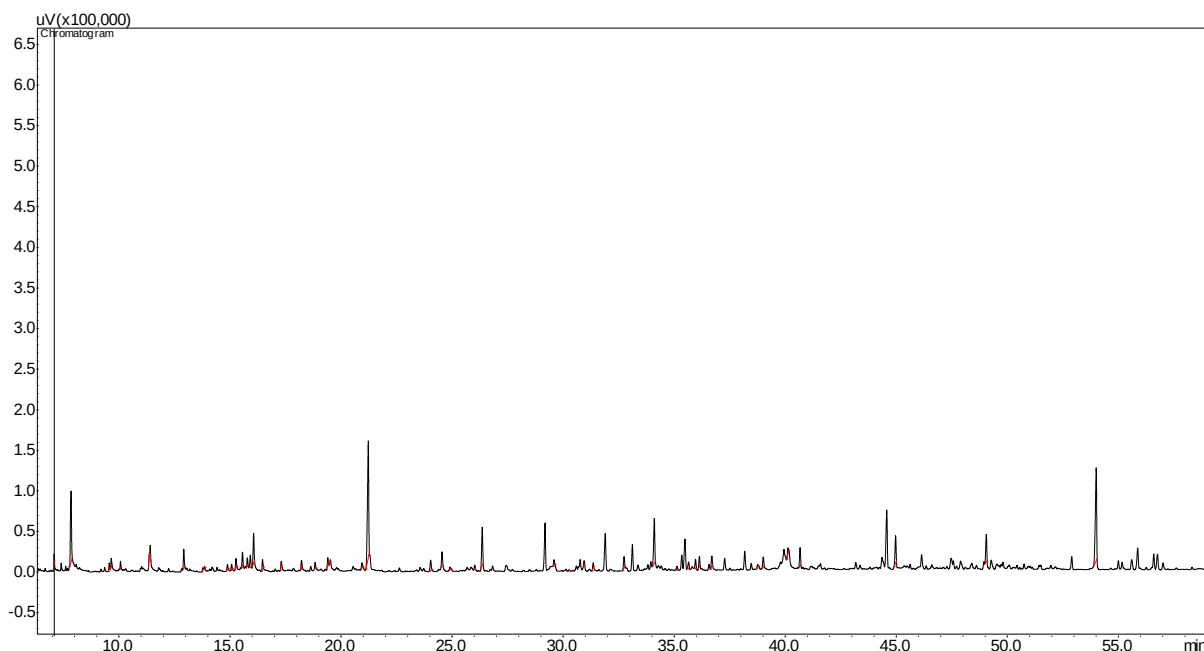


Figure 1. GC-MS chromatogram of *S. yildirimlii*.

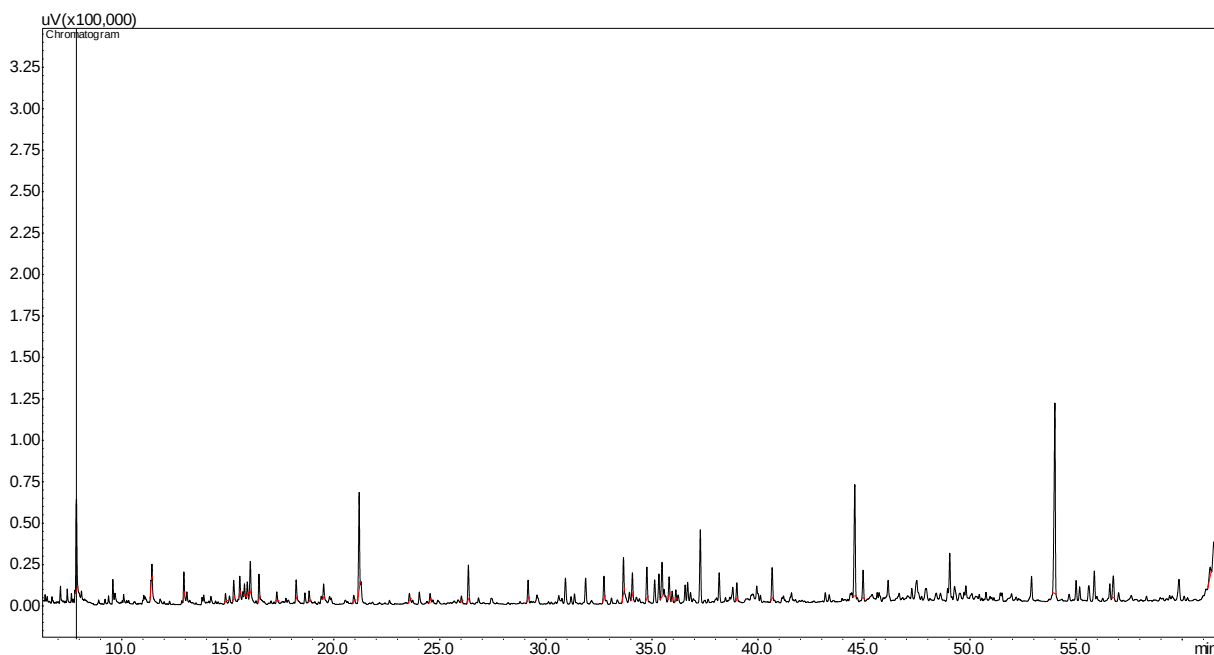


Figure 2. GC-MS chromatogram of *S. zorkunensis*.

Table 1. Essential oil composition of *S. yildirimlii* and *S. zorkunensis* species.

No	Compounds	RT	RI _{Lit} [*]	RI _{Exp} ^a	Area % ^b	
					<i>S. yildirimlii</i>	<i>S. zorkunensis</i>
1	Toluene	7.08	733	743	0.64	-
2	Hexanal	7.84	803	806	9.52	8.62
3	(Z)-3-Hexanal	9.56	800	810	0.52	-
4	(Z)-3-Hexenol	9.65	859	853	0.84	-
5	Hexanol	10.07	863	867	0.53	-
6	Nonane	11.36	900	888	0.23	0.28
7	Heptanal	11.41	899	895	0.96	0.55
8	2,7-Dimethyloxepine	12.92	934	930	2.14	1.57
9	6-Methyl-2-heptanone	13.78	957	953	0.23	-
10	(E)-2-Heptenal	13.85	956	955	0.16	-
11	1-Octen-3-ol	14.89	986	982	0.52	0.58
12	2,3-Octanedione	15.07	987	986	0.57	-
13	3-Octanone	15.27	984	989	1.10	-
14	6-Methyl-5-hepten-2-one	15.28	988	992	-	1.47
15	2-Pentyl furan	15.56	993	999	1.45	1.16
16	2E,4E-Heptadienal	15.78	1009	1004	0.78	0.67
17	Decane	15.92	1000	1001	1.46	0.79
18	Octanal	16.06	1003	1007	3.63	2.60
19	2Z,4Z-Heptadienal	16.47	1013	1014	1.03	1.96
20	2-Ethyl hexanol	17.31	1045	1040	0.56	0.71
21	Phenyl acetaldehyde	18.22	1045	1052	0.81	1.53
22	2-Octenal	18.83	1056	1060	-	0.78
23	2E-Octen-1-ol	18.83	1060	1066	0.67	-
24	1-Octanol	19.41	1068	1072	0.74	-
25	p-Tolualdehyde	19.52	1079	1075	0.29	1.07
26	Undecane	20.94	1100	1101	0.70	0.58
27	Nonanal	21.19	1102	1104	18.76	8.73
28	Camphor	23.56	1146	1151	-	0.59
29	2E-Nonenal	24.04	1157	1163	1.44	-
30	Isoborneol	24.53	1162	1165	-	0.52
31	Nonanol	24.55	1186	1180	1.76	-
32	Menthol	24.91	1172	1182	0.27	-
33	Dodecane	26.01	1200	1203	0.41	-
34	Citronellol	26.02	1245	1242	-	0.38
35	(E)-2-Decenal	26.34	1266	1261	5.15	-
36	(2E)-Decen-1-ol	26.36	1271	1273	-	3.04
37	Tridecane	29.16	1300	1302	0.67	-
38	(E)-2-Undecenal	29.59	1360	1357	-	1.55
39	4-Acetyl-2-methylphenol	30.26	1323	1329	0.13	-
40	Tetradecane	30.95	1400	1401	0.44	-
41	Dodecenal	31.36	1412	1415	0.56	-
42	Aristolene	32.73	1428	1418	-	1.89
43	γ-Gurjuene	33.65	1409	1419	-	3.10
44	Neoclovene	32.74	1434	1428	1.42	-
45	(E)-2-Dodecenal	34.11	1466	1456	6.48	1.81
46	α-Himachalene	34.76	1451	1461	-	2.96
47	D-Germacrene	35.12	1485	1475	0.45	3.49
48	γ-Guaijene	35.80	1505	1499	-	1.47
49	Pentadecane	35.65	1500	1501	0.93	-
50	cis-β-Guaine	35.95	1493	1493	-	0.56
51	2-Tridecanone	35.96	1494	1496	1.14	-
52	Dodecanal	36.12	1510	1508	-	0.77
53	Tridecanal	36.14	1510	1509	1.19	-
54	(Z)-γ-Bisabolene	36.69	1515	1516	1.29	-
55	(E)-Nerolidol	38.76	1563	1568	0.29	-
56	n-Tridecanol	39.01	1575	1580	1.25	1.30
57	Hexadecane	40.13	1600	1602	0.71	-
58	Tridecanal	40.66	1611	1613	2.39	-
59	Tetradecanal	40.67	1611	1615	-	2.99

60	Cedroxyde	44.56	1714	1716	-	12.07
61	Hexadecanal	44.95	1811	1806	-	2.47
62	Hexadecanol	44.97	1811	1810	3.55	-
63	Heptadecanal	49.05	1922	1917	3.63	-
64	2-Nonadecanone	53.99	2110	2108	-	21.62
65	Phytol	54.00	2111	2110	15.58	-
66	Linoleic acid	56.75	2131	2139	-	2.44
67	Tricosane	61.32	2300	2302	-	1.28
Chemical classes						
	Terpenoids				17.89	25.55
	Aldehydes				56.20	34.55
	Alkanes				5.13	2.93
	Alcohols				10.82	6.53
	Ketones				3.17	23.68
	Others				6.75	6.70
	Total				99.96	99.94

RT: Retention time; *KI_{Lit.}: literature retention index values; ^a: KI_{Exp.}: The experimental retention index was calculated from retention times relative to the *n*-alkane series (C₆-C₃₀); ^b: % was the percentage obtained by FID peak-area normalization.

In both species, 17 compounds, such as hexanal, nonane, heptanal, 2,7-dimethyloxepine, 1-octen-3-ol, 2-pentyl furan, 2*E*,4*E*-heptadienal, decane, octanal, 2*Z*,4*Z*-heptadienal, 2-ethyl hexanol, phenyl acetaldehyde, *p*-tolualdehyde, undecane, nonanal, (*E*)-2-dodecenal, D-germacrene, and *n*-tridecanol, were found in different ratios (Table 1). The chemical classes of the EOs from *S. yildirimlii* and *S. zorkunensis* were classified according to their structures (Table 1). Aldehydes were detected as the main components in the EOs of *S. yildirimlii* and *S. zorkunensis* at 56.20% and 34.55%, respectively. The amounts of terpenic components in the EOs of *S. yildirimlii* and *S. zorkunensis* were determined as the second major class of components at a rate of 17.89% and 25.25%, respectively. However, the terpenic content differed markedly between the two species. Phytol (15.58%) was the major terpenoid in the EO of *S. yildirimlii*. D-Germacrene (3.49%) was the major terpenic compound in the EO of *S. zorkunensis*.

In literature, the EO of *Scorzonera undulata* was analyzed by GC-MS, and the results revealed the presence of fifty-one compounds belonging to diverse chemical classes, including fatty acids and their esters, long-chain hydrocarbons, long-chain alcohols, and heterocyclic compounds (Najah et al., 2024). The EOs of *Scorzonera bella* and *S. veratrifolia* species were analyzed by GC-MS, and phytochemical compositions of nonpolar fractions of the plants differed significantly in phthalic acid esters, ursane, and hopane-type triterpenoids (Şahin et al., 2023). The EO of *Scorzonera hispanica* was analyzed by GC-MS, and the composition of the oil revealed that fatty acids and β-sitosterol were the primary components of the seed oil (Lendzion et al., 2022). The EOs of aerial parts of *Scorzonera pseudolanata* Grossh were analyzed by GC-MS. A total of 46 secondary volatile compounds were reported across all the extracts. *n*-Hexadecane (13.6%) was the dominant compound in the roots, phytone (16.36%) in the leaves, and nonadecane (56.45%) in the seeds (Özcan Aykutlu et al., 2025). 56 constituents were detected in *S. papposa* using GC-MS analysis. The highest amounts of methyl palmitate (16.78%) in root, phytone (30.44%) in stem, phytone (40.17%) in leaf, and phytol (31.84%) in seed were reported (Yurteri et al., 2022). Fifty-five compounds from the EOs of *S. pisidica* and *S. sandrasica* were identified by GC-MS. Major classes of constituents were found to be monoterpenes (12.8%) and monoterpenoids (15.1%) among all terpenes in the SPME, and SPME of *n*-hexane extract of *S. pisidica* and *S. sandrasica*, respectively (Yaylı et al., 2022). The EO for the aerial parts of *S. calyculata* was extracted by solvent-free microwave extraction and analyzed by GC-MS. The EO was reported to be rich with nonterpenoid compounds (50.35%) (Ayromlou et al., 2020). The EO constituent for the roots of *S. undulata* subsp. *deliciosa* was reported by GC-MS. 43 compounds were identified (94.2% of total oil), and hexadecanoic acid (42.2%), *n*-tetradecanoic acid (16.1%), 9-octadecenoic acid (7.7%), and 9-hexadecenoic acid (4.5%) were reported to be major constituents (Harkati et al., 2010). The

constituents of the EOs in the root, stem, leaf, and flower of six *Scorzonera* species were analyzed by GC-MS, and a total of 40 components were reported as fatty acids, esters, hydrocarbons, alcohols, aldehydes, phenols, and heterocyclic compounds. All parts of the plants contained fatty acids, esters, and hydrocarbons (Zhao *et al.*, 2010). The EOs constituents of *S. undulata* from its aerial parts were analyzed by GC-MS. Thirty components are classified as fatty acids, aliphatic hydrocarbons, aromatic components, monoterpenes, and sesquiterpenes. Hexadecanoic acid (21.49%) and dodecanoic acid (15.31%) were reported to be the predominant components (Mahjoub *et al.*, 2009). The EO of *S. undulata* subsp. *deliciosa* was analyzed by GC-MS. A total of 40 components were identified, comprising a high proportion of fatty acids and their esters (60.1%) (Boussaada *et al.*, 2008). GC-MS analysis of the EO constituents of *S. mongolica* identified hentriacontane (34.75%) and A-neogammacer-22(29)-en-3 β -ol (21.47%) as the major constituents (Wang *et al.*, 2007). The study observed that the essential oil components differ among *Scorzonera* species.

Antimicrobial Activities

The antimicrobial activities of the EOs of *S. yildirimlii* and *S. zorkunensis* against three Gram (-) bacteria (*E. coli*, *Y. pseudotuberculosis*, and *P. aeruginosa*), three Gram (+) bacteria (*S. aureus*, *E. faecalis*, and *B. cereus*), one no gram (*M. smegmatis*), and two yeast fungi (*C. albicans* and *Saccharomyces cerevisiae*) were investigated (Table 2) (Barry, 1999; Woods *et al.*, 2003; Cansu *et al.*, 2013). The EO of *S. yildirimlii* was only effective against *S. aureus*, *B. cereus*, *M. smegmatis*, and *C. albicans* with IC₅₀ values of 130.5 μ g/mL, 234.3 μ g/mL, 32.63 μ g/mL, and 346.4 μ g/mL, respectively. The EO of *S. zorkunensis* showed activity only against *S. aureus*, *B. cereus*, and *M. smegmatis* with IC₅₀ values of 526.0 μ g/mL, 468.5 μ g/mL, and 65.82 μ g/mL, respectively. The EOs of *S. yildirimlii* and *S. zorkunensis* species showed no activity against Gram-negative bacteria. The high amount of aldehyde and terpenoid components in the EOs of *S. yildirimlii* and *S. zorkunensis* influences antimicrobial activity.

Table 2. Screening for the antimicrobial activity of EOs obtained from *S. yildirimlii* and *S. zorkunensis*.

EOs	Stock Sol. (μ g/mL)	Microorganisms and minimal inhibitory concentration (MIC, μ g/mL) ^a								
		Gram (-)			Gram (+)			No Gr.	Fungi	
		<i>Ec</i>	<i>Yp</i>	<i>Pa</i>	<i>Sa</i>	<i>Ef</i>	<i>Bc</i>	<i>Ms</i>	<i>Ca</i>	<i>Sc</i>
<i>S. yildirimlii</i>	5.220	-	-	-	130.5	-	234.3	32.63	346.4	-
<i>S. zorkunensis</i>	10.530	-	-	-	526.0	-	468.5	65.81	-	-
Amp.	10	10	18	>128	35	10	15	-	-	-
Strep.	10							4		
Flu.	5								8	8

^a: Broth microdilution assay (100 μ L per well). *Ec*: *Escherichia coli*. *Yp*: *Yersinia pseudotuberculosis*. *Pa*: *Pseudomonas aeruginosa*. *Sa*: *Staphylococcus aureus*. *Ef*: *Enterococcus faecalis*. *Bc*: *Bacillus cereus* 702 Roma. *Ms*: *Mycobacterium smegmatis*. *Ca*: *Candida albicans*. *Sc*: *Saccharomyces cerevisiae*. (-): No activity of the test concentrations.

The antimicrobial activity of the EO was also reported against *S. aureus*, *S. epidermidis*, *E. coli*, *P. aeruginosa*, *Salmonella typhimurium*, *Micrococcus luteus*, *Aspergillus niger*, *Fusarium oxysporum*, *Alternaria ssp.*, and *Penicillium ssp.* (Boussaada *et al.*, 2008). The chemical constituents of EOs from different parts of *Scorzonera albicaulis* Bunge were reported, and aliphatic acid and ester were the most abundant chemical classes among them (Zhao *et al.*, 2010). The volatile constituents of the EOs for two *Scorzonera pisdica* Hub.-Mor. And *Scorzonera sandrasica* Hartvig & Strid species were reported, with aldehydes being the primary chemical class of organic compounds (49.5% and 44.9%), respectively. The antimicrobial

activity of the EOs of *S. pisidica* and *S. sandrasica* was tested against nine microorganisms and reported to be moderate (Yaylı et al., 2022). Essential oil from the aerial parts of *Scorzonera calyculata* Boiss. was rich in oxygenated monoterpenes. The EO exhibited high toxicity against Gram-positive bacteria, with an IC₅₀ value of 9.8 mg/mL reported for its cytotoxicity (Ayromlou et al., 2019). The chloroform extract of *Scorzonera sandrasica* Hartvig et Strid also yielded caryophyllene oxide (19.7%), manoyl oxide (16.5%), and manool (11.3%) as major compounds (Ugur et al., 2010). In our case, the EOs of *S. yildirimlii* and *S. zorkunensis* were more active against *S. aureus*, *B. cereus*, and *M. smegmatis*, which may be attributable to terpenic compounds present in the EOs of both species.

DISCUSSION and CONCLUSION

Recent research has highlighted the biological importance of the *Scorzonera* species, prompting increased scientific inquiry into their volatile components and antibacterial properties. Antimicrobial activity tests of essential oils of some *Scorzonera* species have been conducted. The major volatile constituents for the aerial parts of *Scorzonera undulata* Vahl subsp. *deliciosa* (Guss.) Maire were reported to be methyl hexadecanoate (30.4%), methyl linolenate (23.9%), and heneicosane (12.2%). The essential oils (EOs) of *S. yildirimlii* and *S. zorkunensis* demonstrated notable chemical diversity and antimicrobial potential. The observed variations in major constituents between the two species suggest species-specific metabolic profiles, likely influenced by environmental conditions such as altitude, climate, and soil composition. This chemical differentiation appears to contribute directly to their differing degrees of antimicrobial activity. Although previous studies on various *Scorzonera* species have reported diverse chemical compositions and moderate antimicrobial effects, the present findings underscore the potential value of *S. yildirimlii* and *S. zorkunensis* as sources of bioactive essential oils. Their relatively low MIC values further support this potential. In our case, the pronounced activity of both EOs against *S. aureus*, *B. cereus*, and *M. smegmatis* is particularly noteworthy, especially considering the growing resistance of these microorganisms to conventional antibiotics.

In conclusion, a total of 67 compounds were identified in the EOs analysis of *S. yildirimlii* and *S. zorkunensis*. Aldehydes (56.20% / 34.55%) and terpenoids (17.62% / 25.55%) were the major classes of compounds, and phytol (15.58%) and D-germacrene (3.49%) were the major terpenoids in the EOs of *S. yildirimlii* and *S. zorkunensis*, respectively. According to the broth microdilution assay (MIC values), the essential oils of *S. yildirimlii* and *S. zorkunensis* showed activity against Gram-positive bacteria and *M. smegmatis*. In contrast, no activity was observed against Gram-negative bacteria. EOs of both species exhibited the most potent antimicrobial activity against *M. smegmatis* with MIC values of 32.63 µg/mL and 65.81 µg/mL, respectively. The strong activity against *M. smegmatis* in particular highlights the potential of these oils to develop new antimycobacterial agents. Thus, the antimicrobial assay results showed that the EOs of both species could be promising for pharmaceutical applications. In future studies, bio-guided isolation of extracts should be conducted to determine their bioavailability.

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Declaration of Conflicting Interests and Ethics

The authors declare no conflict of interest. This research study complies with research and publishing ethics. The scientific and legal responsibility for manuscripts published in IJSM belongs to the authors.

Data Availability Statement

The research data supporting the findings of this study are available from the corresponding author upon reasonable request.

Authorship Contribution Statement

B.K.: Conceptualization, Methodology, Investigation, Formal analysis, Writing – original draft, Writing – review and editing. **G.B.:** Investigation, Formal analysis, Visualization. **B.Ş.:** Investigation, Methodology, Formal analysis. **S.Y.:** Methodology, Investigation, Formal analysis. **K.C.:** Plant material identification, Resources, Validation. **S.M.:** Investigation, Methodology, Validation. **Ş.A.K.:** Antimicrobial activity studies, Methodology, Supervision, Validation. **N.Y.:** Conceptualization, Methodology, Resources, Supervision, Writing – review and editing.

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