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# Aromatic Plants from Western Balkans: A Potential Source of Bioactive Natural Compounds

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Additional information is available at the end of the chapter

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## Abstract

Documentation of traditionally used aromatic and medical plants has been carried out in many European countries over the last several years. Over the last decade, the Western Balkans has become the area of a huge number of ethnobiological field studies. Many of those focused on Balkans ethnobotany are linked to the long and ongoing history of gathering and trading local wild aromatic and medicinal plants from this territory into Western European markets. But only less than a half percent of these have been studied for their chemical composition and medicinal value. The most investigated aromatic species in this area belongs to the few biggest families: Asteraceae, Apiaceae, Lamiaceae and Rosaceae. Medicinal value of plants lies in some chemical substances that produce physiological action on the human body, which leads to positive effect on health. Essential oils are secondary metabolites which are the most examined, as well as various plant extracts. Isolation and identification of the compounds in combination with its biological screening can considerably contribute to plant studies. Also, application of new activities and novel techniques for susceptibility testing provide better knowledge of wild growing medicinal plants as potential sources of biological agents and justified their traditional uses.

**Keywords:** Western Balkans, ethnobiological studies, wild growing plants, essential oil, extract

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## 1. Introduction

World is endowed with wealth of medicinal and aromatic plants. Plants have always been the principal form of traditional medicine in many undeveloped countries, and presently, they are becoming popular throughout the developed world, where people strive to stay healthy because of influence of chronic stress and pollution. One definition says that aromatic plants

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are the local heritage of global importance [1]. In many countries of Balkans, people practiced traditional medicine which is based on the use of plants. The way of use is determined with culture, philosophy and personal attitude. This practice is usually different than conventional medicine. Long period of using traditional medicine has demonstrated that it is safe and effective [2]. Medicinal plants also play an important role in the lives of rural people, particularly in remote parts of developing countries with a few health facilities. It is estimated that around 70,000 plant species have been used at one time or another for medicinal purposes. At the present time, when there is a tendency to respect nature and natural processes more and more, the value of local knowledge on the stability of ecosystem dynamics *in sensu lato* deserves the most attention of scientists [3]. Various pathological conditions of humans that could not be fully treated by conventional pharmaceutical agents are numerous [4]. For this reason, there is a growing tendency in use of herbal preparations. However, scientific researches need to provide additional evidence of their safety and efficacy. Medicinal plants contain active substances which may have active effects on human body and its health. Different diseases could be treated with different plants, which may have 2–3 up to 30–40, sometimes even more, different active substances. Any wrong use can cause various complications, due to the established cytotoxicity for many plant compounds [5]. For all these reasons, medicinal and aromatic plants are in focus of many scientific groups which doing experiments and trying to find new useful compounds.

## 2. Plant diversity of Western Balkans countries

It is estimated that at least 265,000 species of seed plants [6] exist on earth. Only less than a half percent of these have been studied exhaustively for their chemical composition and medicinal value [7]. With about 6340 different vascular plant species reported, the Balkans, compared to 10,500 species accepted in the Flora Europaea, is one of the most important biodiversity centres of Europe [8]. Region of Serbia is rich in medicinal herbs; about 700 species exist on its territory which is 10.7% of total flora with 3662 taxa. Abundance of medicinal herbs placed Serbia in 158 centres of biodiversity in the world [9]. Despite the inconspicuous extension of the territory of Bosnia and Herzegovina (Western Balkan Peninsula; Southeast Europe), the country holds about 3600 species of vascular plants [10]. In Flora Croatica, around 5000 species and subspecies are registered. Among them, 1144 species and subspecies (21% of total flora) are used for different purpose. The greatest number (25%) of these plants is used in traditional as well in official medicine [11]. Croatia is also one of the centres of endemism in south-eastern Europe. No less than 5.65% of the total numbers of known plant species are endemic. Flora of Montenegro consists about 2632 species of vascular plants, as well as of numerous lower infraspecies taxa as varieties and forms [12]. New data suggest 104 taxa more in second supplement to Rohlena's Conspectus [13]. The flora of the Republic of Macedonia is among the richest floras not only in respect to the Balkan Peninsula, but also in the context of the whole European continent. According to recent data, 210 families, 920 genera and 3700 species comprise the flora of higher plants, angiosperms being the richest group with about 3200 species. Endemic taxons represent a special characteristic and value of the Macedonian flora. Among them, 114 flowering plant species are Macedonian endemics [14].

### 3. Ethnobotanical studies

The knowledge of plants, which are used by local people in different geographical areas, is documented in ethnobotanical studies. People in rural areas with traditional knowledge about plants, which are used as a food, spices, flavouring and for medicinal purposes, transmitted that information from one generation to the next. This knowledge is associated to plant identification, conservation and uses. An extensive ethnobotanical work yielded interesting results that confirmed many assumptions and estimates about plant uses [15].

A group of scientists investigated the local traditions of using wild food plants around Lake Vrana (northern Dalmatia, Zadar region) [16]. This research includes studies and interviews of 43 inhabitants of six traditional villages north of Lake Vrana. On average, 12 species were listed, which in total produced an inventory of 55 food plants. The most common medicinal species were *Rosa canina* L., *Salvia officinalis* L., *Achillea millefolium* L., *Helichrysum italicum* (Roth) G. Don and *Mentha* spp.

Ethnobotanical study on medicinal use of wild and cultivated plants in middle, south and west Bosnia and Herzegovina was presented with 228 wild and cultivated species (belonged to 50 families and 124 genera) and 730 different preparations for the use in human therapy. Species of the genus *Achillea* L., *Hypericum* L., *Mentha* L., *Teucrium* L., *Thymus* L. and *Urtica* L. were particularly highly recommended, by almost 90% of the informants that used these species in preparations. Medicinal plants are often used for treatment of different illness such as urogenital tract—16.0%, respiratory system—16.0%, gastrointestinal tract—14.4%, skin ailments—11.5%, blood system—8.8%, nervous system—7.1%, cardiovascular system—6.6%, rheumatism—5.9%; metabolism disorders—3.8%, senses disorders—2.1%, influenzal infections—2.1%, lever and gall disorders—1.9%, parasitic induced ailments—1.6%, inflammations—1.0%, musculoskeletal system—0.8%, endocrinological—0.3% [10].

Usually used plants from the region of Suva Planina Mountain are from families of Lamiaceae—20, Asteraceae—17, Rosaceae—16, Brassicaceae—5, Alliaceae—4 and Apiaceae—4. On this region were identified 128 plants and 2 fungi. Most of them are used in ethnomedicine but some of them in ethnoveterinary medicine. Some plants have 'other' purposes. While the most common conditions treated with medicinal plants are respiratory (79), urogenital (53), gastrointestinal (51), skin (43) and those relating to the circulatory system (35) [17]. On Kopaonik Mountain (the central part of Serbia), 83 wild plant species reported by informants to have medicinal properties have been recorded. The most often used plants belong to six families: Asteraceae—15.8%, Lamiaceae—15.8%, Rosaceae—7.3%, Malvaceae—3.7%, Apiaceae—3.7% and Plantaginaceae—3.7%, within 69 genera and 41 families. In all other families, authors detected the uses of only two or one species (2.4 and 1.2%). Based on investigations, they concluded that tested plants had the highest influence on gastrointestinal ailments—50%, skin injures and problems—25.6%, respiratory—20.5%, urinary-genital—20.5%, cardiovascular problems—19.2%, antiseptic—15.4% and anti-infective effect—14.1% [18]. Botanical remedies in the South-western Serbia (Zlatibor district) comprise 69 species belonging to 36 families. The predominant botanical families were Rosaceae (16%), Lamiaceae (13%) and Asteraceae (12%). From 69 mentioned species, 23 species are included in European Pharmacopoeia 7.0 [19].

Those plants are used for treatment of gastrointestinal—33.1%, respiratory diseases—29.6%, dermatologic diseases—14.8%, urinary tract ailments—6.1%, circulatory system—5.1%, nervous system and psyche—5.1%, nutritional endocrine glands and metabolism—4.3%, skeletal, muscle and connective tissues problems—1.0%, gynecological complications—0.5%, disease of the sensorial system—0.3% [20].

On Prokletije Mountains (Montenegro), the most often used are Rosaceae—11 species which makes 11.7%, Asteraceae—10 species or 10.6% and Lamiaceae—7 species which make 7.4%. Ninety-four species are reported, 35 species in Ph. Eur. 6.0, which makes 37.2%, 12 species in national pharmacopoeias or 12.8%. In most cases, aerial parts were used—43.6%. People usually used those plants for treating gastrointestinal—57.4% and respiratory diseases—41.5% [21].

In one of the most remote and poorest areas of Europe, the village of Theth, which is located in the upper Shala Valley in the Northern Albanian Alps, 79 botanical taxa known and used by the local population. This area is characterised by total absence of medical assistance, but villagers of Theth used a small number of medicinal herbs for minor ailments. They usually used aerial parts of *Origanum vulgare* L., also *Hypericum maculatum* Crantz, as well as aerial part of *Agrimonia eupatoria* L., and they used roots of *Gentiana lutea* L. [22]. Among of ethnobiological study of Pešter plateau (South-western Serbia), where two communities of Serbians and Albanians have been lived together from three centuries ago when they immigrated to the area, 62 taxa in 129 plant-based remedies recorded as well as 204 plant uses. *Chenopodium-bonus hendricus* (L.)Rchb., *Gentiana lutea* L., *O. vulgare* L., *Hypericum* spp., *R. canina* L., *Urtica dioica* L., which are mostly used in the same way and for the same folk medical purposes, may be viewed as the medicinal plants whose cultural salience, measured through the lens of quotations elicited during the free listing exercises, appears remarkable in both communities [23].

A medico-ethnobotanical study was conducted among Albanians, Macedonians and Gorani in 41 villages located in the Sharr Mountains in Western Macedonia. Seventy-six mainly wild taxa (belonging to 34 families) were found to represent the remaining folk medical heritage of the area. The most frequently cited families were Lamiaceae (15.7%), Asteraceae (14.4%), Rosaceae (5.2%), Malvaceae (5.2%) and Fabaceae (5.2%). The large majority of the recorded plants are used in form of teas, and mainly for minor dysfunctions of the respiratory system (46%). According to results of investigations, leaves of *Ballota nigra* L. as a tea is used as a digestive, leaves and fruits of *Cornus sanguine* L. as a tea against stomachaches, topically applied leaves of *Chenopodium urbicum* L. for treating hemorrhoids, aerial parts of *Convolvulus arvensis* L. as a tea against hypertension. This could be interesting for further phytopharmacological investigations. Similar uses were reported by Gorani and Albanians, because those two communities lived together over the century in the same area shared faith, while Orthodox Macedonians reported different uses of these ethnic groups [24].

Comparison with traditional therapy in neighbouring countries showed that there exists considerable similarity with respect to plants used and the way of usage [25, 18, 26]. Results obtained in the area of Suva Planina Mountain comparing with results from other investigated areas of the Western Balkans showed similarities with Zlatibor region—37.2% and Kopaonik Mountain—32.3%. Compare the wider regions showed similarities with Bosnia

and Herzegovina—40.9% and Bulgaria—40.6% [17]. It has also been observed that the inhabitants of mountain regions have longer traditional therapeutic tradition (more than six generations) compared to the rest of the population [10].

An important point in research is paying attention on analysis of endemic and rare species, because they are potential source of new active compounds. However, strict rule and regulations for protection of its localities are necessary because of threat of its extermination. If phytochemical analyses show that those plants represent valuable sources of new compounds, it could be necessary to find adequate way to its cultivations and preservation. The new activities and novel techniques for susceptibility testing provide field for research of well-known medicinal plants as well as unknown plants.

#### 4. Composition and biological activity of essential oils and extracts of wild growing Lamiaceae species

The knowledge of plants which in ethnobotanical studies of Western Balkans countries *O. vulgare* is recognised as a plant with a range of health benefits. This uses are confirmed by scientific research. Essential oil of this, well-known species, was characterised with dominance of carvacrol (64.1%) and linalool (17.6%) and possesses strong antifungal activity against wild-type strains [27]. The cytotoxic, antioxidant and antibacterial activities are attributed mostly to the presence of the isomeric phenolic constituents, carvacrol and thymol [28]. The dominance of 1.8-cineole (44.3%) was found in essential oils of *Rosmarinus officinalis* L. as well as in sample of wild growing *Hyssopus officinalis* L. subsp. *pilifer* (Pant.) Murb (36.4%) (Table 1) [27, 29]. The results showed that antifungal activity offered by 1.8-cineole was incomplete and exhibited moderate activity at the highest concentration tested. Otherwise, this compound was arguably the most effective compounds regarding fumigant activities against storage pest *Cryptolestes ferrugineus* Stephens followed by camphor and carvacrol [30]. Phenolic acids were identified in post-distillation waste extract of *H. officinalis* subsp. *pilifer* which possessed valuable radical scavenging activities (Table 1). The antioxidant activity of phenolic acids is related to the number and position of hydroxyl groups [29]. *Stachys anisochila* Vis. et Panč. is Balkans endemic species, distributed in Bulgaria, Serbia and Albania. Essential oil composition of *S. anisochila* collected from Stara Planina, Serbia, shows  $\alpha$ -pinene (7.6%),  $\alpha$ -copaene (6.2%),  $\beta$ -pinene (5.3%) and  $\beta$ -caryophyllene (4.5%) as the main compounds. Many species of genus *Stachys* L. possess strong antioxidant and antimicrobial activity [31].

Nine species of genus *Satureja* L. have been registered in the area of the Central and Western Balkans. The essential oils isolated from various *Satureja* species have shown antibacterial, fungicidal, antiviral and antioxidant activities. Essential oil of *Satureja horvatii* Šilić (Table 1) shows significant antimicrobial effect, and this oil successfully inhibited the development of *Lysteria monocytogenes* in pork meat and also can be a useful source of natural antioxidants [32]. Oxygenated monoterpene hydrocarbons were the major compounds: carvacrol, thymol, carvacrol methyl ether and  $\beta$ -linalool in essential oil of *S. montana* L. subsp. *pisidica* (Wettst.) Silic from two localities (mountains Korab and Galičica, Macedonia). Both oils showed excellent antimicrobial activity and good cytotoxic potential [33]. Antioxidant activity of essential oils and water wastes after distillation process of *S. montana* L. and *S. cuneifolia* Ten. was demonstrated

Plant	Origin	Essential oil/main compounds	Activity	References
<i>Hyssopus officinalis</i> L. subsp. <i>pilifer</i> (Pant.) Murb	Sicevo gorge (Serbia)	1.8-cineole (36.43%), $\beta$ -pinene (19.55%), isopinocampone (15.32%) pinocampone (6.39%)	Antifungal, antioxidant	[29]
<i>Micromeria dalmatica</i> Benth.	Mt. Lovcen (Montenegro)	piperitenone (41.46%), pulegone (19.02%), piperitenone oxide (14.49%), D-limonene (6.23%) and p-menthone (5.06%)	Antimicrobial	[35]
<i>Satureja montana</i> L.	Mt Biokovo (Croatia)	Carvacrol (63.4%), thymol (19.4%)	Antioxidant	[34]
<i>Satureja montana</i> L. ssp. <i>montana</i>	Budva Cetinje Mt Orijen (Montenegro)	Thymol (24.7%), carvacrol (15.2%), linalool (15.4%). Carvacrol (24.5%), linalool (17.9%), cis-sabinene hydrate (14.61%), terpinen-4-ol (10.6%). Linalool (32.6%), cis-sabinene hydrate (23.0%), terpinen-4-ol (11%), nerolidol (9.4%)	Antimicrobial, antioxidant, anticholinesterase activity	[39]
<i>Satureja horvatii</i> Šilić	Mt Orijen (Montenegro)	p-cymene (33.1%), thymol (26.1%) and thymol methyl ether (15.1%)	Antimicrobial	[32]
<i>Satureja cuneifolia</i> Ten.	Mt Biokovo (Croatia)	Carvacrol (17.7%), spathulenol (13.2%), caryophyllene oxide (9.5%), $\alpha$ -cadinol (7.1%), amorpho-4,9-dien-2-ol (6.7%)	Antioxidant	[34]
<i>Thymus praecox</i> Opiz ssp. <i>polytrichus</i>	Mt Pasjača (Serbia)	trans-nerolidol (24.2%), germacrene-D (16.0%), thymol (9.6%)	Antimicrobial, antioxidant	[38, 40]
<i>Thymus longicaulis</i> C. Presl	Jasenice (Croatia)	Thymol (46.3%), $\gamma$ -terpinene (16.2%), thymyl methyl ether (11.4%) and p-cymene (9.4%)	Antimicrobial	[41]

**Table 1.** Main components and biological activity of essential oils from wild growing plants from Western Balkans—Lamiaceae family.

(Table 1). The extract from waste water after hydrodistillation of these plant species was rich in thymoquinone (38.7%) and (E)-coniferyl alcohol (18.1%), respectively [34]. *Micromeria dalmatica* Benth. is an endemic species of Balkan Peninsula. In essential oil of *M. dalmatica*, the dominant compounds were piperitenone, pulegone and piperitenone oxide (Table 1). This oil possess high antimicrobial efficacy against food spoilage microorganisms, and significant activity of this oil in pork meat against *Salmonella typhimurium* enhances the possibility to use it in food preservation. Also, the essential oil of *S. horvatii* and oregano has been shown to be more or less effective against spoilage microbiota in meat products [35].

Collection of *Sideritis raeseri* Boiss & Heldr. subsp. *raeseri* has a long tradition in local communities in the Ohrid-Prespa region. Recently, identified 17 compounds could be classified into flavonoid glycosides or hydroxycinnamic acid derivatives [36]. They found that hypolaetin

derivatives, known for their anti-inflammatory activity, were more abundant in *S. raeseri* subsp. *raeseri* grown in National Park Galičica (Macedonia) in comparison with *S. scardica* Griseb grown near Galičica.

Since ancient times, plants from the genus *Thymus* L. are known according to their therapeutic benefit. Recently, scientists discovered its new medicinal properties. They reported their chemical composition, biological activities and occurrence of *Thymus* species from Balkans [37]. Essential oil of wild growing *T. praecox* Opiz showed high radical scavenging and antimicrobial activities (Table 1). The major component, which is identified in supercritical extracts, was thymol, with the strongest antimicrobial activity. Hexane/ethanol extract possessed strongest antibacterial potential, while supercritical extracts were more efficient antifungal agents. In 1,1-diphenyl-2-picrylhydrazyl (DPPH), radical scavenging assay hexane/ethanol extract of *T. praecox* showed the best antioxidant activity, which is connected with the high level of phenolics antioxidants [38].

## 5. Composition and biological activity of essential oils and extracts of wild growing Apiaceae species

Many plants from “spices” family, Apiaceae, are phytochemically characterised, and they are used in official medicine, but for much of them data are still missing or scant. *Eryngium palmatum* Vis. et Pancic is an endemic perennial herb, distributed in the central part of the Balkan Peninsula (Serbia, Bulgaria, Macedonia and Albania). Essential oil of *E. palmatum*, collected from Ozren Mountain (Serbia), was characterised by high presence of sesquiceneol (21.3%), caryophyllene oxide (16.0%), spathulenol (16.0%) and sabinene (5.5%). Related species, *Eryngium serbicum* Pancic, endemic in Serbia, in essential oil of aerial parts contains germacrene D (19.7%),  $\beta$ -elemene (10.0%) and spathulenol (6.9%). The main compounds in both studied species consisted of sesquiterpenes [42]. In general, sesquiterpenes possess promising anti-inflammatory, antiparasitic and anticarcinogenic activities, but some of them can cause serious toxicity. The essential oils of different *Seseli* L. species show antimicrobial and antifungal activity, while extracts exhibit anti-inflammatory and antinociceptive properties. Essential oil from aerial parts in the flowering stage and rosette in the vegetative stage of *Seseli annum* L. collected on mountain Rtanj (Serbia), as dominant compounds contain sesquiterpenes  $\beta$ -selinene, germacrene D, caryophyllene oxide, germacrene A (0–21.4, 3.4–19.1, 1.2–18.1, 0–14.6%, respectively) and in lowest percentage  $\alpha$ -selinene,  $\beta$ -elemene, E-caryophyllene,  $\alpha$ -pinene, vetiselinol, isodaucene (0–12.4, 0–11.4, 3.2–10.3, 0.6–7.5, 0–6.3, 0–5.4%, respectively) [43]. Also, different extracts from three *Seseli* taxa (*Seseli pallasii* Besser, *S. libanotis* (L.) Koch ssp. *libanotis* and *S. libanotis* (L.) Koch ssp. *intermedium* (Rupr.) P. W. Ball, growing wild in Serbia) possessed antioxidant and antimicrobial activity [44]. Correlation from the total phenolic and flavonoid content and in vitro antioxidant and antimicrobial activity of methanol and water extracts was presented from *Tordylium maximum* L. (Ozren Mountain, Serbia) [45]. Essential oil isolated from the aerial parts and fruits of *Cachrys cristata* DC., a rare and critically endangered species in the flora of Serbia (Table 2), were rich in sesquiterpenes (45.7%) and oxygenated sesquiterpenes (32.9%), while fruit oil consisted of a higher percentage of sesquiterpenes (48.3%) and oxygenated sesquiterpenes (36.7%) [46]. In fruit and aerial part was



found germacrene D which is known for its effect on insects and present a potential source of antibacterial and antifungal agents. It cannot be said that only germacrene D is responsible for high activity because essential oils present mixture of different components which have synergetic effect. Various extracts of traditionally used medicinal plants prepared with different extraction method and solvent of different polarity possessed valuable antimicrobial and antioxidant activity. Good activity is related to high concentration of total phenolic and total

Plant	Origin	Essential oil/Main compounds	Activity	References
<i>Cachrys cristata</i> DC.	Mt Rujan (Serbia)	Aerial parts: phytol (13.1%), germacrene D (12.9%), $\beta$ -caryophyllene (9.7%), $\beta$ -bourbonene (8.5%) Fruit: suberosin (19.7%), germacrene D (12.3%), germacrene B (10.0%)	Antimicrobial, antioxidant	[46, 50]
<i>Echinophora sibthorpiana</i> Guss.	Stip (Macedonia)	Aerial parts: methyl eugenol (60.4%), p-cymene (11.2%), $\alpha$ -phellandrene (10.2%), $\alpha$ -Phellandrene epoxide (6.9%)	Antimicrobial, antioxidant	[51]
<i>Ferulago macedonica</i> Micevski & E. Mayer	Negotino city (Macedonia)	Inflorescence: $\alpha$ -pinene (43.1%), sabinene (26.7%), limonene (6.5%) Aerial part: $\alpha$ -pinene (22.8%), sabinene (15.5%), terpinen-4-ol (9.6%), cis-chrysanthenyl acetate (9.5%) and p-cymene (9.1%)	Antimicrobial, antioxidant	[52]
<i>Heracleum orphanidis</i> Boiss.	Mt Pelister (Macedonia)	n-octanol (39.6%), octylhexanoate (17.6%), n-octyl acetate (14.1%)	Antimicrobial, antioxidant, antiquorum sensing	[47]
<i>Heracleum sphondylium</i> L.	Mt Kopaonik (Serbia)	ar-curcumene (13.4%), $\beta$ -sesquiphellandrene (11.9%), caryophyllene oxide (9.2%)	Antimicrobial, antioxidant	[48]
<i>Laserpitium latifolium</i> L.	Mt Staroplanina (Serbia)	Sabinene (47.8%), $\alpha$ -pinene (24.9%), $\beta$ -pinene (7.1%), terpinen-4-ol (5.4%)	Antimicrobial, antioxidant	[53]

**Table 2.** Main components and biological activity of essential oils from wild growing plants from Western Balkans—Apiaceae family.

flavonoid content. Recently, in the study of four *Peucedanum* L. species (*P. officinale* L., *P. longifolium* W. et K., *P. aegopodioides* (Boiss.) Vandas and *P. alsaticum* L. from Serbia), their various extracts were found significant correlation coefficient between radical scavenging DPPH and 2,2-azino-bis(3-ethylbenz-thiazoline-6-sulfonic acid) (ABTS) radical scavenging activities with the total phenolic content/total flavonoids content. Therefore, total phenolic components can be used as an indicator in assessing the antioxidant activity of fruits and vegetables, including *Peucedanum* species [47]. Many *Heracleum* L. species are edible, and medicinal plants *Heracleum sphondylium* L. are used as food or food additive in many countries. Essential oil and extracts of these plants were presented in **Table 2**. Aerial parts of *H. sphondylium* showed antioxidant and antimicrobial effects [48]. Essential oil of *Heracleum orphanidis* Boiss consisted mainly of fatty acid derivate (80.8%) was effective antimicrobial agent (**Table 2**). The methanol extracts from aerial parts and roots of *H. orphanidis* were characterised by furanocoumarins, but stronger antioxidant potential was detected by extracts from aerial parts. *H. orphanidis* showed considerable biological potential considering free radical and various pathogenic strains, including wild type of *Pseudomonas aeruginosa*. One of a new strategy for the treatment of bacterial infections is inhibition of bacterial quorum sensing activity. The higher plants represent native source rich in anti-quorum compounds as novel virulence inhibitors [49].

## 6. Composition and biological activity of essential oils and extracts of wild growing Asteraceae species

Considering chemical composition of *Artemisia absinthium* L. essential oil, different chemotypes have been established in Croatia  $\beta$ -thujone/(Z)-epoxy ocimene chemotype, while in samples of *A. absinthium* from Serbia, pure  $\beta$ -thujone chemotype and  $\beta$ -thujone/cis-epoxy ocimene chemotype and sabinene/ $\alpha$ -phellandrene/sabinyl acetate chemotype were found. In previous study were analysed chemical composition and biological activity of the essential oil of *A. absinthium* (**Table 3**) [54]. This oil showed high antimicrobial and significant antioxidant activity. Undiluted *A. absinthium* essential oil shown negative skin irritant reaction on all 30 tested volunteers. Essential oil in oral application did not cause mortality in the treated mice. Negative effects were neurological, muscle and gastrointestinal problems. In examinations with *Drosophila melanogaster*, the result showed that the essential oil was toxic for insect larvae in development.

The chemical analysis of essential oils of *Tanacetum parthenium* (L.) Sch. Bip., *Achillea grandifolia* Friv. and *Achillea crithmifolia* Waldst. & Kit. (collected on the territory of Southeast Serbia) was contained the monoterpenes. The major class of components showed camphor in *T. parthenium*, *A. grandifolia* and *A. crithmifolia* and 1,8—cineole in *A. grandifolia* and *A. crithmifolia* (**Table 3**). The antiradical and antioxidant activities were determined using ABTS and DPPH radical scavenging methods. The essential oil of *A. grandifolia* showed the highest antioxidant activity. The antimicrobial activity was tested against 16 multi-resistant pathogenic bacteria isolated from human source material. The essential oils of plant species used in the present study can be considered as potential source of antimicrobial substances and may contribute to solution of bacterial multiresistance [53].

Pant	Origin	Essential oil/Main compounds	Activity	References
<i>Artemisia absinthium</i> L.	Near the city of Niš (Srbia)	Sabinene (24.5%), sabinyl acetate (13.6%), $\alpha$ -phellandrene (10.3%)	Antimicrobial, antioxidant, insect repellent	[54]
<i>Tanacetum parthenium</i> (L.) Sch.Bip.	Mt Staroplanina (Serbia)	Camphor (51.4%), camphene (7.3%)	Antimicrobial, antioxidant	[53]
<i>Achillea grandifolia</i> Friv.	Jerma Gorge (Serbia)	Camphor (45.4%), 1,8-cineole (16.4%), $\alpha$ -thujone (15.1%), borneol (8.1%)	Antimicrobial, antioxidant	[53]
<i>Achillea crithmifolia</i> Waldst. & Kit.	Mt Staroplanina (Serbia)	Artemisia ketone (31.7%), camphor (25.4%), 1,8-cineole (14.8%)	Antimicrobial, antioxidant	[53]
<i>Helichrysum italicum</i> (Roth) G. Don	Bar (Montenegro)	$\gamma$ -curcumene (22.5%), $\alpha$ -pinene (15.9%) and neryl acetate (7.8%), $\beta$ -selinene (6.9%)	Antifungal	[55]

**Table 3.** Main components and biological activity of essential oils from wild growing plants from Western Balkans—Asteraceae family.

## 7. Composition and biological activity of essential oils and extracts of wild growing Rosaceae species

Investigation was carried out on air-dried flowers, leaves, stem-bark and wood of *Prunus mahaleb* L. (wild growing trees near Sinj, south Croatia). The main component that was isolated from bark volatiles is coumarin with 34.1%, while in the wood is hexadecanoic acid with 46.0%. In the wood, eicosane was also detected with 12.9%. Hexadecanoic acid was isolated in the leaves and bark (17.8 and 9.3%, respectively). As the main compound in the flowers are isolated n-alkanes, heneicosane with 22.1% and octacosane with 13.0%. Phytol was isolated in the leaves with 5.1%. In addition to the main components, three fatty acids—dodecanoic, tetradecanoic and linoleic acids—were presented in all samples [56].

*Geum rhodopeum* Stoj. & Stef. is representative of the East Moesian endemic taxa of the Balkans floristic subregion. Aerial parts of *G. rhodopeum* were collected at Prestojceva mahala (Cemernik Mountain, Serbia). The major component of aerial parts from this essential oil was  $\alpha$ -bisabolol with 12.7% constituting of the oil. It is documented that  $\alpha$ -bisabolol may be a useful therapeutic candidate for the treatment of skin inflammation. Significant compounds were also myrtenal (9.5%), 1-isopropyl-4,8-dimethylspiro[4.5]dec-8-en-7-one (7.7%), palmitic acid (6.4%), myrtanal (5.8%) and 1-octen-3-ol (5.3%) [57]. The major component of aerial part from *G. coccineum* Sibth. et Sm. essential oil (collected from natural populations of Jablanica Mountain, Macedonia) was phytol constituting 24.3% of the oil [58]. According to the literature data, dewberry (*Rubus caesius* var. *aquaticus* Weihe. & Nees.) leaves have been used in

traditional medicine due to their anti-inflammatory, antiviral and antimicrobial, antiproliferative activity against cancer cells and antitumor and wound-healing properties. Leaf methanol, ethanol, acetone and water extracts from dewberry collected near city of Zaječar (Serbia) were examined for its antioxidant activity using DPPH, ABTS, ferric reducing power (FRAP) assay, total reducing power (TRP) methods. Acetone extract was with the highest antioxidant activity against DPPH and ABTS•+ radicals as well as for total reducing capacity. Obtained results showed that phenolic compounds are major contributors to the antioxidant properties of *R. caesius* var. *aquaticus*) leaves [59].

## 8. Conclusion

According to numerous references, many aromatic plants from Western Balkans represented valuable sources of potential new bioactive compounds. Considerable efforts were made for investigation of essential oils and extracts and discovering new, natural antimicrobials, antioxidants or cytotoxic agents. The results encourage the application of the plants for further evaluations of other possible bioactivities and detection of active pure compounds as constituents of the essential oils and extracts. Studies to date have identified a number of plant compounds and explained its mechanism of action in organisms. All presented data additionally validate the use of well-known aromatic plants in new treatments, as well as endemic or rare plants which could be only scientifically investigated. High protection of their natural localities is necessary, and new potential active compounds from those plants could be used only with their possible cultivation. The beneficial effect of the aromatic plants from Western Balkans that are recognised in traditional knowledge could be useful for conventional medicine or other aspects for improving life quality.

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