



Review Article

Chemical composition of the essential oils isolated from members of the Asteraceae

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Abstract

Essential oils extracted from the Asteraceae family, one of the largest families of angiosperms, have shown numerous biological properties and are widely used in the pharmaceutical, perfumery, agricultural, and food industries. The biological properties of these natural agents are directly related to their chemical composition. Therefore, the present review aims to investigate the chemical components of essential oils from the Asteraceae family and introduce their major compounds. The Asteraceae family, essential oils, chemical components, and major compounds were used as keywords in the searches. Terpene and phenylpropanoid compounds were identified as the dominant compounds in most of the essential oils. For instance, the major components of *Artemisia annua* L. essential oil are artemisia ketone, 1,8-cineole, and camphor. (*Z*)- β -ocimene was identified in all specimens of *Tagetes minuta* L. essential oils. Agglomerative hierarchical cluster analysis (HCA) was used for the essential oils that had been studied extensively. For example, in the *Artemisia absinthium* L. essential oil, three different chemotypes, sabinyl acetate, β -thujone-rich cluster, and 6,7-epoxyocimene, were identified. In some cases, diverse chemotypes from different locations have been introduced. For example, the chemotypes of *Achillea millefolium* L. are not restricted to geographical locations and the largest cluster (the β -pinene cluster) has representatives from India, Iran, Brazil, Sardinia, Lithuania, Cuba, and Portugal. Likewise, essential oils from Iran represent all five different chemotypes. The results of this review can be used to make decisions about the use of Asteraceae essential oils.

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1. Introduction

The Asteraceae family is known as the largest family of flowering plants, comprises approximately 23,000 species across 1,500 genera. Most members of this family are herbaceous or shrubby and can be annual, biennial, or perennial. Their stems may be erect, ascending, or prostrate, and their root systems exhibit significant variability, including taproots, fibrous roots, rhizomes, or stolons. Leaf morphology also

varies widely, with some species having only basal or cauline leaves, while others possess both types. Leaf forms can range from simple and unlobed to lobed or compound. The inflorescence, known as a capitulum, contains a few to many florets surrounded by bracts called phyllaries, which form the involucre. The flower heads may feature ray florets that are zygomorphic, often with erose or lobed tips, in

addition to disc florets that are actinomorphic, short-tubular, and typically four- or five-lobed. The fruits produced by the Asteraceae family are called cypselae; these are dry, single-seeded fruits that develop from bicarpellate inferior ovaries [1, 2].

The aromatic properties of several Asteraceae species are primarily due to the volatile constituents of their essential oils. In general, essential oils play a critical role in protecting plants against herbivores, particularly insects, mites, and nematodes, although other effects, such as the attraction of pollinators or phytotoxic activity against damaging weeds, have also been documented [3]. The diverse biological effects of many Asteraceae essential oils have been demonstrated in previous studies. These essential oils are an important source of insecticidal agents, and their high potential for controlling many insect pests from various groups, including crop, greenhouse, stored-product, and orchard pests, and medically important ones, has been well documented [4–10]. In addition, the acaricidal, nematocidal, antifungal, antibacterial, antiprotozoal, antiviral, antioxidant, cytotoxic, and phytotoxic effects of these natural agents have been documented, which are related to the chemical profiles of essential oils [11–25].

The chemical composition of essential oils isolated from the Asteraceae family, which mainly comprises terpenes, phenylpropanes, and other low molecular weight aromatic and aliphatic constituents, has been extensively studied in numerous species worldwide. It has also been reported that the chemical profile of Asteraceae essential oils can vary in response to various endogenous and exogenous factors, including geographical location, harvesting season, plant ontogeny (growth stage), chemotype or subspecies, the specific plant part used, and even the extraction method [26–32].

Accordingly, this review comprehensively focuses on the significant findings regarding the chemical profiles of essential oils from the Asteraceae family. Agglomerative hierarchical cluster analysis (HCA) was conducted using XLSTAT v. 2018.1.1.62926 (Addinsoft, Paris, France). The analysis employed the percentages of the main components of each essential oil, with clustering determined by Euclidean distance and agglomeration defined by Ward's method.

Essential oils are generally obtained by three different methods: (1) cold pressing (now used almost exclusively for the production of *Citrus* peel essential oils), (2) steam distillation or hydrodistillation (the most frequently used method for obtaining essential oils), and (3) dry distillation, which is rarely used. Volatile components of plants have also been obtained by non-polar solvent extraction (e.g., hexane), or by supercritical CO₂ extraction, however, the oils obtained are not considered "essential oils". In this review, unless otherwise indicated, essential oils were obtained by steam distillation or hydrodistillation.

2. Materials and methods

The complete list of Asteraceae genera was obtained from World Flora Online [33]. Each genus, coupled with the search terms "Asteraceae", "essential oil", or "chemical composition" was searched using the databases GoogleScholar, Scopus, and Web of Science. The search was conducted until April, 2025. Reports based on solvent extracts or those with unreliable gas chromatographic analyses were excluded.

3. Results and discussion

3.1. Chemical composition of essential oils

3.1.1. *Acanthospermum* Schrank

The genus is primarily Neotropical comprised of six species: *Acanthospermum australe* (Loefl.) Kuntze, *Acanthospermum consobrinum* S.F. Blake, *Acanthospermum glabratum* (DC.) Wild, *Acanthospermum hispidum* DC., *Acanthospermum humile* DC., and *Acanthospermum microcarpum* B.L. Rob. Of these, *A. hispidum* has been naturalized in many areas of the world [33].

Acanthospermum hispidum DC. This plant is native to Central and South America, but has been naturalized in Eurasia, Africa, and North America [34, 35]. The essential oil compositions of *A. hispidum* have been reported from Argentina, Congo, Ivory Coast, and Nigeria (Table 1) and are largely dominated by sesquiterpenoids, especially (*E*)- β -caryophyllene.

3.1.2. *Achillea* L.

The essential oil composition of *Achillea* species was reviewed in 2005 [41] and 2016 (from Türkiye) [42]. The following summary complements these previous reviews.

Table 1. Chemical compositions of *Acanthospermum hispidum* essential oils.

Geographical location	Plant tissue	Major components (> 5%)	Ref.
Argentina	Aerial parts	(<i>E</i>)- β -Caryophyllene (35.2%), α -bisabolol (11.4%), germacrene D (11.1%), <i>trans</i> - β -elemene (10.0%), α -humulene (9.7%), bicyclogermacrene (9.7%)	[36]
Congo	Leaves	(<i>E</i>)- β -Caryophyllene (34.0-42.7%), α -humulene (1.4-12.7%), germacrene D (6.4-10.1%), bicyclogermacrene (5.3-10.6%), α -bisabolol (3.7-11.2%)	[37]
Ivory Coast	Aerial parts	(<i>E</i>)- β -Caryophyllene (33.3-34.9%), germacrene D (7.3-8.4%), bicyclogermacrene (6.3-9.5%), α -bisabolol (6.5-9.9%), α -humulene (6.5-7.0%), α -pinene (4.6-7.9%)	[38]
Nigeria	Aerial parts	(<i>E</i>)- β -Caryophyllene (28.0%), α -pinene (15.9%), bicyclogermacrene (11.0%), α -bisabolol (8.9%), germacrene D (6.9%), α -humulene (6.0%),	[39]
Nigeria	Leaves	(<i>E</i>)- β -Caryophyllene (21.8%), α -bisabolol (20.7%), bicyclogermacrene (7.9%), caryophyllene oxide (6.6%), germacrene D (6.1%), α -humulene (5.9%)	[40]

Table 2. Chemical compositions of *Achillea filipendulina* essential oils.

Geographical location	Plant tissue	Major components (> 5%)	Ref.
Iran	Aerial parts	Santolina alcohol (31.4%) ^a , carvacrol (14.9%), borneol (11.6%), 1,8-cineole (8.1%), bornyl acetate (5.1%)	[43]
Iran	Aerial parts	Santolina alcohol (17.9%), 1,8-cineole (7.5%), borneol (5.5%)	[44]
Iran	Aerial parts	Santolina alcohol (37.2%), borneol (12.7%), 1,8-cineole (8.6%), germacrene D (6.2%)	[45]
Iran	Flowers	Ascaridole (30.2%), <i>trans</i> -isoascaridole (25.0%), 1,8-cineole (12.4%), <i>p</i> -cymene (9.5%), camphor (6.7%)	[46]
Iran	Flowers	Chrysanthenyl acetate (19.1%), 1,8-cineole (17.2%), borneol (9.7%), α -pinene (9.6%), β -pinene (7.1%)	[47]
Iran	Flowers	α -Terpineol (14.6%), chrysanthenyl acetate (13.7%), γ -terpinen (11.2%), bornyl acetate (10.0%), α -pinene (7.7%), α -campholenal (7.6%),	[48]
Iran	Leaves	1,8-Cineole (32.7%), camphor (17.7%), ascaridole (7.1%), <i>trans</i> -isoascaridole (6.6%)	[46]
Iran	Leaves	Chrysanthenyl acetate (16.3%), 1,8-cineole (12.0%), α -pinene (8.8%), borneol (7.7%), bornyl acetate (7.2%), β -pinene (5.7%), <i>cis</i> -verbenol (5.7%),	[47]
Iran	Leaves	1,8-Cineole (29.9%), chrysanthenyl acetate (16.7%), bornyl acetate (14.0%), α -pinene (8.4%), terpinen-4-ol (5.7%), camphene (5.4%)	[48]
Kazakhstan	Aerial parts	Santolina alcohol (29.0%), borneol (27.8%), 1,8-cineole (19.1%), bornyl acetate (8.1%)	[49]
Tajikistan	Aerial parts	Santolina alcohol (46.3%, 43.6%), 1,8-cineole (8.8%, 11.4%), <i>cis</i> -chrysanthenyl acetate (6.5%, 9.3%), borneol (5.3%, 6.0%), <i>iso</i> -borneol (4.8%, 5.4%),	[50]
Türkiye	Aerial parts	Santolina alcohol (43.8%), 1,8-cineole (14.5%), <i>cis</i> -chrysanthenyl acetate (12.5%)	[51]

^a Identified as 2,7-dimethyl-4(*E*),6-octadien-2-ol

Achillea filipendulina Lam. Several studies have been reported on the essential oil composition of *A. filipendulina* (Table 2). Santolina alcohol, 1,8-cineole, and borneol generally dominate the aerial part essential oils, while the floral and leaf essential oils have shown some variation.

Achillea millefolium L. The essential oil compositions of *A. millefolium* have been extensively investigated from

numerous geographical locations, including Brazil [52], Cuba [53], Egypt [54], Estonia [55], England [56], France [57], Greece [58, 59], India [60–62], Iran [63–71], Kaliningrad [72], Italy [73], Kashmir [74], Kazakhstan [75], Kosova [76], Lithuania [77], Macedonia [78], Poland [4, 79], Portugal [80, 81], Sardinia [80], Serbia [82, 83], and Türkiye [84].

A hierarchical cluster analysis (HCA, Fig. 1) indicates

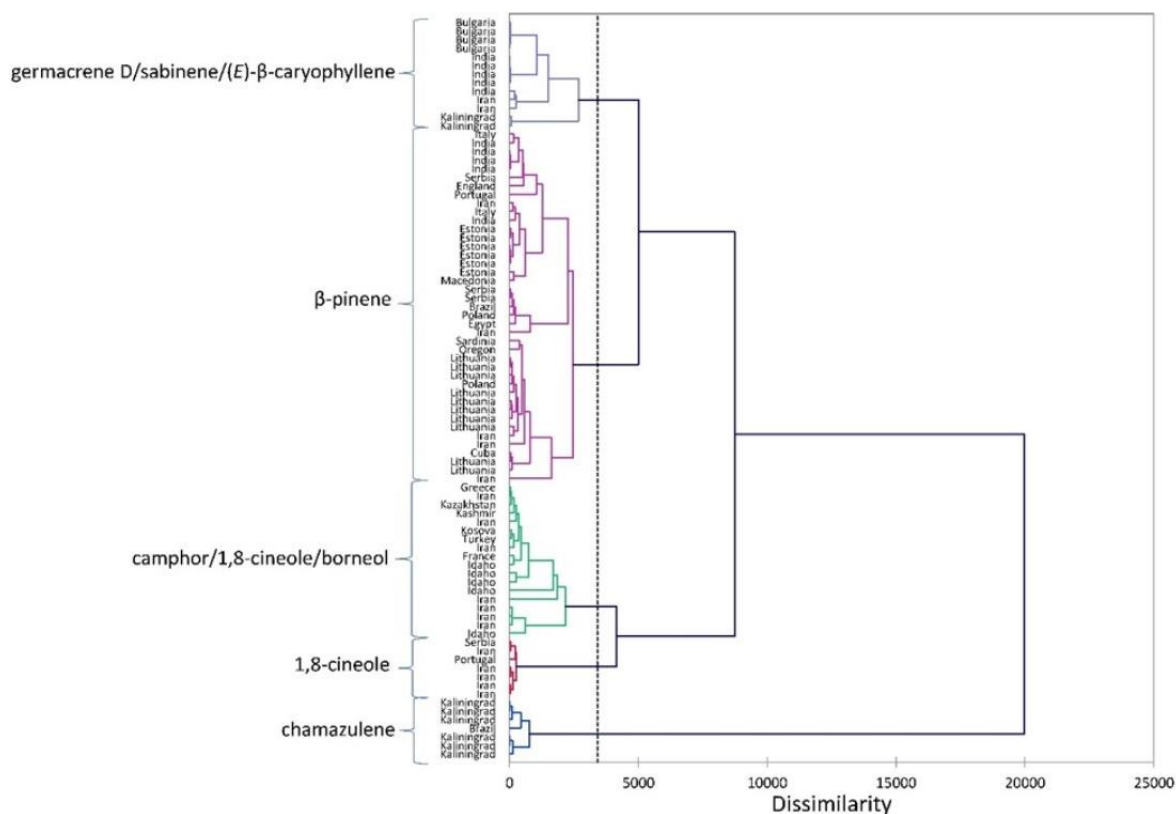


Figure 1. Dendrogram obtained by hierarchical cluster analysis (HCA) based on the essential oil compositions of *Achillea millefolium*.

at least five different chemotypes of *A. millefolium* based on the essential oil compositions. Interestingly, chemotypes are not restricted to geographical locations. For example, the largest cluster (the β -pinene cluster) has representatives from India, Iran, Brazil, Sardinia, Lithuania, Cuba, and Portugal. Likewise, essential oils from Iran represent all five different chemotypes. Some additional miscellaneous *Achillea* essential oils are summarized in Table 3.

3.1.3. *Acmella* Rich. ex Pers.

There are 30 species of *Acmella* currently recognized by the World Flora Online [33], but *Acmella oleracea* (L.) R.K. Jansen is the most important. The plant is believed to have derived from central Peru, but is known only from cultivation [89] and is now cultivated worldwide, including in Bolivia, Brazil, the Caribbean, China, Ecuador, India, Madagascar, Nepal, Peru, and Tanzania [90]. The essential oil compositions of *A. oleracea* are summarized in Table 4. The essential oils are generally characterized by sesquiterpenoids: (*E*)- β -caryophyllene, caryophyllene oxide, and germacrene D, monoterpenes: β -pinene,

myrcene, and β -phellandrene, as well as the fatty acid derivatives: spilanthol and acmellonate.

The major components in the essential oil from the aerial parts of *Acmella radicans* (Jacq.) R.K. Jansen collected in Kerala, India, were 2-tridecanone (30.1%), 1-pentadecene (25.2%) and (*E*)- β -caryophyllene (12.8%) [97]. The essential oil from Baoshan, Yunnan Province, China, on the other hand, showed 2-tridecanone (30.5%), caryophyllene oxide (19.2%), (*E*)- β -caryophyllene (7.7%), and a sesquiterpenoid identified as 4,8,11,11-tetramethylbicyclo [7.2.0]undec-3-en-5-ol (7.8%) (note: this structure is not found in the Dictionary of Natural Products [98], so the identification is doubtful) [99].

3.1.4. *Ageratum* L.

There are around 52 species of *Ageratum* in the Asteraceae, all of which are native to the Neotropics [33, 100]. Three species have been extensively studied in terms of their essential oils.

Ageratum conyzoides L. Although native to South America, this plant has been introduced throughout the tropics and is a noxious invasive weed in many

Table 3. Chemical compositions of essential oils of miscellaneous *Achillea* species.

Achillea species	Geographical location	Plant tissue	Major components (> 5%)	Ref.
<i>Achillea arabica</i> Kotschy.	Türkiye	Leaves	Piperitone (31.1%), camphor (12.5%), 1,8-cineole (10.9%)	[85]
<i>Achillea arabica</i> Kotschy.	Iran	Aerial parts	<i>p</i> -Cymene (14.6%), piperitone (13.1%), camphor (12.8%), 1,8-cineole (12.0%), germacrene D (9.7%), borneol (6.5%), linalool (6.1%), α -terpinene (5.4%)	[45]
<i>Achillea cartilaginea</i> Ledeb. ex Rchb.	Kazakhstan	Aerial parts	α -Thujone (26.2%), β -thujone (11.8%), 1,8-cineole (8.8%), terpinen-4-ol (7.8%), camphor (6.8%)	[49]
<i>Achillea eriophora</i> DC.	Iran	Leaves	Camphor (34.0%), 1,8-cineole (29.3%), camphene (5.9%)	[65]
<i>Achillea eriophora</i> DC.	Iran	Aerial parts	Camphor (19.6%), 1,8-cineole (19.1%), camphene (9.6%), α -pinene (7.4%), borneol (6.7%), bornyl acetate (5.4%)	[45]
<i>Achillea fragrantissima</i> Sch. Bip.	Yemen	Leaves	Artemisia ketone (49.5%), camphor (14.8%), α -bisabolol (11.2%)	[86]
<i>Achillea fragrantissima</i> Sch. Bip.	Saudi Arabia	Aerial parts	α -Thujone (34.5%), santolina alcohol (25.6%), β -thujone (11.9%), artemisia ketone (9.9%), β -sesquiphellandrene (5.5%)	[87]
<i>Achillea grandiflora</i> M. Bieb.	Kazakhstan	Aerial parts	β -Pinene (8.9%), selin-11-en-4 α -ol (8.5%), γ -eudesmol (6.3%), 1,8-cineole (5.9%),	[75]
<i>Achillea ledebourii</i> Heimerl	Kazakhstan	Aerial parts	Germacrene D (20.5%), spathulenol (10.9%), (<i>E</i>)- β -caryophyllene (6.5%), caryophyllene oxide (6.2%), unidentified (21.4%), unidentified (5.5%)	[49]
<i>Achillea lingulata</i> Waldst. & Kit.	Bosnia and Herzegovina	Aerial parts	Borneol (30.1%), <i>trans</i> -verbenol (15.5%), 2-tridecanone (12.2%), fragranol (8.3%), myrtenol (7.9%)	[88]
<i>Achillea magnifica</i> Heimerl ex Hub.-Mor.	Türkiye	Aerial parts	Linalool (27.5%), spathulenol (5.8%), terpinen-4-ol (5.5%)	[51]
<i>Achillea nobilis</i> L.	Iran	Leaves	α -Thujone (54.0%), 1,8-cineole (12.8%), cadin-4-en-7-ol (6.7%), β -thujone (5.9%)	[65]
<i>Achillea nobilis</i> L.	Iran	Flowers	α -Thujone (58.7%), 1,8-cineole (9.2%), β -thujone (6.0%)	[65]
<i>Achillea nobilis</i> L.	Kazakhstan	Aerial parts	Camphor (17.0%), 1,8-cineole (15.6%), terpinen-4-ol (10.0%), borneol (7.2%), α -eudesmol (7.1%)	[75]
<i>Achillea sudetica</i> Opiz	Kazakhstan	Aerial parts	Linalool (11.8%), bornyl acetate (8.9%), γ -eudesmol (6.9%), 1,8-cineole (5.9%), borneol (5.9%), unidentified (5.9%)	[49]
<i>Achillea tenuifolia</i> Lam.	Türkiye	Aerial parts	Artemisia ketone (12.4%), camphor (7.1%), terpinen-4-ol (5.9%)	[51]

locations. Nevertheless, it is an important ethnomedicine in many locations. There have been numerous reports on the chemical compositions and biological activities from several geographical locations, including Benin [101], Brazil [102–105], Cameroon [106–108], Congo [109], Fiji [110], Ghana [111], India [112, 113], Ivory Coast [114, 115], Nepal [116], Nigeria [117–119], Pakistan [120], Reunion [121], São Tomé e Príncipe [122], Thailand [123], and Vietnam [124, 125]. The essential oils of *A. conyzoides* are generally dominated by precocene I (6-demethoxyageratochromene), precocene II (ageratochromene), and (*E*)- β -caryophyllene.

Hierarchical cluster analysis (HCA) revealed three well-defined clusters, a precocene I/(*E*)- β -caryophyllene cluster, a precocene I cluster, and a precocene II/precocene I cluster (Fig. 2).

Ageratum fastigiatum (Gardner) R.M. King & H. Rob. Essential oils from *A. fastigiatum* were obtained from leaves, stems and inflorescences, of plants obtained in Minas Gerais, Brazil, in which essential oils were largely dominated by sesquiterpenoids (Table 5).

Ageratum houstonianum Mill. The essential oils of *A. houstonianum* are dominated by precocene I (6-demethoxyageratochromene), precocene II (ageratochromene), and (*E*)- β -caryophyllene.

Table 4. Chemical compositions of *Acmella oleracea* essential oils.

Geographical location	Plant tissue	Major components (> 5%)	Ref.
Castelfidardo, Italy	Flowers	(<i>E</i>)- β -Caryophyllene (20.8%), β -pinene (17.3%), myrcene (17.1%), caryophyllene oxide (10.0%), germacrene D (5.2%), β -phellandrene (5.1%)	[91]
Umuarama, Paraná, Brazil	Leaves	Germacrene D (20.2%), (<i>E</i>)- β -caryophyllene (7.8%), caryophyllene oxide (6.4%), <i>cis</i> - β -santalol (5.8%), manoyl oxide (5.7%), <i>epi</i> -globulol (5.6%)	[92]
Campos dos Goytacazes, Brazil	Aerial parts	Spilanthol (14.4-29.5%), phytol (15.3-27.1%), acmellonate (12.2-15.9%), 1-pentadecene (2.8-12.2%), (<i>E</i>)- β -caryophyllene (0.7-6.8%)	[93]
Belém, Pará, Brazil	Flowers	(<i>E</i>)- β -Caryophyllene (27.1%), myrcene (25.0%), germacrene D (10.3%), β -pinene (10.0%)	[94]
Belém, Pará, Brazil	Flowers	(<i>E</i>)- β -Caryophyllene (25.7%), germacrene D (14.8%), 1-pentadecene (11.4%), spilanthol (5.2%)	[95]
Belém, Pará, Brazil	Leaves	Caryophyllene oxide (28.1%), (<i>E</i>)- β -caryophyllene (27.3%), germacrene D (17.9%)	[94]
Castelfidardo, Italy	Aerial parts	(<i>E</i>)- β -Caryophyllene (19.4%), myrcene (17.4%), β -pinene (14.7%), germacrene D (11.8%), caryophyllene oxide (10.0%), β -phellandrene (6.5%), (<i>Z</i>)- β -ocimene (6.0%)	[96]

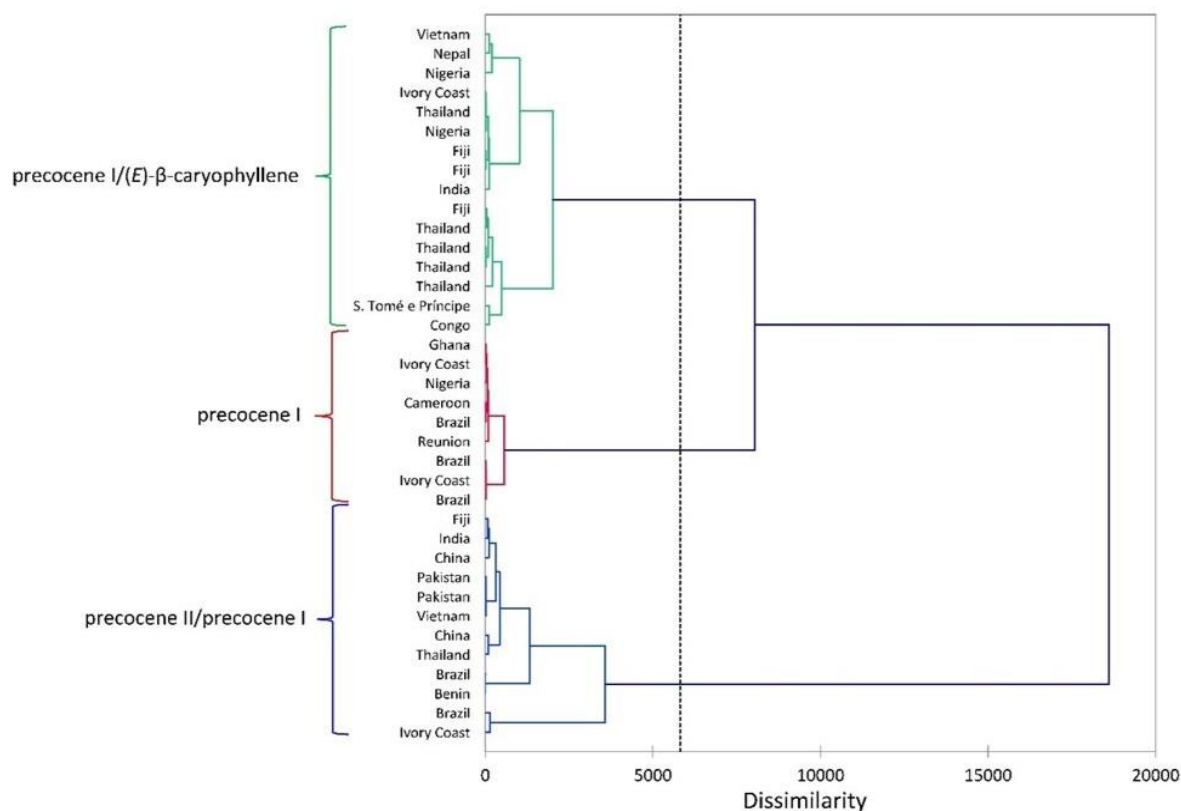


Figure 2. Dendrogram obtained by hierarchical cluster analysis (HCA) based on the essential oil compositions of *Ageratum conyzoides*.

mene), and (*E*)- β -caryophyllene (Table 6).

3.1.5. *Ainsliaea* DC.

Essential oil compositions of *Ainsliaea aptera* DC. [136], *Ainsliaea fragrans* Champ. ex Benth. [137], and *Ainsliaea pertyoides* Franch. [138] have been reported.

Essential oils from the aerial parts of *A. aptera* from two different sites in Uttarakhand state, India, showed the sesquiterpenoids germacrene D (14.6%, 3.2%), bicyclogermacrene (10.2%, 3.3%), δ -cadinene (4.2%, 6.9%), spathulenol (11.6%, 3.0%), τ -muurolol (7.6%,

Table 5. Chemical compositions of *Ageratum fastigiatum* essential oils.

Geographical location	Plant tissue	Major components (> 5%)	Ref.
Diamantina, Minas Gerais, Brazil	Aerial parts	1,6-Humuladien-3-ol (17.7%), caryophyllene oxide (13.6%), humulene epoxide II (8.4%), α -pinene (7.5%), limonene (5.9%)	[126]
Rio Paranaíba, Minas Gerais, Brazil	Leaves	Germacrene D (42.1%), (<i>E</i>)- β -caryophyllene (13.3%), α -pinene (10.6%), α -humulene (9.5%)	[11]
São João Del-Rei, Minas Gerais, Brazil	Leaves	Germacrene D (20.0%), (<i>E</i>)- β -caryophyllene (19.6%), 1,10-di- <i>epi</i> -cubenol (15.4%), nonadecane (14.6%)	[127]
São João Del-Rei, Minas Gerais, Brazil	Stems	(<i>E</i>)- β -Caryophyllene (34.9%), germacrene D (26.5%), α -humulene (9.6%), 1,10-di- <i>epi</i> -cubenol (5.9%)	[127]
São João Del-Rei, Minas Gerais, Brazil	Leaves	Germacrene D (24.2%), α -humulene (11.2%), β -cedrene (10.6%), α -pinene (9.5%), δ -cadinene (7.0%), α -muurolene (5.7%)	[128]
Diamantina, Minas Gerais, Brazil	Flowers	α -Pinene (41.2%), limonene (16.5%), germacrene D (8.23%), (<i>E</i>)- β -caryophyllene (5.8%), β -pinene (5.0%)	[129]
Diamantina, Minas Gerais, Brazil	Leaves	α -Pinene (51.3%), limonene (17.2%), germacrene D (9.1%)	[129]

Table 6. Chemical compositions of *Ageratum houstonianum* essential oils.

Geographical location	Plant tissue	Major components (> 5%)	Ref.
Palampur, Himachal Pradesh, India	Aerial parts	Precocene II (42.2%), precocene I (18.7%), (<i>E</i>)- β -caryophyllene (15.6%)	[130]
Jammu region, India	Aerial parts	Precocene II (44.0%), precocene I (23.3%), (<i>E</i>)- β -caryophyllene (9.2%)	[131]
Giza, Egypt	Flowers	Precocene I (34.6%), precocene II (29.7%), (<i>E</i>)- β -caryophyllene (13.6%), (<i>E</i>)- β -farnesene (10.2%)	[132]
Giza, Egypt	Leaves	(<i>E</i>)- β -Caryophyllene (63.9%), precocene I (22.4%), precocene II (10.9%)	[132]
Palampur, India	Aerial parts	Precocene II (52.6%), precocene I (22.5%), (<i>E</i>)- β -caryophyllene (9.7%)	[133]
Lishui City, Zhejiang Province, China	Aerial parts	Precocene II (62.7%), precocene I (13.2%), (<i>E</i>)- β -caryophyllene (7.9%)	[134]
Bafoussam region, Cameroon	Leaves	Precocene I (32.0%), (<i>E</i>)- β -caryophyllene (27.5%), precocene II (24.0%)	[106]
Dschang, Cameroon	Flowers	Precocene I (48.0%), precocene II (36.6%), (<i>E</i>)- β -caryophyllene (8.4%)	[12]
Shobra El-Khema, Egypt	Aerial parts	Precocene II (48.8%), (<i>E</i>)- β -caryophyllene (20.8%), caryophyllene oxide (11.8%), (γ - <i>cadinene</i> (9.4%)	[135]
Pantnagar, Uttarakhand, India	Aerial parts	Precocene II (32.0%), (<i>E</i>)- β -caryophyllene (23.1%), precocene I (8.5%), (<i>E</i>)- β -farnesene (6.5%)	[5]

10.8%) and α -cadinol (13.8%, 19.5%) to be the major components. Phenylpropanoids dominated the essential oil of *A. fragrans* aerial parts from Zhejiang Province, China, with myristicin (41.3%), elemicin (11.9%), and (*Z*)-isosafole (11.5%), along with borneol (9.1%) and (*E*)- β -caryophyllene (8.8%). The major components of the essential oil from fresh aerial parts of *A. pertyoides* from Yunnan Province, China, were (*E*)- β -caryophyllene (24.5%), *trans*- β -elemene (16.3%),

germacrene B (10.5%), α -guaiene (7.2%), and (*E*)-nerolidol (6.3%).

3.1.6. *Artemisia* L.

The essential oils of *Artemisia* have been reviewed [3, 18, 139, 140]. Therefore, this report summarizes the recent compositions of *Artemisia* essential oils.

Artemisia absinthium L. has been the subject of numerous essential oil investigations. Several reviews have been conducted on *A. absinthium* essential oils

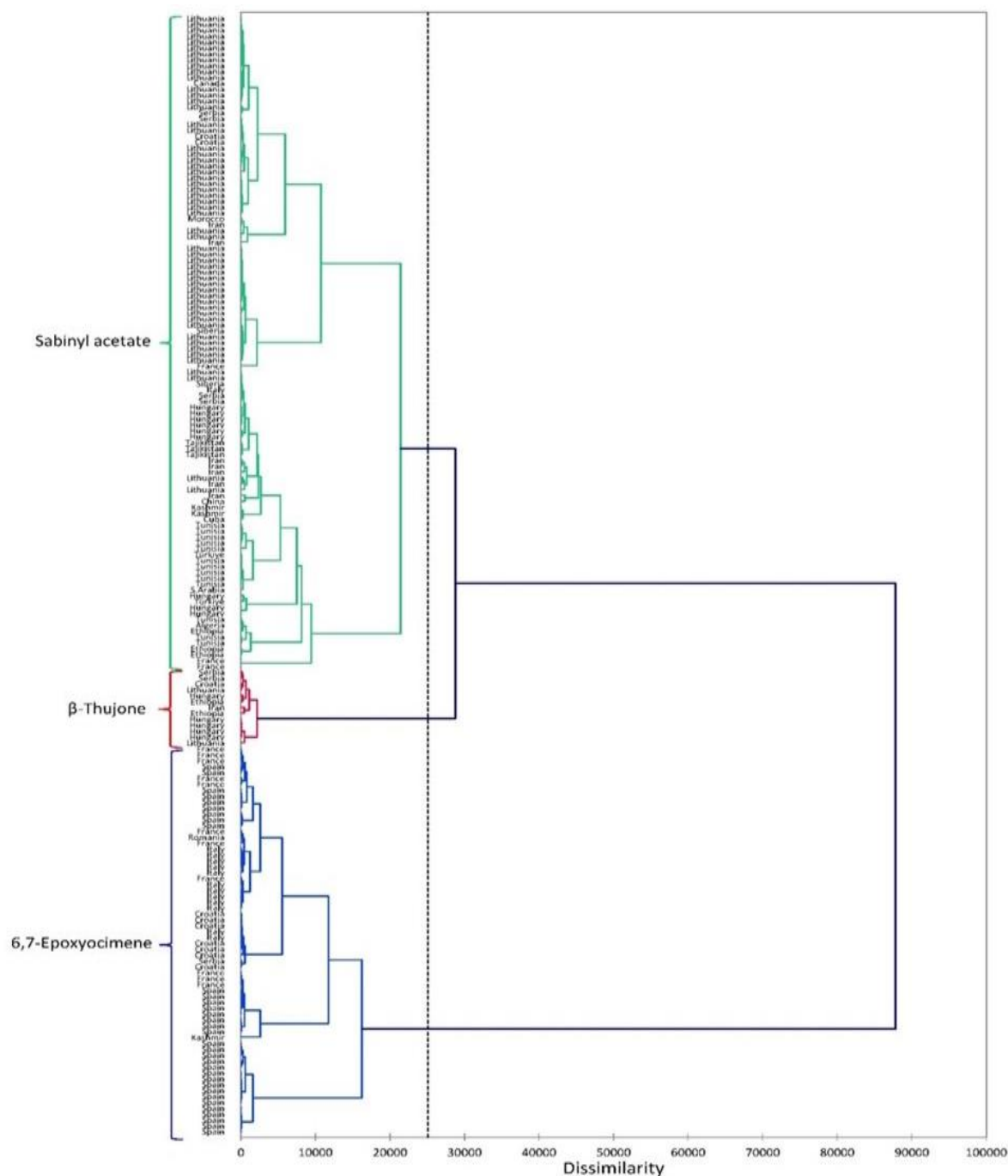


Figure 3. Dendrogram obtained by hierarchical cluster analysis (HCA) based on the essential oil compositions of 190 accessions of *Artemisia absinthium*.

and their bioactivities [141–144]. A hierarchical cluster analysis of 190 accessions from the literature, based on the major essential oil components, reveals at least three different chemotypes (Fig. 3): (1) a cluster dominated by sabinyl acetate, (2) a β -thujone-rich cluster, and (3) a 6,7-epoxyocimene cluster, which is consistent with that previously reported by Chialva and co-workers [145].

Artemisia abyssinica Sch. Bip. ex A. Rich. The plant is

native to Chad, Eritrea, Ethiopia, Saudi Arabia and Yemen [146]. The essential oils of *A. abyssinica* have been analyzed and reported in Ethiopia and Yemen (Table 7). The essential oils from Yemen are rich in camphor and davanone, whereas those from Ethiopia are dominated by yomogi alcohol and artemisyl acetate.

Artemisia annua L. The chemical compositions of *A. annua* essential oils has been extensively reviewed

Table 7. Chemical compositions of *Artemisia abyssinica* essential oils.

Geographical location	Plant tissue	Major components (> 5%)	Ref.
Sana'a, Yemen	Aerial parts	Davanone (42.3%), camphor (22.9%), (<i>E</i>)-nerolidol (9.0%)	[147]
Alhodiadah, Yemen	Aerial parts	Camphor (42.5%), davanone (32.3%), <i>cis</i> -sabinene hydrate (5.8%)	[148]
Sana'a, Yemen	Aerial parts	Camphor (42.1%), davanone (34.5%)	[148]
Taiz, Yemen	Aerial parts	Davanone (49.4%), camphor (29.6%), (<i>E</i>)-nerolidol (5.1%)	[148]
Addis Ababa, Ethiopia	Aerial parts	Yomogi alcohol (32.2%), artemisyl acetate (26.7%), nonanone (6.4%)	[149]
Inchini, Ethiopia	Leaves	Yomogi alcohol (38.5%), artemisyl acetate (24.9%), artemisia alcohol (6.7%)	[150]

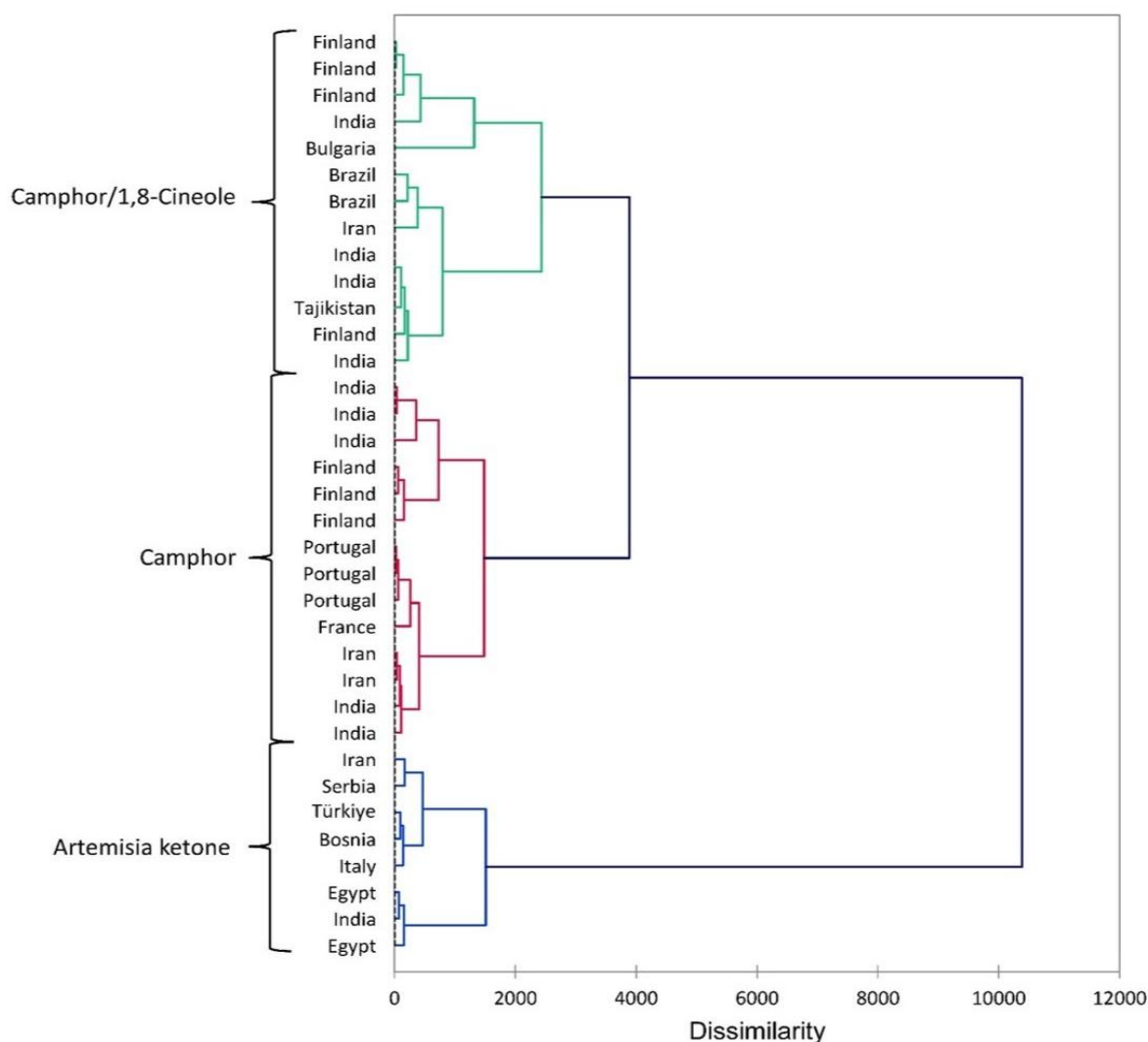


Figure 4. Dendrogram obtained by hierarchical cluster analysis (HCA) based on the essential oil compositions of 37 accessions of *Artemisia annua*.

[151–154]. Essential oils are generally complex and variable in composition, depending on geographical location and growing conditions. However, the major components are often artemisia ketone, 1,8-cineole, and camphor (Fig. 4). For example, the major components in the floral essential oil of *A. annua* from

Rasht, Iran, were camphor (13.1%), artemisia ketone (11.8%), β -selinene (10.7%), pinocarvone (7.4%), 1,8-cineole (6.8%), α -pinene (5.9%), and caryophyllene oxide (5.4%) [155], while the essential oil from the aerial parts growing in Tajikistan were rich in camphor (32.5-58.9%), 1,8-cineole (13.7-17.8%), and

camphene (4.5-8.4%) [156]. In contrast, the essential oil from the aerial parts of Belgrade, Serbia, was dominated by pinocarvone (29.4%) and artemisia ketone (19.2%) [157].

Artemisia arborescens L. The natural range of *A. arborescens* is along the Mediterranean coastal strips of Portugal, Spain, Italy, Greece, Morocco, Algeria, Tunisia, Libya, and Türkiye, as well as along the Tyrrhenian and Adriatic coasts, 0-1000 m asl [158]. At least four chemotypes of *A. arborescens* have been identified based on their essential oil compositions (Table 8): chamazulene β -thujone camphor/chamazulene and β -thujone/chamazulene types [159, 160]. A notable exception is the essential oil sample from Yemen, which was dominated by artemisia ketone (51.1%) [147].

Artemisia campestris L. This plant has a broad natural range in the northern hemisphere, including North Africa, temperate Asia, Europe, and North America [33, 179]. It is a complex species, composed of many races, and its taxonomy is still unclear. The essential oils of *A. campestris* have exhibited several chemotypes, that are generally correlated with geographical location, environmental conditions, or subspecies (Table 9) [180–182].

Artemisia capillaris Thunb. The plant is native to Assam, China North-Central, China South-Central, China Southeast, Hainan, Inner Mongolia, Irkutsk, Japan, Korea, Manchuria, Mongolia, Nansei-shoto, Pakistan, Primorye, Qinghai, Tibet, West Himalaya, Xinjiang, and has been introduced into Afghanistan, Borneo, Cambodia, India, Java, Lesser Sunda Islands, Malaya, Myanmar, Nepal, Philippines, Sulawesi, Sumatera, Taiwan, Thailand, and Vietnam [206]. The major essential oil components of *A. capillaris* are summarized in Table 10.

Artemisia dracunculus L. The essential oil chemistry of *A. dracunculus* has been recently reviewed [26,213]. Commercially important French tarragon essential oil is rich in estragol (69.0-84.0%) [214]. The essential oil compositions of *A. dracunculus* are highly variable and several chemotypes have been described [213, 215], including ocimene, α -terpinene, capillene, methyl eugenol, (Z)-artemidin, and estragole chemotypes, as well as a mixed (sabinene/elemicin/estragole/capillene/anethole) chemotype. The recent *A. dracunculus*

essential oil compositions are summarized in Table 11.

Artemisia herba-alba Asso. *Artemisia herba-alba* is a perennial shrub that naturally grows in the dry steppes of the Iberian Peninsula and North Africa [224, 225]. The essential oil compositions of *A. herba alba* prior to 2017 have been summarized in previous studies [18, 139, 140, 226]. Recent reports on the essential oil compositions of *A. herba alba* are summarized in Table 12. Several chemotypes have been described based on the essential oil compositions, including α -thujone, β -thujone, camphor, davanone, chrysanthenone, pinocarvone, and 1,8-cineole [227, 228]. Based on the data in Table 12, there may be several additional chemotypes (e.g., β -copaene, 2,6-dimethyl-1,3,5-heptatriene, chrysanthenyl acetate, and α -thujene).

Artemisia maritima L. *Artemisia maritima* is a perennial shrub, that grows to about 1 m tall, with a limited range. This plant has been reported in the cold desert regions of Afghanistan, Pakistan, and northwestern India, including Kashmir, Kurram, and Kishtwar [262, 263]. 1,8-Cineole, camphor, or chrysanthenone are the dominant volatile components (Table 13).

Artemisia monosperma Delile. The native range of *A. monosperma* is to North Africa (Libya, Egypt), eastern Mediterranean (Lebanon, Syria, Palestine), and the Arabian Peninsula (Gulf States, Kuwait, Oman, and Saudi Arabia) [33]. There are wide variations in the chemical compositions of the essential oils of *A. monosperma* (Table 14).

Artemisia nilagirica (C.B. Clarke) Pamp. *Artemisia nilagirica* is native to tropical Asia, including the Indian subcontinent, western Himalayas, and Indo-China [33]. The essential oils showed a wide variation in composition (Table 15).

Artemisia rutifolia Steph. ex Spreng. This plant has been reported in China, Mongolia, Middle Asia, and the Himalayas [33]. There are only a few reports on the essential oil compositions, but there are at least three different chemotypes (Table 16).

Artemisia scoparia Waldst. & Kit. The natural range of *A. scoparia* includes Europe, Asia, and the Middle East including Afghanistan, China, India, Japan, Korea, Pakistan, Russia, and Thailand; central and southwestern Asia; eastern, central, and southern

Table 8. Chemical compositions of *Artemisia arborescens* essential oils.

Geographical location	Plant tissue	Major components (> 5%)	Ref.
Amizour, Algeria	Leaves	Chamazulene (31.4%), β -thujone (28.9%), β -eudesmol (8.4%), catalponol (5.7%)	[161]
Cap Bouak, Algeria	Leaves	β -Thujone (59.8%)	[161]
Sahel, Algeria	Leaves	Camphor (58.7%), β -thujone (12.0%)	[161]
Algeria	Aerial parts	Chamazulene (30.2%), β -thujone (27.8%), β -eudesmol (8.1%), catalponol (5.5%)	[162]
Sana'a, Yemen	Aerial parts	Artemisia ketone (51.1%), camphor (14.1%), α -bisabolol (12.6%)	[147]
Southwestern Tunisia	Not indicated	Chamazulene (31.9%), camphor (25.8%), bornyl acetate (7.7%), terpinen-4-ol (5.1%)	[163]
Messina, Italy	Aerial parts	Chamazulene (51.8%), camphor (14.8%), β -thujone (6.9%), myrcene (5.1%)	[164]
Ras al Biyyada, Lebanon	Aerial parts	β -Thujone (68.5%), chamazulene (12.3%)	[165]
Budva, Montenegro	Aerial parts	Chamazulene (38.3%), (<i>E</i>)- β -caryophyllene (15.6%), camphene (7.1%), camphor (6.4%), α -pinene (5.7%)	[157]
Stari Ulcinj Island, Montenegro	Aerial parts	Camphor (39.5%), β -thujone (28.6%)	[157]
Usellus, Sardinia	Aerial parts	Camphor (35.7%), β -thujone (24.0%), chamazulene (7.7%)	[166]
Sicily, Italy	Leaves	β -Thujone (33.7%), chamazulene (26.6%), camphor (6.7%)	[167]
Armenoi, Crete	Aerial parts	Chamazulene (59.3%), camphor (20.7%), β -thujone (6.2%)	[168]
North-western Sicily	Aerial parts	β -Thujone (45.0%), chamazulene (22.7%), camphor (6.8%)	[169]
Petru, Sicily	Aerial parts	Chamazulene (49.4%), β -thujone (20.5%)	[159]
Diga, Sicily	Aerial parts	β -Thujone (49.5%), chamazulene (24.9%)	[159]
Felice, Sicily	Aerial parts	β -Thujone (55.9%), chamazulene (15.2%), myrcene (5.1%)	[159]
Arte, Sicily	Aerial parts	β -Thujone (44.0%), chamazulene (15.7%), myrcene (5.4%)	[159]
Venti, Sicily	Aerial parts	β -Thujone (41.7%), chamazulene (18.5%), myrcene (6.8%)	[159]
Marathon, Athens, Greece	Aerial parts	β -Thujone (28.6%), nonanal (10.0%), chamazulene (9.9%), myroxide (9.0%)	[170]
La Maddalena, Sardinia	Aerial parts	Chamazulene (51.5%), β -thujone (38.0%)	[171]
Ventimiglia, Italy	Aerial parts	β -Thujone (24.2%), camphor (18.9%), aromadendrene (6.5%), camphene (6.0%), 8-cedren-13-ol (5.2%)	[172]
Sicily, Italy	Leaves	Chamazulene (37.6%), camphor (21.4%)	[173]
Calabria Island, Italy	Leaves	Camphor (39.5%), chamazulene (27.1%)	[173]
Lipari Island, Italy	Leaves	Chamazulene (34.6%), camphor (20.1%), β -thujone (6.6%)	[173]
Ain Drahem, Tunisia	Leaves	Camphor (57.3%), chamazulene (14.0%), linalool (5.8%), terpinen-4-ol (5.3%)	[174]
Oued Meliz, Tunisia	Leaves	Camphor (30.4%), chamazulene (15.3%), linalool (10.6%), <i>trans</i> -sabinene hydrate (7.1%), terpinen-4-ol (6.5%), bornyl acetate (5.0%)	[174]

Table 8. (Continued).

Geographical location	Plant tissue	Major components (> 5%)	Ref.
Fernana, Tunisia	Leaves	Camphor (38.9%), chamazulene (26.2%), terpinen-4-ol (9.6%), bornyl acetate (7.1%), linalool (5.3%)	[174]
Jendouba, Tunisia	Leaves	Camphor (58.1%), chamazulene (18.5%), terpinen-4-ol (13.1%)	[174]
Elkef, Tunisia	Leaves	Camphor (29.4%), chamazulene (17.1%), terpinen-4-ol (14.4%), linalool (7.3%)	[174]
Beja, Tunisia	Leaves	Chamazulene (33.1%), camphor (25.7%), bornyl acetate (9.5%), terpinen-4-ol (6.9%)	[174]
Thala, Tunisia	Leaves	Camphor (36.0%), chamazulene (29.8%)	[174]
Kasserine, Tunisia	Leaves	Camphor (31.6%), chamazulene (16.5%), bornyl acetate (11.3%), germacrene D (7.1%)	[174]
Gafsa, Tunisia	Leaves	Chamazulene (28.4%), camphor (24.0%), β -thujone (11.3%), bornyl acetate (8.0%), <i>trans</i> -sabinene hydrate (6.5%)	[174]
Mateur, Tunisia	Leaves	Chamazulene (45.3%), camphor (36.3%), terpinen-4-ol (5.7%)	[174]
Menzel Bourguiba, Tunisia	Leaves	β -Thujone (36.5%), chamazulene (17.2%), camphor (15.1%)	[174]
Bizerte, Tunisia	Leaves	β -Thujone (35.0%), camphor (22.8%), chamazulene (20.7%), terpinen-4-ol (5.5%)	[174]
Zaghouan, Tunisia	Leaves	Camphor (47.0%), chamazulene (11.7%), β -thujone (7.9%)	[174]
Bouficha, Tunisia	Leaves	Camphor (28.5%), chamazulene (27.0%), bornyl acetate (16.0%)	[174]
Cultivated, Tunisia	Leaves	Chamazulene (47.0%), camphor (24.9%), myrcene (5.5%)	[175]
Capo Zafferano, Sicily	Aerial parts	Chamazulene (51.7%), β -thujone (13.5%), camphor (10.0%)	[160]
Alimena, Sicily	Aerial parts	Chamazulene (55.4%), β -thujone (34.4%)	[160]
Lami, Lipari Island, Italy	Aerial parts	Camphor (65.6%), chamazulene (14.9%)	[160]
Acqua Calda, Lipari Island, Italy	Aerial parts	Chamazulene (63.0%), camphor (21.5%)	[160]
Bechar, Algeria	Aerial parts	β -Thujone (27.0%), camphor (25.7%), chamazulene (13.8%), terpinen-4-ol (7.7%)	[176]
Ain Sefra, Algeria	Aerial parts	β -Thujone (71.3%)	[176]
Capo Zafferano, Sicily	Aerial parts	Chamazulene (43.1%), β -thujone (19.6%), camphor (8.8%)	[176]
Termini Imerese, Sicily	Aerial parts	Chamazulene (36.8%), β -thujone (19.9%), camphor (8.7%)	[176]
Chania, Crete	Aerial parts	Camphor (30.5%), β -thujone (18.4%), chamazulene (15.7%), <i>iso</i> -bornyl acetate (8.0%)	[177]
Commercial (Anyang, Korea)	Not indicated	β -Thujone (43.7%), camphor (22.9%), myrcene (7.2%)	[6]
Beni Snous, Algeria	Aerial parts	Camphor (72.2%)	[178]
Bidar, Algeria	Aerial parts	Camphor (50.3%), myrcene (7.4%), terpinen-4-ol (6.1%)	[178]
Chetouane, Algeria	Aerial parts	Camphor (32.8%), terpinen-4-ol (8.9%), chamazulene (8.7%)	[178]

Table 9. Chemical compositions of *Artemisia campestris* essential oils.

Geographical location	Plant tissue	Major components (> 5%)	Ref.
<i>A. campestris</i> L. (subspecies not identified)			
Bengardane, Tunisia	Aerial parts	β -Pinene (49.8%), α -pinene (9.1%), limonene (8.4%), γ -terpinene (5.2%)	[183]
Benikhdache, Tunisia	Aerial parts	β -Pinene (45.8%), α -pinene (12.5%), limonene (7.7%)	[183]
Jerba, Tunisia	Aerial parts	β -Pinene (36.4%), α -pinene (9.7%), <i>p</i> -cymene (8.0%), limonene (5.8%)	[183]
Tataouine, Tunisia	Aerial parts	β -Pinene (37.8%), α -pinene (10.4%), limonene (9.3%), γ -terpinene (5.5%)	[183]
Beni-Khedache, Tunisia	Aerial parts	β -Pinene (34.2%), limonene (8.2%), germacrene D (7.3%), γ -terpinene (6.1%), myrcene (6.0%), α -pinene (5.3%)	[184]
Lmarija, Morocco	Aerial parts	Camphor (19.0%), car-3-en-5-one (11.3%), thujone (6.6%, isomer not indicated), chrysanthenone (6.2%)	[185]
Gafsa, Tunisia	Aerial parts	β -Pinene (33.0%), limonene (15.1%), α -pinene (12.3%), γ -terpinene (7.6%), myrcene (5.5%)	[186]
Salah Bey, Algeria	Aerial parts	β -Pinene (15.2%), α -pinene (11.2%), myrcene (10.3%), germacrene D (9.0%), (<i>Z</i>)- β -ocimene (8.1%), γ -curcumene 6.4%)	[187]
Djebel Amour, Algeria	Leaves	β -Pinene (25.6%), sabinene (17.0%), α -pinene (9.9%), limonene (6.6%)	[188]
Boussaada, Algeria	Aerial parts	α -Terpinyl acetate (18.8%), α -pinene (18.4%), camphor (9.2%), camphene (7.7%), limonene (5.2%), borneol (5.2%)	[189]
Vojvodina, Serbia	Aerial parts	Spathulenol (9.2%), β -pinene (9.1%)	[190]
Tajerouine, Le Kef, Tunisia	Leaves	β -Pinene (35.0%), 1,8-cineole (14.4%), <i>p</i> -cymene (10.9%), α -pinene (8.1%)	[191]
Djelfa Wilaya, Algeria	Aerial parts	(<i>Z,E</i>)-Farnesol (10.3%), cedrol (5.4%)	[192]
Oued Moura, Algeria	Aerial parts	α -Pinene (18.7%), myrcene (17.3%), β -pinene (16.8%), germacrene D (10.3%), limonene (5.9%)	[193]
Ćemovsko polje, Montenegro	Aerial parts	Germacrene D (24.2%), bicyclogermacrene (14.7%), γ -himachalene (12.6%), β -pinene (9.1%)	[157]
Zintan, Libya	Aerial parts	β -Pinene (46.4%), α -pinene (6.8%), <i>p</i> -cymene (6.1%), limonene (5.4%)	[157]
Hassi Bahbah, Djelfa, Algeria	Leaves	Camphor (42.0%), chrysanthenone (14.0%), 1,8-cineole (13.3%), β -thujone (7.0%)	[194]
Near Tendirara, Morocco	Aerial parts	<i>p</i> -Cymene (17.3%), spathulenol (16.8%), β -pinene (15.6%), α -pinene (11.4%), α -campholenal (8.8%)	[195]
Central Tunisia	Leaves	β -Pinene (32.0%), limonene (17.3%), α -pinene (11.4%), myrcene (6.0%), γ -terpinene (5.5%)	[196]
Kasserine, Tunisia	Aerial parts	β -Pinene (11.6%), β -eudesmol (6.5%), α -pinene (5.9%), γ -terpinene (5.5%)	[197]
North Tunisia	Aerial parts	Germacrene D (30.5%), β -pinene (16.8%), limonene (7.0%), β -eudesmol (6.6%), α -farnesene (5.0%)	[198]
Tunisia	Aerial parts	Germacrene D (16.4%), β -pinene (16.3%), limonene (9.2%), <i>p</i> -cymene (6.6%)	[199]
<i>A. campestris</i> subsp. <i>campestris</i>			
El Mergueb, Algeria	Aerial parts	β -Pinene (15.3%), limonene (6.6%), <i>p</i> -cymene (6.2%), germacrene D (6.2%), spathulenol (6.0%), α -pinene (5.4%), β -eudesmol (5.2%)	[200]

Table 9. (Continued).

Geographical location	Plant tissue	Major components (> 5%)	Ref.
<i>A. campestris</i> subsp. <i>campestris</i>			
Laghouat, Algeria	Aerial parts	Capillene (25.6%), α -pinene (9.1%), β -pinene (8.9%), <i>p</i> -cymene (8.1%), spathulenol (5.3%)	[182]
Lithuania	Aerial parts	Caryophyllene oxide (8.4-38.8%), germacrene D (3.5-15.0%)	[180]
Łodz, Poland	Aerial parts	Germacrene D (23.0%), β -pinene (13.9%), γ -humulene (7.5%), β -elemene (5.9%)	[201]
<i>A. campestris</i> subsp. <i>glutinosa</i> (Gay ex Bess.) Batt.			
Laghouat, Algeria	Aerial parts	β -Pinene (26.9%), limonene (8.4%), γ -terpinene (5.0%)	[182]
Djelfa, Algeria	Aerial parts	β -Pinene (32.8%), limonene (9.2%), <i>p</i> -cymene (8.3%), α -pinene (7.5%), (γ -terpinene (5.4%)	[182]
Figuiq, Morocco	Aerial parts	Spathulenol (13.1%), β -pinene (11.9%), <i>p</i> -cymene (9.4%), α -pinene (7.3%)	[179]
Camargue, southern France	Aerial parts	1-Phenyl-2,4-pentadiyne (29.7%), capillene (22.3%), γ -terpinene (20.8%), methyl eugenol (6.6%)	[202]
Tuzluca, Igdır, Türkiye	Leaves	Camphor (31.8%), 1,8-cineole (23.1%), α -thujone (16.8%), camphene (11.7%),	[203]
Tamanrasset, Algeria	Aerial parts	β -Pinene 28.9%), <i>p</i> -cymene (13.4%), α -pinene (8.8%)	[204]
<i>A. campestris</i> subsp. <i>maritima</i> (DC.) Arcang.			
Figueira da Foz, Portugal	Aerial parts	β -Pinene (54.5%), cadin-4-en-7-ol (9.5%), (<i>Z</i>)- β -ocimene (6.0%)	[205]

Table 10. Chemical compositions of *Artemisia capillaris* essential oils.

Geographical location	Plant tissue	Major components (> 5%)	Ref.
Milam Glacier, Uttarakhand, India	Leaves	Capillene (60.2%), γ -terpinene (11.1%)	[207]
Jinan, Korea	Aerial parts	Capillene (32.7%), β -pinene (9.4%)	[208]
Beijing, China	Aerial parts	β -Pinene (12.7%), germacrene D (8.4%), γ -terpinene (8.2%), (<i>E</i>)- β -caryophyllene (7.7%), 1,8-cineole (6.9%), (<i>E</i>)- β -farnesene (5.7%), (<i>Z</i>)- β -ocimene (5.3%)	[209]
Uttarakhand, India	Aerial parts	Capillene (42.1%), (<i>E</i>)- β -caryophyllene (12.5%). Myrcene (9.2%), β -pinene (8.6%), <i>p</i> -cymene (6.8%), limonene (6.4%), (<i>E</i>)- β -ocimene (5.8%), γ -terpinene (5.3%)	[210]
Jianguo, China	Aerial parts	Capillin (24.2%), β -pinene (12.1%), (<i>E</i>)- β -caryophyllene (5.2%)	[211]
Jinan, Korea	Aerial parts	Acenaphthylene (37.9%), β -pinene (12.1%), 4-carene (10.6%), γ -curcumene (9.9%), (<i>E</i>)- β -caryophyllene (8.8%), germacrene D (5.9%)	[212]

Table 11. Chemical compositions of *Artemisia dracunculus* essential oils.

Geographical location	Plant tissue	Major components (> 5%)	Ref.
Cultivated, Kashan, Iran	Aerial parts	Estragole (81.9%)	[216]
Cultivated, Black Sea, Russia	Aerial parts	Estragole (79.3%), (<i>Z</i>)- β -ocimene (11.9%), (<i>E</i>)- β -ocimene (6.8%)	[217]
Cultivated (?), Taounate, Mernissa, Morocco	Aerial parts	Estragole (69.2%), (<i>E</i>)- β -ocimene (9.1%), (<i>Z</i>)- β -ocimene (7.9%), limonene (5.7%)	[218]

Table 11. (Continued).

Geographical location	Plant tissue	Major components (> 5%)	Ref.
Cultivated, Iran	Aerial parts	Estragole (81.6-88.1%)	[219]
Commercial essential oil, Iran	Not indicated	Estragole (75.0%), (Z)- β -ocimene (8.3%), (E)- β -ocimene (7.8%)	[220]
Cultivated, Tehran, Iran	Aerial parts	Estragole (64.9%), (Z)- β -ocimene (10.6%), (E)- β -ocimene (10.2%), <i>p</i> -cymene (5.4%),	[221]
Cultivated, Iasi, Romania	Aerial parts	(E)-Isoelemicin (38.9%), methyl eugenol (23.4%), terpinen-4-ol (6.5%), carvacrol (5.0%)	[222]
Wild-growing, Kukteppa village, Ziddi, Varzob rebion, Tajikistan	Aerial parts	Sabinene (29.1%), estragole (24.6%), limonene (7.8%)	[213]
Wild-growing, southwestern Idaho	Aerial parts	Terpinolene (20.0%), 5-phenyl-1,3-pentadiyne (191.2%), capillene (13.8%), (Z)- β -ocimene (11.1%), methyl eugenol (8.7%), β -phellandrene (5.8%)	[223]

Table 12. Chemical compositions of *Artemisia herba alba* essential oils.

Geographical location	Plant tissue	Major components (> 5%)	Ref.
Djelfa, Algeria	Aerial parts	Davanone (48.8%), chrysanthenone (16.0%), camphor (14.8%), 1,8-cineole (5.7%)	[229]
Djelfa, Algeria	Leaves	Camphor (22.4%), 1,8-cineole (12.0%), α -thujone (8.2%), chrysanthenone (7.3%), β -thujone (5.4%)	[230]
Amskrod, Morocco	Aerial parts	Chrysanthenone (56.8%), β -thujone (31.1%)	[231]
Boulemane, Morocco	Aerial parts	α -Thujone (29.0%), β -thujone (28.6%), chrysanthenone (14.8%), 1,8-cineole (11.7%)	[232]
Riyadh, Saudi Arabia	Aerial parts	Piperitone (44.6%), ethyl (E)-cinnamate (14.7%)	[226]
Souk-Ahras, Algeria	Aerial parts	β -Copaene (16.2%), limonene (14.6%), 1,8-cineole (14.5%), camphor (13.7%), borneol (5.4%)	[233]
Azzemour, Morocco	Aerial parts	α -Thujone (25.5%), β -thujone (17.7%), vanillyl alcohol (11.5%), <i>nor</i> -davanone (7.8%), <i>cis</i> - <i>threo</i> -davanafuran (5.8%)	[234]
Taroudant, Morocco	Aerial parts	Chrysanthenone (39.7%), camphor (13.3%), α -thujone (12.9%), β -thujone (11.5%)	[229]
Guelmim, Morocco	Aerial parts	α -Thujone (28.9%), borneol (22.3%), pulegone (14.4%),	[235]
Bejaia, Algeria	Aerial parts	Camphor (32.0%), α -thujone (13.7%), 1,8-cineole (9.8%), β -thujone (5.0%)	[236]
Ain Aghbal, Morocco	Aerial parts	Camphor (49.8%), (3E)-2,6-dimethyl-1,3,5-heptatriene (18.3%), α -thujone (13.5%), camphene (6.1%)	[227]
Tizi Lafaka, Morocco	Aerial parts	Camphor (53.7%), (3E)-2,6-dimethyl-1,3,5-heptatriene (12.0%), α -thujone (7.7%), camphene (6.1%), 1,8-cineole (5.8%), β -thujone (5.1%)	[227]
Lakhtatba, Morocco	Aerial parts	Camphor (58.8%), borneol (9.9%), (3E)-2,6-dimethyl-1,3,5-heptatriene (9.6%), camphene (6.4%), 1,8-cineole (5.2%),	[227]
Talezzarte, Morocco	Aerial parts	Camphor (59.8%), α -thujone (7.8%), camphene (7.0%), 1,8-cineole (5.2%)	[227]
Bni Boufrah, Morocco	Aerial parts	α -Thujone (47.4%), camphor (10.1%), β -thujone (8.9%), borneol (5.2%)	[227]
Boudnib, Morocco	Aerial parts	α -Thujone (75.4%), β -thujone (10.5%)	[227]
Ighrem, Morocco	Aerial parts	Camphor (32.6%), davanone (12.3%), 1,8-cineole (8.8%), davana ether (6.4%), α -thujone (5.1%)	[227]
Tata, Morocco	Aerial parts	α -Thujone (49.7%), camphor (30.7%), β -thujone (8.2%)	[227]
Es-Smara, Morocco	Aerial parts	Davanone (41.4%), camphor (12.9%), 1,8-cineole (7.2%)	[227]

Table 12. (Continued).

Geographical location	Plant tissue	Major components (> 5%)	Ref.
Tlemcen, Algeria	Aerial parts	Camphor (32.3%), chrysanthenone (25.6%), camphene (10.3%), 1,8-cineole (8.4%)	[237]
Bouilef, Algeria	Aerial parts	Camphor (50.5%), α -thujone (12.7%), β -thujone (10.0%), chrysanthenone (8.2%), 1,8-cineole (8.2%)	[238]
Er-rich, Morocco	Aerial parts	Camphor (14.7%), chrysanthenone (14.1%), β -thujone (12.6%), α -thujone (9.2%), α -pinene (6.1%)	[239]
Thala, Tunisia	Aerial parts	β -Thujone (23.9%), chrysanthenone (17.4%), α -thujone (10.3%), 1,8-cineole (9.8%), <i>p</i> -cymene (8.3%), terpinen-4-ol (5.2%)	[240]
Jerada, Morocco	Aerial parts	(3 <i>E</i>)-2,6-Dimethyl-1,3,5-heptatriene (36.4%), camphor (22.5%), thujone ^a (7.21%), 1,8-cineole (6.0%), (1,3-dimethyl-2-methylene-cyclopentyl)-methanol ^b (6.5%)	[241]
Taurirt, Morocco	Aerial parts	Camphor (55.3%), 1,8-cineole (14.6%), camphene (10.0%)	[241]
Karak, Jordan	Leaves	α -Pinene (17.2%), α -thujone (11.4%), 1,8-cineole (10.4%), sabinene (8.4%), (<i>E</i>)- β -caryophyllene (8.3%), β -pinene (6.2%), artemisia alcohol (5.2%), germacrene D (5.1%)	[242]
Talsint, Morocco	Aerial parts	Davanone (38.3%), davana ether isomer 1 (9.9%), davana ether isomer 2 (8.3%), camphor (6.3%)	[243]
Guedaman, Morocco	Aerial parts	Camphor (46.6%), borneol (5.7%), 1,8-cineole (5.6%)	[244]
Imizar-Azilal, Morocco	Aerial parts	Chrysanthenone (47.7%), <i>cis</i> -dihydro- β -terpineol (21.6%)	[245]
Jelma, Tunisia	Aerial parts	β -Thujone (27.8%), camphor (22.7%), chrysanthenone (18.0%), α -thujone (13.6%)	[246]
Al- Jabal Al-Akhder, Libya	Aerial parts	α -Thujone (63.1%), β -thujone (26.6%), camphor (5.8%)	[247]
Taliouine, Morocco	Aerial parts	Camphor (55.4-57.4%), 1,8-cineole (8.3-8.4%). Camphene (6.9-8.8%), santolina alcohol (4.3-6.7%)	[248]
Rabat, Morocco	Aerial parts	α -Thujone (65.0%), β -thujone (14.4%), camphor (6.0%)	[249]
Guelma, Algeria	Aerial parts	Camphor (26.2%), chrysanthenone (12.4%), 1,8-cineole (8.0%), α -thujone (7.8%), β -thujone (7.8%)	[250]
Fez-Boulemane, Morocco	Aerial parts	<i>cis</i> -Chrysanthenyl acetate (26.7-30.0%), β -thujone (12.9-23.2%), chrysanthenone (1.0-14.0%), 1,8-cineole (1.5-11.8%), <i>trans</i> -dihydro- β -terpineol (6.9-7.8%), α -thujone (3.1-5.4%)	[251]
Djelfa, Algeria	Aerial parts	Camphor (37.5%), chrysanthenone (10.4%), 1,8-cineole (8.6%), α -thujone (7.0%), camphene (6.0%)	[252]
Sidi Bel Abbess, Algeria	Aerial parts	Camphor (30.6%), (3 <i>E</i>)-2,6-dimethyl-1,3,5-heptatriene (26.7%), safranal (7.0%)	[253]
Agadir, Morocco	Aerial parts	β -Thujone (24.3%), camphor (22.2%), α -thujone (14.6%), 1,8-cineole (10.3%), camphene (7.6%)	[254]
Boussâada, Algeria	Aerial parts	Chrysanthenone (24.1%), camphor (16.2%), α -thujone (12.8%), 1,8-cineole (5.6%)	[255]
Taounate, Morocco	Aerial parts	Piperitone (85.7%)	[256]
Bechar, Algeria	Aerial parts	α -Thujone (48.0%), β -thujone (13.4%), camphor (13.1%)	[257]
Ouarzazate, Morocco	Flowers	β -Thujone (59.2%), camphor (18.4%), dehydrosabina ketone (10.0%)	[258]
Biskra, Algeria	Aerial parts	β -Thujone (51.2%), α -thujone (13.2%), camphor (8.8%), chrysanthenone (6.9%)	[259]
Giza, Egypt	Aerial parts	α -Thujone (61.4%)	[260]
Truel, Spain	Aerial parts	Camphor (29.8%), β -thujone (22.0%), 1,8-cineole (14.5%), α -thujone (10.8%)	[261]

^a Correct isomer was not indicated. ^b This structure is not found in the Dictionary of Natural Products [98], therefore, the identification is doubtful.

Table 13. Chemical compositions of *Artemisia maritima* essential oils.

Geographical location	Plant tissue	Major components (> 5%)	Ref.
Keylong, Himachal Pradesh, India	Aerial parts	1,8-Cineole (41.1%), bornyl acetate (18.1%), myrcene (9.6%), sabinene (6.4%)	[264]
Western Himalayas, India	Aerial parts	1,8-Cineole (23.8-44.2%), chrysanthenone (0.8-38.1%)	[265]
Jhelum, Uttarakhand, India	Aerial parts	1,8-Cineole (25.0%), chrysanthenone (23.6%), germacrene D (7.4%)	[266]
Jhelum, Uttarakhand, India	Aerial parts	Chrysanthenone (25.7%), 1,8-cineole (23.6%), germacrene D (6.7%)	[267]
Commercial sample, source not indicated	Not indicated	1,8-Cineole (41.1%), camphor (20.3%)	[268]
Keylong, Himachal Pradesh, India	Aerial parts	1,8-Cineole (23.2%), camphor (20.7%), borneol (13.7%), bornyl acetate (13.2%)	[269]
Lahaul-Spiti, Hamachal Pradesh, India	Aerial parts	Camphor (44.4%), 1,8-cineole (27.3%), camphene (5.5%)	[263]
Lahaul valley, Himachal Pradesh, India	Aerial parts	1,8-Cineole (38.9-49.9%), terpinen-4-ol (9.7-14.2%), bornyl acetate (8.0-13.5%), camphor (1.8-5.5%), myrcene (1.6-5.8%)	[270]

Table 14. Chemical compositions of *Artemisia monosperma* essential oils.

Geographical location	Plant tissue	Major components (> 5%)	Ref.
Ghat region, Saudi Arabia	Aerial parts	7- <i>epi-trans</i> -Sesquisabinene hydrate (8.3-25.1%), dehydroaromadendrene (0.9-13.5%), junipene (3.5-6.3%), α -bulnesene (3.2-5.9%), 6- <i>epi</i> -shyobunol (1.9-10.4%), dehydrocyclolongifolene oxide (0.4-6.6%)	[271]
Thumamah, Saudi Arabia	Aerial parts	7- <i>epi-trans</i> -Sesquisabinene hydrate (6.1-20.4%), dehydroaromadendrene (9.5-15.0%), junipene (4.5-13.1%), 6- <i>epi</i> -shyobunol (9.1-13.4%), dehydrocyclolongifolene oxide (4.1-9.0%)	[271]
Giham, Saudi Arabia	Aerial parts	7- <i>epi-trans</i> -Sesquisabinene hydrate (7.9-19.0%), dehydroaromadendrene (9.8-11.3%), junipene (4.5-8.8%), 6- <i>epi</i> -shyobunol (9.6-10.1%), dehydrocyclolongifolene oxide (6.8-8.3%)	[271]
Matrouh, Egypt	Leaves	Capillene (36.9%), capillin (14.7%), γ -terpinene (12.5%), β -pinene (7.9%)	[272]
South Sinai, Egypt	Aerial parts	β -Pinene (20.7%), spathulenol (8.8%), limonene (7.5%), shyobunone (7.1%), citronellyl isovalerate (6.6%)	[273]
Al Qalibah, Saudi Arabia	Aerial parts	2-Vinylnaphthalene (24.9%), β -eudesmol (15.4%), β -pinene (11.9%), limonene (8.8%)	[273]
Tobruk Desert, Libya	Aerial parts	Bornyl acetate (8.0-31.0%), β -pinene (9.0-24.0%), sabinene (13.2-22.9%), (<i>E</i>)- β -ocimene (3.7-12.9%), (<i>Z</i>)- β -ocimene (5.3-11.0%), myrcene (4.6-7.0%), <i>p</i> -cymene (1.1-11.2%), limonene (3.0-5.3%), α -pinene (1.1-6.2%)	[274]
Gabal Ataka, Suez Desert, Egypt	Aerial parts	β -Pinene (56.4%), δ -cadinene (18.4%), α -pinene (6.8%), limonene (5.4%)	[275]
New Damietta, Egypt	Aerial parts	γ -Eudesmol (14.7%), widdrol (7.6%), biphenyl (6.6%), β -pinene (6.4%), <i>ar</i> -curcumene (5.7%), viridiflorol (5.6%), 2-vinylnaphthalene (5.2%)	[276]
Ha'il region, Saudi Arabia	Leaves	β -Pinene (29.9%), terpinolene (8.6%), bornyl acetate (7.6%), (<i>E</i>)- β -ocimene (7.1%), limonene (5.7%), <i>cis</i> -sabinene hydrate (5.3%)	[277]
Cairo, Egypt	Aerial parts	Artemisia ketone (31.7%), camphor (16.9%), α -bisabolol (11.6%), β -phellandrene (10.2%)	[278]

Table 15. Chemical compositions of *Artemisia nilagirica* essential oils.

Geographical location	Plant tissue	Major components (> 5%)	Ref.
Pantnagar, Uttarakhand, India	Aerial parts	Artemisia ketone (62.6%)	[279]
Milam glacier, Uttarakhand, India	Leaves	Artemisia ketone (55.1%), (<i>E</i>)- β -caryophyllene (6.5%), germacrene D (5.8%)	[280]
Coimbatore, Tamilnadu, India	Aerial parts	Camphor (19.7%), caryophyllene oxide 13.9%), 1,8-cineole (9.2%), humulene epoxide II (7.3%), α -humulene (7.0%), (<i>E</i>)- β -caryophyllene (6.6%)	[281]
Meghalaya, India	Aerial parts	Artemisia ketone (32.7%), artemisia alcohol (13.4%)	[282]
Nilgris, Tamil Nadu, India	Aerial parts	α -Thujone (33.8%), germacrene D (9.3%), β -thujone (6.0%), (<i>E</i>)- β -caryophyllene (5.9%), caryophyllene oxide (6.2%)	[283]
Pokhari-Nagnath, Uttarakhand, India	Aerial parts	α -Thujone (36.4%), β -thujone (9.4%), germacrene D (6.3%), terpinen-4-ol (6.3%), camphene (5.5%), (<i>E</i>)- β -caryophyllene (5.4%)	[284]
Uttarakhand, India	Aerial parts	Linalool (16.3%), α -thujone (13.9%), (<i>E</i>)- β -caryophyllene (7.5%), germacrene D (7.1%), terpinen-4-ol (7.1%),	[210]
Gorakhpur, India	Aerial parts	Camphor (22.8%), (<i>E</i>)- β -caryophyllene (16.7%), α -thujone (14.6%), sabinene (14.3%)	[285]
Palampur, India	Aerial parts	Camphor (12.6%), artemisia ketone (10.2%), caryophyllene oxide (7.4%), 1,8-cineole (5.3%), borneol (5.3%)	[263]

Table 16. Chemical compositions of *Artemisia rutifolia* essential oils.

Geographical location	Plant tissue	Major components (> 5%)	Ref.
Kharkhira Mountain, Mongolia	Aerial parts	Santolina triene (22.4%), myrcene (21.8%), (<i>E</i>)- β -caryophyllene (7.2%), caryophyllene oxide (5.8%), <i>p</i> -mentha-1(7),8-diene (5.3%)	[286]
Buryatia, Russia	Aerial parts	Benzylacetone (35.0%), camphor (16.7%), 1,8-cineole (16.5%)	[287]
Khonaobod, Tajikistan	Aerial parts	β -Thujone (47.3%), α -thujone (20.9%)	[288]
Chormaghzak, Tajikistan	Aerial parts	α -Thujone (36.6%), β -thujone (36.1%), 1,8-cineole (11.7%)	[288]
Altai Mountain, Mongolia	Aerial parts	Benzylacetone (33.1%), camphor (22.4%), 1,8-cineole (19.1%)	[289]

Europe [33, 290]. There is a wide variation in the reported essential oil compositions of *A. scoparia* and there are likely numerous chemotypes of this species [291]. The recent chemical compositions of *A. scoparia* are listed in Table 17.

Artemisia sieberi Besser. *Artemisia sieberi* grows naturally in Iran, Syria, Palestine, Iraq, Afghanistan, Turkey, and Central Asia [301]. The phytochemistry, including essential oil composition, and the antifungal activities of *A. sieberi* were reviewed in 2017 [302]. The predominant chemotypes were thujone, chrysanthenone, 1,8-cineole/camphor, and santolina alcohol, however, their compositions are subject to seasonal and geographical variations. Zare and co-workers examined the chemical compositions of 17 accessions from different geographical regions of Iran [303]. These workers identified five different chemotypes, namely thujane, davanone, menthane,

bornane, and a chemotype based on irregular monoterpenoids. The recently published essential oil compositions are summarized in Table 18.

Artemisia vulgaris L. The plant is native to Eurasia, but is now established in the eastern North America, Central America, and Colombia [33]. The volatile phytochemistry of *A. vulgaris* has been extensively reviewed [3, 18, 139, 140, 311–313]. Judzentiene and Budiene carried out an extensive study of *A. vulgaris* essential oils throughout Lithuania [314]. These workers were able, to define six chemotypes based on the compositions: I, a *cis*-chrysanthenyl chemotype; II, an artemisia ketone chemotype; III, a sabinene chemotype; IV, a 1,8-cineole chemotype; V, a sabinene/*cis*-chrysanthenyl acetate chemotype; and VI, a camphor chemotype. In addition, Haider and co-workers [315] examined *A. vulgaris* essential oils from various locations in Uttarakhand Himalaya, India,

Table 17. Chemical compositions of *Artemisia scoparia* essential oils.

Geographical location	Plant tissue	Major components (> 5%)	Ref.
Riyadh, Saudi Arabia	Aerial parts	2-Nonanone (55.0%), 2-undecanone (24.5%), 2-nonyl acetate (9.3%)	[292]
Mashhad, Iran	Aerial parts	Artemisia ketone (21.0-25.8%), camphor (11.9-16.4%), 1,8-cineole (12.4-13.7%), myrcene (9.5-13.3%), α -pinene (6.6-8.0%)	[293]
Khovd aimag, Mongolia	Aerial parts	Capillene (20.8%), methyl eugenol (11.9%), eugenol (10.9%), spathulenol (11.8%), eugenyl 2-methylbutanoate (7.7%), <i>ar</i> -curcumene (5.9%)	[294]
Hawal Bagh, Uttarakhand, India	Aerial parts	Capillene (28.8%), β -pinene (12.6%), α -terpinolene (12.5%), limonene (11.8%) (<i>E</i>)- β -caryophyllene (8.5%), (<i>E</i>)- β -ocimene (8.1%)	[295]
Niška Banja, Serbia	Aerial parts	Capillene (63.8%), 2,4-pentadiynylbenzene (10.0%)	[296]
Various locations, Serbia	Aerial parts	Capillene (33.6-67.9%), 2,4-pentadiynylbenzene (9.8-24.7%), β -pinene (4.7-16.9%), (<i>Z</i>)- β -ocimene (4.6-8.5%)	[297]
Various locations, Pakistan	Aerial parts	Capillene (9.6-31.8%), myrcene (6.8-21.5%), γ -terpinene (9.2-19.5%), <i>p</i> -cymene (3.2-14.6%), limonene (4.4-14.1%), (<i>E</i>)- β -caryophyllene (0.8-12.4%), methyl eugenol (0.2-12.7%), (<i>Z</i>)- β -ocimene (2.8-7.4%), 2,4-pentadiynylbenzene (0.4-6.1%),	[298]
Grocka, Serbia	Aerial parts	1,8-Cineole (57.2%), β -thujone (34.5%)	[299]
Tehran, Karaj, Iran	Aerial parts	β -Pinene (13.1-30.5%), 2,4-pentadiynylbenzene (7.9-22.0%), (<i>Z</i>)- β -ocimene (1.9-16.2%), bicyclogermacrene (7.9-10.5%), (<i>E</i>)- β -caryophyllene (6.0-7.5%)	[300]
Chormaghzak, Yovon region, Tajikistan	Aerial parts	2,4-Pentadiynylbenzene (34.2%), β -pinene (21.3%), methyl eugenol (5.5%), myrcene (5.2%), limonene (5.0%)	[291]

Table 18. Chemical compositions of *Artemisia sieberi* essential oils.

Geographical location	Plant tissue	Major components (> 5%)	Ref.
Riyadh, Saudi Arabia	Aerial parts	Davanone (36.1%), camphor (24.1%), terpinen-4-ol (5.4%), (<i>E</i>)-nerolidol (5.0%)	[292]
Hail, Saudi Arabia	Aerial parts	<i>cis</i> -Chrysanthenyl acetate (48.6%), davanone (10.3%), 1,8-cineole (6.8%), caryophyllene diepoxide (5.3%)	[304]
Bandar Abbas, Iran	Fruits	Camphor (47.0%), 1,8-cineole (20.9%)	[305]
Shabestar-Eeat, Iran	Aerial parts	Camphor (33.6%), 1,8-cineole (25.7%), camphene (15.7%), chrysanthenone (7.9%)	[306]
Geno Mountain, Bandar Abbas, Iran	Aerial parts	1,8-Cineole (48.7%), camphor (32.7%)	[307]
Ardabil, Iran	Leaves	Camphor (19.5%), β -thujone (17.4%), 1,8-cineole (16.3%), germacrene D (8.4%), terpinen-4-ol (5.1%)	[301]
Commercial sample, Kashan, Iran	Not indicated	α -Thujone (38.2%), santolinyl acetate (23.8%), β -thujone (11.3%), camphor (6.3%)	[308]
Arak, Iran	Aerial parts	α -Thujone (31.5%), camphor (12.3%), β -thujone (11.9%), 1,8-cineole (10.1%), camphene (8.7%)	[309]
Qom, Iran	Aerial parts	Camphor (25.2%), 1,8-cineole (6.3%), α -terpineol (6.2%), sabinene (5.2%)	[310]

and identified three chemotypes: vulgarole, artemisia ketone, and thujone chemotypes. Recent reports on the essential oil compositions of *A. vulgaris* are summarized in Table 19. A perusal of Table 19 reveals at least one additional chemotype: germacrene D/(*E*)- β -caryophyllene. The essential oil compositions of

several *Artemisia* species are summarized in Table 20.

3.1.7. Aster L.

Aster is a genus comprising approximately 250 species growing throughout the northern hemisphere [33]. Despite the large number of species in this genus, only a few have been analyzed for their essential oil

Table 19. Chemical compositions of *Artemisia vulgaris* essential oils.

Geographical location	Plant tissue	Major components (> 5%)	Ref.
Zeytinburnu Medicinal Plants Garden, İstanbul, Türkiye	Aerial parts	α -Thujone (30.7-47.1%), (<i>E</i>)- β -caryophyllene (7.9-22.1%), 1,8-cineole (6.8-9.6%), β -thujone (6.3-9.1%), germacrene D (2.6-8.2%)	[316]
Urumqi, China	Aerial parts	<i>cis</i> -Sabinol (15.2%), <i>trans</i> -sabinyl acetate (11.1%), 1,8-cineole (10.9%), <i>trans</i> -piperitol (8.4%), <i>trans</i> -sabinene hydrate (6.2%)	[317]
Northwestern Lithuania	Aerial parts	Germacrene D (10.6-30.5%), (<i>E</i>)- β -caryophyllene (3.3-16.7%), 1,8-cineole (2.7-9.8%), caryophyllene oxide (4.1-9.3%), α -humulene (2.8-5.5%)	[318]
Pauri region, Uttarakhand, India	Aerial parts	Camphor (10.8%), β -eudesmol (9.0%), (<i>E</i>)- β -caryophyllene (6.5%), borneol (6.5%), bornyl acetate (6.3%)	[319]
Sao Luís, Maranhão, Brazil	Aerial parts	(<i>E</i>)- β -Caryophyllene (37.5%), germacrene D (16.2%), α -humulene (13.7%), borneol (6.8%), caryophyllene oxide (5.7%)	[320]
Pasighat, Arunachal Pradesh, India	Leaves	1,8-Cineole (16.8%), camphor (11.9%), isopulegol (9.4%), borneol (8.1%)	[321]
Timisoara, Romania	Aerial parts	Terpinen-4-ol (18.2%), spathulenol (12.1%), τ -muurolol (11.8%), palmitic acid (11.2%), α -terpineol (10.0%), caryophyllene oxide (8.5%), cuminol (7.2%)	[220]
Karaj, Iran	Aerial parts	Camphor (30.6-49.9%), 1,8-cineole (17.5-31.2%), camphene (6.1-10.9%)	[300]
Hetauda Makwanpur, Nepal	Aerial parts	α -Thujone (30.5%), 1,8-cineole (12.4%), camphor (10.3%), β -thujone 7.1%)	[322]
Manipur, India	Leaves	1,8-Cineole (29.9%), sabinene (8.4%), borneol (8.2%), 2,7-dimethyl-2,6-octadien-4-ol (6.8%), 10- <i>epi</i> - γ -eudesmol (6.5%)	[323]
Wuhan, China	Leaves	1,8-cineole (46.5%), borneol (10.2%), piperitol (9.5%), α -cadinene (8.9%), camphor (6.2%), α -humulene (5.5%)	[324]

Table 20. Chemical compositions of *Artemisia* essential oils.

<i>Artemisia</i> species	Geographical location	Plant tissue	Major components (> 5%)	Ref.
<i>Artemisia anethoides</i> Mattf.	Gansu province, China	Leaves	1,8-Cineole (36.5%), 2-isopropyl-5-methyl-3-cyclohexen-1-one (10.4%), terpinen-4-ol (8.6%), <i>o</i> -cymene (6.2%), pinocarveol (5.1%)	[325]
<i>Artemisia aragonensis</i> Lam. (syn. <i>Artemisia herba alba</i> Asso)	Morocco	Aerial parts	β -Thujone (29.0%), camphor (14.7%), octacosane (14.0%)	[7]
<i>Artemisia brachyloba</i> Franch.	Shanxi province, China	Aerial parts	α -Terpineol (21.7%), davabibe (10.7%), 1,8-cineole (6.2%)	[326]
<i>Artemisia douglasiana</i> Besser	Santa Barbara, California, USA	Leaves	Camphor (29.0%), artemisia ketone (26.1%), artemisia alcohol (13.2%), α -thujone (9.7%), 1,8-cineole (7.5%), hexanal (5.3%)	[327]
<i>Artemisia dubia</i> Wall. ex Besser	Kirtipur, Kathmandu, Nepal	Leaves	Chrysanthenone (29.0%), coumarin (18.3%), camphor (16.4%), verbenone (5.2%)	[322]
<i>Artemisia eriopoda</i> Bunge.	Xiaolongmeng National Forest Park, China	Aerial parts	Germacrene D (21.6%), 1,8-cineole (14.2%), δ -elemene (8.0%), sabinene (7.8%)	[328]
<i>Artemisia frigida</i> Willd.	Hohhot, Mongolia	Aerial parts	<i>cis-p</i> -Menth-2-en-1-ol (20.8%), 1,8-cineole (12.0%), borneol (10.2%), lavandulol (9.3%), camphor (6.9%), bicyclogermacrene (5.5%)	[329]

Table 20. (Continued).

Artemisia species	Geographical location	Plant tissue	Major components (> 5%)	Ref.
<i>Artemisia indica</i> Willd.	Dhulikhel, Kavre, Nepal	Leaves	Ascaridole (15.4%), isoascaridole (9.9%), <i>trans-p</i> -mentha-2,8-dien-1-ol (9.7%), <i>trans</i> -verbenol (8.4%), <i>cis-p</i> -mentha-1(7),8-dien-2-ol (6.0%), α -terpineol (5.6%), menthol (5.4%)	[322]
<i>Artemisia judaica</i> L.	Sinai Peninsula, Egypt	Aerial parts	Piperitone (32.4%), camphor (20.6%), ethyl (<i>E</i>)-cinnamate (8.2%)	[330]
<i>Artemisia judaica</i> L.	Gabal Ataka, Suez Desert, Egypt	Aerial parts	Piperitone (43.8%), artemisia ketone (38.9%)	[275]
<i>Artemisia khorassanica</i> Podlech	Khorasane-Razavi, Iran	Leaves	1,8-Cineole (17.7%), camphor (13.9%), davanone (12.2%), isogeraniol (5.7%)	[331]
<i>Artemisia lavandulifolia</i> DC.	Changchun, China	Aerial parts	Artemisia ketone (33.7%), 3-hydroxy-3-methylvaleric acid (7.5%), γ -terpinene (7.0%), butyl acetate (5.1%)	[332]
<i>Artemisia leucotricha</i> Krash. ex Ladygine	Khashkhorog, Ishkoshim District, Tajikistan	Aerial parts	β -Thujone (41.5%), 1,8-cineole (33.0%), camphor (18.3%)	[333]
<i>Artemisia lobelii</i> All.	Zlatibor, Serbia	Aerial parts	Camphor (41.9%), 1,8-cineole (13.8%), <i>syn-anti-anti</i> -Helifolen-12-al A (10.2%), camphene (8.9%)	[157]
<i>Artemisia mongolica</i> (Fisch. ex Besser) Fisch. ex Nakai	Beijing, China	Aerial parts	1,8-Cineole (13.8%), germacrene D (10.4%), camphor (8.6%), artemisia ketone (7.0%), calarene (5.6%)	[209]
<i>Artemisia mongolica</i> (Fisch. ex Besser) Fisch. ex Nakai	Anshan City, China	Aerial parts	1,8-Cineole (39.9%), <i>cis</i> -verbenol (14.9%), terpinen-4-ol (7.2%), camphor (6.0%)	[334]
<i>Artemisia negrei</i> A. Ouyahya	Atlas Mountains, Morocco	Aerial parts	α -Thujone (29.0%), 6-camphenol (14.7%), octacosane (14.0%), 1,8-cineole (5.6%)	[335]
<i>Artemisia negrei</i> A. Ouyahya	Morocco	Aerial parts	Camphor (25.0%), borneol (13.2%), 1,8-cineole (10.9%), fenchone (10.2%), bisabolone oxide A (5.6%)	[7]
<i>Artemisia ordosica</i> Krasch.	Kubuqi Desert, Inner Mongolia, China	Aerial parts	(<i>E</i>)- β -Caryophyllene (17.8%), β -bisabolene (12.1%), spathulenol (10.6%), caryophyllene oxide (8.7%), (<i>E</i>)-phytol (5.6%), β -elemene (5.6%)	[336]
<i>Artemisia ordosica</i> Krasch.	Kubuqi Desert, Inner Mongolia, China	Aerial parts	Spathulenol (9.9%), <i>ar</i> -curcumene (9.2%), α -bisbolol (6.5%), (<i>E</i>)-nerolidol (5.3%)	[337]
<i>Artemisia princeps</i> Pamp.	South Korea	Aerial parts	1,8-Cineole (20.1%), (<i>E</i>)- β -caryophyllene (16.3%), limonene (12.6%), phenol (7.5%), naphthalene (5.5%), <i>cis</i> -sabinene hydrate (5.0%)	[338]
<i>Artemisia rupestris</i> L.	Hebei, China	Aerial parts	α -Terpinyl acetate (37.2%), spathulenol (10.7%), α -terpineol (10.1%), linalool (7.6%)	[339]
<i>Artemisia rupestris</i> L.	Karkaralisk, Kazakhstan	Aerial parts	Myrcene (9.5%), β -elemene (5.4%), decanoic acid (5.1%)	[340]
<i>Artemisia rupestris</i> L.	Altay, China	Leaves	Longifolene (6.0%), tricyclene (5.1%)	[341]
<i>Artemisia santonicum</i> L.	Erzurum region, Türkiye	Aerial parts	Camphor (18.2%), 1,8-cineole (7.5%), β -eudesmol (7.2%)	[342]
<i>Artemisia santonicum</i> L.	Near Eskiköy, Türkiye	Aerial parts	Camphor (36.6%), 1,8-cineole (10.2%), α -thujone (10.1%)	[343]
<i>Artemisia spicigera</i> K. Koch	Erzurum region, Türkiye	Aerial parts	Camphor (34.9%), 1,8-cineole (9.5%), borneol (5.1%)	[342]

Table 20. (Continued).

Artemisia species	Geographical location	Plant tissue	Major components (> 5%)	Ref.
<i>Artemisia spicigera</i> K. Koch	Azarbayjane-Sharghi and Azarbayjane-Ghabi, Iran	Aerial parts	1,8-Cineole (9.1-47.2%), camphor (15.3-39.3%), α -thujone (2.6-21.2%), camphene (2.0-18.7%)	[344]
<i>Artemisia subdigitata</i> Mattf.	Xiaolongmeng National Forest Park, China	Aerial parts	1,8-Cineole (12.3%), <i>ar</i> -curcumene (10.8%), β -pinene (7.4%), borneol (6.2%), eugenol (5.9%)	[345]
<i>Artemisia tridentata</i> subsp. <i>tridentata</i> Nutt.	Swan Falls area, Snake River Canyon, Idaho, USA	Aerial parts	Yomogi alcohol (19.1%), camphor (11.7%), artemisia alcohol (7.8%), β -artemisyl acetate (7.8%), (<i>Z</i>)-tagetone (5.9%)	[346]
<i>Artemisia tridentata</i> subsp. <i>vaseyana</i> (Rydb.) Beetle	Boise Foothills, Idaho, USA	Aerial parts	α -Thujone (23.6%), camphor (21.3%), 1,8-cineole (10.7%)	[347]
<i>Artemisia tridentata</i> subsp. <i>wyomingensis</i> Beetle & A.L.Young	Snake River Birds of Prey National Conservation Area, Idaho, USA	Aerial parts	Camphor (15.2%), artemiseole (7.5%), methyl santoninate (6.2%), santolina triene (5.9%), β -artemisyl acetate (5.2%)	[347]
<i>Artemisia vachanica</i> Krasch. ex Poljakov	Khashkhorog, Ishkashim District, Tajikistan	Aerial parts	1,8-Cineole (52.0%), santolina triene (14.9%), linalool (5.6%)	[348]

composition (Table 21).

3.1.8. *Baccharis* L.

Baccharis is a large genus in the Asteraceae comprising around 480 species, native to the Americas, but several have been introduced to Africa, Asia, Australia, and Europe [33, 355]. Several *Baccharis* species have been investigated for their essential oils and the essential oil phytochemistry, including the biological activities, of *Baccharis* has been reviewed [356–360]. The essential oils of *Baccharis dracunculifolia* DC. (Table 22), *Baccharis punctulata* DC. (Table 23), and *Baccharis trimera* (Less.) DC. (syn. *Baccharis genistelloides* subsp. *crispa* (Spreng.) Joch. Müll.) (Table 24) have been extensively investigated. In addition, recent and complementary aspects of *Baccharis* essential oil compositions are presented in Table 25. It is obvious that there is much variation in the compositions both *Baccharis* species and within *Baccharis* species. Nevertheless, the data suggest opportunities for additional research into the biological activities and potential medicinal applications of essential oils from various *Baccharis* species.

3.1.9. *Balsamorhiza* Hook.

There are 15 species of *Balsamorhiza*, all of which are distributed in western North America [33]. However, only one species of *Balsamorhiza* essential oil has been described in the literature to date. *Balsamorhiza sagittata* (Pursh) Nutt. is native to western North America. The major essential oil components were germacrene D (10.8-34.5%), β -phellandrene (6.4-19.4%), (*E*)- β -caryophyllene (1.4-15.0%), and (*E*)- β -ocimene (3.1-8.4%) [407].

3.1.10. *Bidens* L.

Bidens is a cosmopolitan genus comprising approximately 245 species [33]. The phytochemistry and biological activities of *Bidens pilosa* L. has been reviewed [408]. The important essential oils produced from *Bidens* species include *Bidens pilosa* L. and *Bidens tripartita* L. (Table 26).

3.1.11. *Blumea* DC.

Blumea is a genus of approximately 115 species, which are found naturally in Africa, temperate and tropical Asia [33]. The essential oil compositions and biological activities of *Blumea* species were reviewed in 2024 [27].

Table 21. Chemical compositions of *Aster* essential oils.

<i>Aster</i> species	Geographical location	Plant tissue	Major components (> 5%)	Ref.
<i>Aster ageratoides</i> Turcz.	Beijing, China	Aerial parts	α -Terpineol (10.8%), (<i>E</i>)- β -caryophyllene (10.3%), linalool (7.2%), limonene (6.9%), spathulenol (6.5%), bornyl acetate (5.8%), bicyclosesquiphellandrene (5.6%)	[349]
<i>Aster koraiensis</i> Nakai	Pohang, Kyungbuk Province, Korea	Aerial parts	Caryophyllene oxide (8.4%), aristolene (7.1%), <i>epi</i> -globulol (5.6%)	[350]
<i>Aster ovatus</i> Franch. & Sav.) Hand.-Mazz.	Yoro town, Gifu, Japan	Aerial parts	Bornyl acetate (13.0%), terpinolene (9.7%), bicyclosesquiphellandrene (9.5%), (<i>E</i>)- β -ocimene (9.1%), (<i>Z</i>)- β -ocimene (7.6%)	[351]
<i>Aster scaber</i> Thunb.	Yangsang, Korea	Leaves	Myrcene (18.8%), β -phellandrene (10.6%), germacrene D (7.3%), limonene (5.7%), (<i>E</i>)- β -caryophyllene (5.3%)	[352]
<i>Aster spathulifolius</i> Maxim.	Jeju Island, South Korea	Leaves	Germacrene D (35.1%), (<i>E</i>)- β -caryophyllene (15.9%), (<i>E</i>)-phytol (14.9%), caryophyllene oxide (6.0%), hexahydrofarnesylacetone (5.6%)	[353]
<i>Aster subulatus</i> Michx.	Selçuk, İzmir, Türkiye	Aerial parts	Elemol (21.5%), β -eudesmol (6.3%), caryophyllene oxide (5.2%), α -eudesmol (5.0%)	[354]
<i>Aster tataricus</i> L. f.	Pohang, Kyungbuk Province, Korea	Aerial parts	Germacrene D (14.1%), spathulenol (13.5%)	[350]

Table 22. Chemical compositions of *Baccharis dracunculifolia* essential oils.

Geographical location	Plant tissue	Major components (> 5%)	Ref.
Rio de Janeiro, Brazil	Leaves	Camphor (25.2%), 1,8-cineole (10.4%), myrcene (10.2%), verbenone (10.1%)	[361]
Santa Helena, Paraná, Brazil	Leaves	Bicyclogermacrene (14.2%), germacrene D (9.9%), (<i>E</i>)- β -caryophyllene (8.4%), (<i>E</i>)-nerolidol (8.0%), limonene (6.7%), δ -cadinene (5.5%), β -pinene (5.3%)	[19]
Guaraniãçu, Brazil	Aerial parts	Spathulenol (27.4%), (<i>E</i>)-nerolidol (23.1%), heptacosane (6.0%), β -pinene (5.4%)	[362]
Not indicated	Not indicated	β -Pinene (9.9%), limonene (9.6%), (<i>E</i>)-nerolidol (7.9%), (<i>E</i>)- β -caryophyllene (7.7%), spathulenol (6.7%), α -muurolene (6.7%), α -pinene (5.3%)	[363]
Brasilia, Federal District, Brazil	Leaves	(<i>E</i>)-Nerolidol (28.2%), spathulenol (17.7%), β -copaen-4 α -ol (8.3%)	[364]
Estiva Gerbi, São Paulo, Brazil	Leaves	Limonene (19.4%), bicyclogermacrene (10.8%), β -pinene (9.6%), (<i>E</i>)- β -caryophyllene (6.4%), γ -gurjunene (6.2%), α -pinene (5.7%), α -cadinene (5.4%)	[364]
Canelinha, Santa Catarina, Brazil	Leaves	Bicyclogermacrene (14.2%), (<i>E</i>)-nerolidol (14.0%), limonene (10.5%), β -pinene (9.7%), spathulenol (9.5%), (<i>E</i>)- β -caryophyllene (8.7%), γ -gurjunene (6.2%)	[364]
Federal University of Technology, Paraná, Brazil	Leaves	(<i>E</i>)-Nerolidol (17.6%), γ -elemene (15.1%), limonene (10.5%), (<i>E</i>)- β -caryophyllene (9.8%), β -pinene (9.6%), spathulenol (8.5%), germacrene D (8.2%)	[365]
Franca, São Paulo State, Brazil	Leaves	(<i>E</i>)-Nerolidol (23.6%), germacrene D (21.5%), bicyclogermacrene (19.2%), (<i>E</i>)- β -caryophyllene (7.2%), spathulenol (6.0%)	[366]
Estación Porvenir, Paysandú, Uruguay	Aerial parts (♀)	(<i>E</i>)-Nerolidol (17.3%), β -pinene (10.9%), limonene (8.9%), spathulenol (5.2%)	[367]

Table 22. (Continued).

Geographical location	Plant tissue	Major components (> 5%)	Ref.
Estación Porvenir, Paysandú, Uruguay	Aerial parts (σ)	(E)-Nerolidol (16.7%), β-pinene (10.5%), limonene (9.1%), spathulenol (5.5%)	[367]
Las Brujas INIA Research Station, Canelones Province, Uruguay	Aerial parts	Spathulenol (13.8%), β-pinene (11.8%), viridiflorol (11.2%), limonene (8.2%), caryophyllene oxide (7.1%)	[368]
Commercial, São Paulo, Brazil	Not indicated	Limonene (20.0%), (E)-nerolidol (13.0%), bicyclogermacrene (10.8%), β-pinene (9.6%), (E)-β-caryophyllene (6.4%), γ-gurjunene (6.2%), α-pinene (6.0%), α-cadinene (5.4%)	[369]
Franca, São Paulo State, Brazil	Aerial parts	(E)-Nerolidol (33.5%), spathulenol (16.2%)	[370]
Bento Gonçalves, Rio Grande do Sul, Brazil	Leaves	β-Pinene (18.0%), ledol (13.6%), spathulenol (13.4%), limonene (10.1%), germacra-1(10),5-dien-4β-ol (5.4%)	[371]
Cerrado biome, Brazil	Leaves	(E)-Nerolidol (22.7-38.6%), spathulenol (7.7-23.5%), limonene (9.9-13.7%), β-pinene (5.3-12.9%), α-pinene (2.5-6.3%)	[372]
Commercial (Harmonia Natural, Canelinha, Santa Catarina, Brazil)	Not indicated	Spathulenol (14.8%), β-pinene (11.4%), (E)-nerolidol (10.2%), limonene (9.1%), (E)-β-caryophyllene (8.5%), bicyclogermacrene (7.7%), iso-aromadendrene epoxide (6.3%), α-pinene (6.1%)	[8]
Particular do Patrimônio Natural (RPPN) Butuquara, Brazil	Leaves	(E)-Nerolidol (8.9-21.7%), limonene (11.7-14.6%), β-pinene (8.9-16.2%), spathulenol (5.1-9.4%), bicyclogermacrene (3.5-8.1%)	[373]

♀ = Female plant. σ = Male plant.

Table 23. Chemical compositions of *Baccharis punctulata* essential oils.

Geographical location	Plant tissue	Major components (> 5%)	Ref.
Santa Helena, Paraná, Brazil	Leaves (♀)	Bicyclogermacrene (42.4%), germacrene D (21.2%), (E)-β-caryophyllene (14.1%)	[374]
Santa Helena, Paraná, Brazil	Leaves (σ)	δ-Elemene (14.3%), germacrene D (11.3%), bicyclogermacrene (10.9%), (E)-β-farnesene (6.7%), β-elemene (6.1%)	[374]
Campos Gerais, Ponta Grossa, Paraná	Aerial parts	α-Bisabolol (23.6%), limonene (11.4%), spathulenol (10.0%), β-pinene (5.0%)	[375]
Roldán City, Argentina	Leaves	Alismol (18.9%), spathulenol (9.4%), caryophyllene oxide (5.2%)	[376]
Luján, Buenos Aires State, Argentina	Leaves (♀)	Verboccidentafuran (16.3-47.5%), δ-elemene (4.8-16.4%), germacra-1(10),5-dien-4α-ol (7.0-10.6%), amorph-4,7(11)-dien (2.2-9.4%)	[377]
Luján, Buenos Aires State, Argentina	Leaves (σ)	Verboccidentafuran (22.4-43.9%), δ-elemene (8.6-9.1%), germacra-1(10),5-dien-4α-ol (0.7-17.3%), amorph-4,7(11)-dien (2.3-7.5%)	[377]
Luján, Buenos Aires State, Argentina	Leaves (σ)	Verboccidentafuran (5.2-49.0%), amorph-4-en-7-ol (2.2-22.8%), alismol (0.0-25.7%), germacra-1(10), 5-dien-4α-ol (2.2-18.9%)	[378]
Estación Porvenir, Paysandú, Uruguay	Aerial parts	Germacra-1(10), 5-dien-4α-ol (7.0%), β-phellandrene (5.2%), bornyl acetate (5.2%)	[367]

♀ = Female plant. σ = Male plant.

Table 24. Chemical compositions of *Baccharis trimera* essential oils.

Geographical location	Plant tissue	Major components (> 5%)	Ref.
Paraná, Brazil	Cladodes	Carquejyl acetate (73.3-73.5%), ledol (6.0-7.7%)	[379]
Santa Catarina, Brazil	Cladodes	Carquejyl acetate (65.1-66.7%), ledol (7.0-7.7%), carquejol (6.2-6.3%)	[379]
Commercial, Laszlo Aromatology Company, Brazil	Leaves	β -Pinene (23.4%), carquejyl acetate (19.0%), (<i>E</i>)- β -caryophyllene (6.4%), limonene (5.9%), germacrene D (5.0%)	[380]
Private Reserve of Natural Patrimony, Paraná, Brazil	Leaves	Carquejyl acetate (28.2%), palustrol (11.5%), β -pinene (9.7%), viridiflorol (7.3%), β -eudesmol (6.4%), bicyclogermacrene (6.0%)	[381]
Unicamp – Campinas, São Paulo, Brazil	Leaves	Germacrene D (15.3%), (<i>E</i>)- β -caryophyllene (14.8%), bicyclogermacrene (14.7%), δ -cadinene (6.8%)	[382]
Atlantic Forest near Piraquara, Paraná, Brazil	Leaves	Limonene (42.2%), carquejyl acetate (22.0%), palustrol (13.1%), β -eudesmol (6.1%)	[383]
Campinas State University (UNICAMP), Paulínia-SP, Brazil	Aerial parts	(<i>E</i>)- β -Caryophyllene (18.9%), bicyclogermacrene (15.6%), germacrene D (10.6%), δ -cadinene (6.7%), caryophyllene oxide (5.5%)	[384]
Erechim, Rio Grande Do Sul, Brazil	Leaves	Carquejyl acetate (73.6%), palustrol (5.5%)	[385]
Bento Gonçalves, Rio Grande do Sul, Brazil	Leaves	Carquejyl acetate (67.5%), α -thujene (6.2%)	[371]
Various sites from northern Argentina and southern Brazil	Aerial parts	Carquejyl acetate (35.5-68.0%), ledol (5.9-24.2%), β -eudesmol (2.3-14.8%)	[386]
Piraquara, Parana, Brasil	Leaves	Carquejyl acetate (52.7%), limonene (18.6%), palustrol (6.4%)	[387]

Table 25. Chemical compositions of *Baccharis* essential oils.

<i>Baccharis</i> species	Geographical location	Plant tissue	Major components (> 5%)	Ref.
<i>Baccharis albilanosa</i> A.S. Oliveira & Deble	Grassland, Rio Grande do Sul, Brazil	Aerial Parts	Spathulenol (38.6%), caryophyllene oxide (14.0%)	[20]
<i>Baccharis anomala</i> DC.	Atlantic Forest near Piraquara, Paraná, Brazil	Leaves	β -Pinene (18.3%), thujopsan-2 α -ol (17.7%), limonene (13.0%), globulol (10.9%), spathulenol (8.0%), viridiflorol (7.2%), α -muurolol (6.3%), β -eudesmol (6.0%)	[383]
<i>Baccharis anomala</i> DC.	Piraquara, Parana, Brasil	Leaves	Limonene (23.9%), germacrene D (19.7%), δ -cadinene (8.0%), (<i>E</i>)- β -caryophyllene (7.3%)	[387]
<i>Baccharis aracatubaensis</i> Malag.	Morro do Canal, Piraquara, Paraná, Brazil	Inflorescences	γ -Muurolene (21.4-23.9%), bicyclogermacrene (21.4-21.7%), (<i>E</i>)- β -caryophyllene (10.9-12.7%), δ -cadinene (6.6-8.2%), mint sulfide (3.2-6.9%)	[21]
<i>Baccharis articulata</i> Pers.	BioEstação Gaia, Piraquara, Paraná, Brazil	Aerial parts	β -Pinene (52.2%), limonene (17.4%), germacrene D (9.0%)	[388]
<i>Baccharis articulata</i> Pers.	Los Cerrillos, Canelones, Uruguay	Aerial parts	β -Pinene (25.6%), spathulenol (12.9%), caryophyllene oxide (10.1%)	[367]

Table 25. (Continued).

Baccharis species	Geographical location	Plant tissue	Major components (> 5%)	Ref.
<i>Baccharis articulata</i> Pers.	Erechim, Rio Grande Do Sul, Brazil	Leaves	β -Pinene (22.3%), (<i>E</i>)- β -caryophyllene (21.5%), bicyclogermacrene (17.6%), guaia-3,9-diene (10.5%), spathulenol (9.9%), <i>neo-iso</i> -longifolene (7.6%), germacrene D (6.8%)	[385]
<i>Baccharis articulata</i> Pers.	Piraquara, Parana, Brasil	Leaves	Limonene (38.4%), β -pinene (30.2%)	[387]
<i>Baccharis axillaris</i> DC.	Piraquara, Parana, Brasil	Leaves	α -Pinene (41.9%), limonene (31.9%), β -pinene (7.4%)	[387]
<i>Baccharis boliviensis</i> (Wedd.) Cabrera	Near La Paz, Bolivia	Leaves	Limonene (17.4-29.6%), α -pinene (11.9-14.7%), β -pinene (10.0-10.4%), <i>p</i> -cymene (8.6-10.4%), sabinene (7.2-11.9%), myrcene (4.6-5.8%)	[389]
<i>Baccharis burchellii</i> Baker	Morro do Canal, Piraquara, Paraná, Brazil	Inflorescences	Bicyclogermacrene (17.8-20.7%), γ -muurolene (7.3-10.8%), (<i>E</i>)- β -caryophyllene (6.9-11.8%), thujopsan-2 α -ol (6.4-9.1%), β -eudesmol (0.4-12.3%)	[21]
<i>Baccharis calvescens</i> DC.	Atlantic Forest near Piraquara, Paraná, Brazil	Leaves	Spathulenol (21.3%), limonene (20.6%), α -pinene (15.7%), thujopsan-2 α -ol (13.2%), β -pinene (11.8%)	[383]
<i>Baccharis calvescens</i> DC.	BioEstação Gaia, Piraquara, Paraná, Brazil	Aerial parts	β -Pinene (25.1%), limonene (22.8%), α -pinene (15.6%), germacrene D (6.5%)	[388]
<i>Baccharis calvescens</i> DC.	Piraquara, Parana, Brasil	Leaves	Limonene (39.5%), β -pinene (13.7%)	[387]
<i>Baccharis coridifolia</i> DC.	Private Reserve of Natural Patrimony, Paraná, Brazil	Aerial parts	Germacrene D (23.7%), bicyclogermacrene (17.1%), (<i>E</i>)- β -caryophyllene (8.4%), (<i>E</i>)- β -ocimene (8.2%), spathulenol (8.1%), myrcene (6.7%), β -pinene (5.8%)	[390]
<i>Baccharis coridifolia</i> DC.	Grassland, Rio Grande do Sul, Brazil	Aerial Parts	Spathulenol (25.1%), caryophyllene oxide (11.3%)	[20]
<i>Baccharis crispa</i> Spreng.	Quebrada de los Quervos, Treinta y Tres, Uruguay	Aerial parts (♀)	Spathulenol (16.1%), globulol (15.0%), caryophyllene oxide (12.7%)	[367]
<i>Baccharis crispa</i> Spreng.	Quebrada de los Quervos, Treinta y Tres, Uruguay	Aerial parts (♂)	Globulol (17.8%), spathulenol (16.4%), caryophyllene oxide (10.8%)	[367]
<i>Baccharis cultrata</i> Baker	Quebrada de los Cuervos, Uruguay	Aerial parts	Sylvestrene (10.6%), terpinen-4-ol (10.1%), spathulenol (10.0%), β -pinene (7.3%), (<i>E</i>)- β -caryophyllene (6.7%), sabinene (5.1%)	[367]
<i>Baccharis densiflora</i> Wedd.	Near La Paz, Bolivia	Leaves	Limonene (46.2%), α -pinene (16.4%), β -pinene (7.2%), (<i>E</i>)- β -ocimene (5.9%), myrcene (5.6%)	[389]
<i>Baccharis erigeroides</i> DC.	Grassland, Rio Grande do Sul, Brazil	Aerial Parts	Spathulenol (19.7%), caryophyllene oxide (11.0%)	[20]
<i>Baccharis erioclada</i> DC.	Campos Gerais, Ponta Grossa, Paraná, Brazil	Aerial parts	Dihydro- <i>ar</i> -turmerone (28.0%), fokienol (13.5%), ledol (9.8%), α -santalol (5.4%)	[391]

Table 25. (Continued).

Baccharis species	Geographical location	Plant tissue	Major components (> 5%)	Ref.
<i>Baccharis gaudichaudiana</i> DC.	Prov. Misiones, Argentina	Aerial parts	Spathulenol (22.0-38.2%), β -pinene (25.1-31.0%), caryophyllene oxide (8.7-14.0%), limonene (4.6-7.2%)	[392]
<i>Baccharis genistifolia</i> DC.	El Pinar, Canelones, Uruguay	Aerial parts	α -Muurolol (13.4%), himachalol (8.0%), α -cadinol (6.6%), γ -muurolene (5.9%)	[367]
<i>Baccharis gibertii</i> Baker	El Pinar, Canelones, Uruguay	Aerial parts	Geranyl acetate (55.5%)	[367]
<i>Baccharis gnaphalioides</i> Spreng.	El Pinar, Canelones, Uruguay	Aerial parts	α -Cadinol (13.8%), spathulenol (11.6%), ζ -muurolol ^a (10.6%), δ -cadinene (5.7%)	[367]
<i>Baccharis halimifolia</i> L.	Poitiers, France	Leaves	Caryophyllene oxide (37.5%), humulene epoxide II (8.1%)	[393]
<i>Baccharis heterophylla</i> Kunth	Capulálpam de Méndez, Oaxaca, México	Aerial parts	Limonene (36.2%), myrcene (29.6%), β -pinene (28.9%), α -pinene (5.3%)	[394]
<i>Baccharis latifolia</i> Pers.	Near La Paz, Bolivia	Leaves	α -Pinene (6.3-8.6%), α -thujene (6.2-8.0%), γ -cadinene (5.3-5.9%), β -pinene (4.3-5.2%), β -cadinene (1.3-10.2%), aromadendrene (0.0-12.1%)	[389]
<i>Baccharis linearifolia</i> Pers. subsp. <i>linearifolia</i>	Quebrada de los Quervos, Treinta y Tres, Uruguay	Aerial parts (♀)	α -Pinene (18.0%), β -pinene (16.7%), benzyl salicylate (14.3%), myrcene (5.9%)	[367]
<i>Baccharis linearifolia</i> Pers. subsp. <i>linearifolia</i>	Quebrada de los Quervos, Treinta y Tres, Uruguay	Aerial parts (♂)	α -Pinene (25.0%), β -pinene (21.6%), benzyl salicylate (9.3%), benzyl benzoate (6.9%)	[367]
<i>Baccharis mesoneura</i> DC.	Atlantic Forest near Piraquara, Paraná, Brazil	Leaves	α -Pinene (72.6%), β -pinene (14.1%), limonene (13.3%)	[383]
<i>Baccharis mesoneura</i> DC.	Piraquara, Parana, Brasil	Leaves	Limonene (32.2%), α -pinene (15.5%), α -thujene (14.4%), β -pinene (8.2%), sabinene (6.3%)	[387]
<i>Baccharis microcephala</i> DC.	Prov. Misiones, Argentina	Aerial parts	Caryophyllene oxide (22.4%), spathulenol (17.4%), humulene epoxide II (12.4%), globulol (10.1%)	[392]
<i>Baccharis microdonta</i> DC.	Campos Gerais, Ponta Grossa, Paraná, Brazil	Aerial parts	Spathulenol (22.7%), kongol (22.2%)	[375]
<i>Baccharis microdonta</i> DC.	Research Station, Canelones Province, Uruguay	Aerial parts	Spathulenol (17.3%), caryophyllene oxide (14.0%), limonene (9.6%), β -pinene (6.1%)	[368]
<i>Baccharis milleflora</i> DC.	Atlantic Forest near Piraquara, Paraná, Brazil	Leaves	β -Pinene (67.5%), limonene (28.2%)	[383]
<i>Baccharis milleflora</i> DC.	BioEstação Gaia, Piraquara, Paraná, Brazil	Aerial parts	Bicyclogermacrene (12.1%), (<i>E</i>)- β -caryophyllene (11.9%), germacrene D (10.1%), α -pinene (6.8%), β -phellandrene (5.9%), α -humulene (5.9%), myrcene (5.3%)	[388]
<i>Baccharis milleflora</i> DC.	Piraquara, Parana, Brasil	Leaves	Viridiflorol (24.1%), limonene (22.6%)	[387]

Table 25. (Continued).

Baccharis species	Geographical location	Plant tissue	Major components (> 5%)	Ref.
<i>Baccharis myriocephala</i> Baker	Piraquara, Parana, Brasil	Leaves	Limonene (41.9%), β -pinene (16.7%)	[387]
<i>Baccharis myriocephala</i> Baker (syn. <i>Baccharis genistelloides</i> subsp. <i>crispa</i> (Spreng.) Joch. Müll)	Teresópolis, Rio de Janeiro State, Brazil	Leaves	β -Copaene (36.1%), (<i>E</i>)- β -caryophyllene (13.8%), myrcene (7.2%)	[395]
<i>Baccharis napaea</i> G. Heiden	Grassland, Rio Grande do Sul, Brazil	Aerial Parts	Spathulenol (28.5%), caryophyllene oxide (15.2%)	[20]
<i>Baccharis oblongifolia</i> Pers.	Atlantic Forest near Piraquara, Paraná, Brazil	Leaves	α -Pinene (22.1%), α -thujene (20.2%), limonene (12.5%), β -pinene (10.8%), sabinene (9.9%), β -phellandrene (6.6%), terpinen-4-ol (5.5%)	[383]
<i>Baccharis oblongifolia</i> Pers.	Piraquara, Parana, Brasil	Leaves	Limonene (32.7%), germacrene D (6.3%), β -pinene (5.0%)	[387]
<i>Baccharis ochracea</i> Spreng.	Quebrada de los Cuervos, Treinta y Tres, Uruguay	Aerial parts	Spathulenol (30.8%), caryophyllene oxide (14.1%)	[367]
<i>Baccharis ochracea</i> Spreng.	Grassland, Rio Grande do Sul, Brazil	Aerial Parts	Spathulenol (28.6%), caryophyllene oxide (12.7%)	[20]
<i>Baccharis odorata</i> Spreng.	Cuzco, Peru	Aerial parts	δ -Cadinene (9.1%), β -pinene (8.8%), α -cadinol (8.1%), limonene (6.2%), τ -cadinol (5.5%)	[396]
<i>Baccharis oreophilla</i> Malme	Piraquara, Paraná, Brazil	Leaves	Khusimone (16.4%), spathulenol (16.1%), δ -cadinol (5.7%)	[397]
<i>Baccharis organensis</i> Baker	Morro do Canal, Piraquara, Paraná, Brazil	Inflorescences	Viridiflorol (11.9-23.0%), bicyclogermacrene (15.1-15.2%), γ -muurolene (6.8-10.4%), curcuphenol (4.8-5.9%)	[21]
<i>Baccharis palustris</i> Heering	Paso Carrasco region, Uruguay	Aerial parts	Baccharisdiyne (52.7%), (7 <i>Z</i>)-dehydrobaccharisdiyne (14.4%), (<i>E</i>)- β -ocimene (8.3%), (<i>Z</i>)-lachnophyllum ester (5.3%)	[398]
<i>Baccharis papillosa</i> Rusby	Near La Paz, Bolivia	Leaves	α -Pinene (20.4-23.6%), α -thujene (7.4-10.3%), β -pinene (5.4-5.9%), α -cubebene (0.8-12.5%), γ -amorphene (1.0-9.6%)	[389]
<i>Baccharis parvidentata</i> Malag.	Pedra do Sino, Teresópolis, Brazil	Aerial parts	Sabinene (15.2%), β -pinene (9.2%), δ -3-carene (5.7%)	[399, 400]
<i>Baccharis pauciflosculosa</i> DC.	Campos Gerais, Ponta Grossa, Paraná	Aerial parts	Limonene (18.8%), β -pinene (18.3%), α -pinene (10.5%), spathulenol (9.5%)	[375]
<i>Baccharis penningtonii</i> Heering	Prov. Entre Ríos, Argentina	Aerial parts	Germacrene D (29.3%)	[392]
<i>Baccharis phyteumoides</i> DC.	Mendoza Chico, Florida, Uruguay	Aerial parts	Limonene (20.1%), spathulenol (7.8%)	[367]
<i>Baccharis phyteumoides</i> DC.	Prov. Santa Fe, Argentina	Aerial parts	(<i>E</i>)-Phytyl acetate (16.2%), β -selinene (12.9%), limonene (8.7%), spathulenol (8.2%), caryophyllene oxide (5.7%)	[392]

Table 25. (Continued).

Baccharis species	Geographical location	Plant tissue	Major components (> 5%)	Ref.
<i>Baccharis pluricapitulata</i> (Deble) G. Heiden	Grassland, Rio Grande do Sul, Brazil	Aerial Parts	Caryophyllene oxide (17.1%), spathulenol (7.5%)	[20]
<i>Baccharis psiadioides</i> (Less.) Joch.Müll.	Morro Santana, Campos Sulinos rebion, Brazil	Leaves	β -Pinene (44.7%), δ -3-carene (13.5%), limonene (6.5%)	[22]
<i>Baccharis reticularia</i> DC.	Restinga de Jurubatiba National Park, Brazil	Aerial parts	Limonene (14.6%), myrcene (12.6%), bicyclogermacrene (12.5%), (<i>E</i>)- β -caryophyllene (10.7%), β -eudesmol (10.4%), spathulenol (6.9%)	[401]
<i>Baccharis reticularioides</i> Deble & A.S.Oliveira	Campos Gerais, Ponta Grossa, Paraná	Aerial parts	α -Pinene (24.5%), β -pinene (7.7%), α -phellandren-8-ol (5.6%), spathulenol (5.5%)	[375]
<i>Baccharis reticulata</i> (Ruiz & Pav.) Pers.	Private Reserve of Natural Patrimony, Paraná, Brazil	Aerial parts	Dillapiole (33.8%), α -pinene (31.7%), β -pinene (9.4%), limonene (7.0%)	[402]
<i>Baccharis semiserrata</i> DC.	Ponta Grossa, Paraná, Brazil	Leaves (♀)	Spathulenol (42.7%), aromadendrene (9.6%), δ -cadinene (9.5%), α -muurolene (8.9%)	[403]
<i>Baccharis semiserrata</i> DC.	Ponta Grossa, Paraná, Brazil	Leaves (σ)	Spathulenol (50.8%), α -eudesmol (5.5%)	[403]
<i>Baccharis sphenophylla</i> Dusén ex Malme	Campos Gerais, Ponta Grossa, Paraná	Aerial parts	β -Pinene (15.2%), limonene (14.3%), spathulenol (13.2%), α -pinene (10.7%)	[375]
<i>Baccharis spicata</i> (Lam.) Baill.	Roldán City, Argentina	Leaves	Caryophyllene oxide (31.9%), spathulenol (26.3%), β -pinene (14.6%), (<i>E</i>)- β -caryophyllene (5.4%)	[376]
<i>Baccharis spicata</i> (Lam.) Baill.	Quebrada de los Quervos, Treinta y Tres, Uruguay	Aerial parts (♀)	β -Pinene (20.1%), spathulenol (18.9%), caryophyllene oxide (9.9%), limonene (8.5%)	[367]
<i>Baccharis spicata</i> (Lam.) Baill.	Quebrada de los Quervos, Treinta y Tres, Uruguay	Aerial parts (σ)	Spathulenol (24.0%), caryophyllene oxide (9.6%), β -pinene (5.9%), limonene (5.1%)	[367]
<i>Baccharis spicata</i> (Lam.) Baill.	Northeastern Argentina	Aerial parts	β -Pinene (7.1-26.0%), spathulenol (13.1-18.7%), caryophyllene oxide 3.6-15.1%), (<i>E</i>)- β -caryophyllene (7.7-8.3%), limonene (4.4-8.1%)	[392]
<i>Baccharis tola</i> Phil.	Near La Paz, Bolivia	Leaves	α -Pinene (15.0-22.0%), β -pinene (18.4-21.9%)	[389]
<i>Baccharis tridentata</i> Vahl	São Francisco de Paula, Rio Grande do Sul, Brazil	Aerial parts (♀)	α -Pinene (29.5%), β -pinene (17.9%), limonene (16.4%), bornyl acetate (10.1%)	[404]
<i>Baccharis tridentata</i> Vahl	São Francisco de Paula, Rio Grande do Sul, Brazil	Aerial parts (σ)	α -Pinene (30.8%), β -pinene (17.0%), limonene (16.7%), bornyl acetate (9.1%)	[404]
<i>Baccharis uncinella</i> DC.	Atlantic Forest near Curitiba, Paraná, Brazil	Leaves	Limonene (88.8%), β -pinene (7.6%)	[383]
<i>Baccharis uncinella</i> DC.	Piraquara, Parana, Brasil	Leaves	Limonene (24.1%), spathulenol (17.2%), α -pinene (6.7%), caryophyllene oxide (6.3%)	[387]

♀ = Female plant. σ = Male plant. ^a This name is not found in the Adams database [405], the Dictionary of Natural Products [98], or NIST website [406].

Table 26. Chemical compositions of *Bidens* essential oils.

<i>Bidens</i> species	Geographical location	Plant tissue	Major components (> 5%)	Ref.
<i>Bidens alba</i> DC.	Kendall, Miami, Florida, USA	Leaves	1-Phenylhepta-1,3,5-triene (54.0%), α -pinene (10.1%), 1-phenylhept-5-ene-1,3-diyne (6.1%)	[409]
<i>Bidens bipinnata</i> L.	Fortaleza, Ceara, Brazil	Aerial parts	Thymol (17.7%), (<i>E</i>)- β -caryophyllene (16.8%), γ -cadinene (14.0%), γ -elemene (11.9%), δ -cadinene (5.8%), α -humulene (10.5%), thymyl methyl ether (5.1%)	[410]
<i>Bidens cernua</i> L.	Vlasina Lake, Serbia	Aerial parts	1-Phenylhepta-1,3,5-triene (57.1%)	[411]
<i>Bidens cernua</i> L.	Southeastern Poland	Aerial parts	Linalool (7.6%), β -elemene (7.3%), (<i>E</i>)- β -caryophyllene (6.7%)	[412]
<i>Bidens frondosa</i> L.	Lishui City, Zhejiang Province, China	Aerial parts	Caryophyllene oxide (20.5%), borneol (17.7%), terpinen-4-ol (17.3%), β -funebrene (6.9%)	[413]
<i>Bidens graveolens</i> Mart.	Chapada dos Veadeiros, Goiás, Brazil	Leaves	Limonene (22.8-47.7%), α -pinene (18.3-21.0%), β -pinene (14.2-14.9%)	[414]
<i>Bidens pilosa</i> L.	San Isidro, Buenos Aires, Argentina	Leaves	1-Phenylhepta-1,3,5-triene (48.0%), germacrene D (18.0%), 1-phenylhept-5-ene-1,3-diyne (13.7%), (<i>E</i>)- β -caryophyllene (6.1%)	[409]
<i>Bidens pilosa</i> L.	Lower Himalaya, India	Roots	Octadecadienol ^a (32.8%), bornyl acetate (19.4%), 1-hexadecanol (7.7%)	[415]
<i>Bidens pilosa</i> L.	Iwo, Nigeria	Leaves	Caryophyllene oxide (37.0%), (<i>E</i>)- β -caryophyllene (10.5%), humulene epoxide II (6.0%), germacrene D (5.5%)	[416]
<i>Bidens pilosa</i> L.	Medicinal Plant Garden, State University of Santa Cruz, Ilhéus, Bahia, Brazil	Leaves	1-Phenylhepta-1,3,5-triene (69.4%)	[417]
<i>Bidens tripartita</i> L.	Białystok, Poland	Roots	α -Pinene (15.0%), β -bisabolene (9.3%), <i>p</i> -cymene (6.0%), hexanal (5.7%)	[418]
<i>Bidens tripartita</i> L.	Bielsk Podlaski, Poland	Aerial parts	<i>allo</i> -Ocimene (38.3%), (<i>Z</i>)- β -ocimene (30.6%)	[419]
<i>Bidens tripartita</i> L.	Kaunas Botanic Garden, Vytautas Magnus University, Lithuania	Aerial parts ^b	(<i>Z</i>)- β -Ocimene (40.5-45.9%), β -elemene (9.9-15.6%), α -pinene (3.7-12.1 %), α -humulene (5.2-8.2%), <i>trans</i> - α -bergamotene (3.3-9.4%), (<i>E</i>)- β -caryophyllene (4.3-6.8%), <i>p</i> -cymene (2.8-8.0 %)	[420]

^a Correct isomer was not identified. ^b Supercritical CO₂ extraction.

3.1.12. *Boltonia* L'Hér.

Boltonia is a relatively small genus comprising seven species found in North America [33]. *Boltonia asteroides* (L.) L'Hér. essential oil was dominated by germacrene D (47.4%) along with (*Z,E*)-matricaria ester (15.4%) and β -pinene (7.3%) [421].

3.1.13. *Chaenactis* DC.

There are 21 species of *Chaenactis* currently listed in the World Flora Online [33], all of which are found in western North America. The essential oil of *Chaenactis*

douglasii Hook. & Arn. showed tiglic acid (35.9%) as the major component, followed by thymol (8.4%) and δ -cadinene (5.0%) [422].

3.1.14. *Chamaemelum* Mill.

The most important species of this genus is *Chamaemelum nobile* All. (syn. *Anthemis nobilis* L., Roman chamomile). The chemotypes of *C. nobile* (syn. *A. nobilis*) have been reviewed [28]. The major essential oil components of *Chamaemelum* species are summarized in Table 27.

Table 27. Chemical compositions of *Chamaemelum* essential oils.

<i>Chamaemelum</i> species	Geographical location	Plant tissue	Major components (> 5%)	Ref.
<i>Chamaemelum fuscatum</i> (Brot.) Vasc.	Cerro del Viento, Badajoz, Spain	Aerial parts	(<i>E</i>)-2-Methyl-2-butenyl methacrylate (18.5%), palmitic acid (10.7%), <i>ar</i> -curcumene (8.1%), 2-methylallyl isobutyrate (7.5%)	[423]
<i>Chamaemelum mixta</i> All.	Corsica	Aerial parts	Santolina alcohol (12.5-26.2%), germacrene D (6.0-28.6%), yomogi alcohol (0.7-16.2%), (<i>E,E</i>)- α -farnesene (3.4-15.6%), artemisia alcohol (1.3-13.2%), (<i>Z</i>)-heptadeca-9,16-dien-7-one (4.4-11.5%), (<i>E</i>)- β -farnesene (1.9-11.3%)	[424]
<i>Chamaemelum mixta</i> All.	Sardinia	Aerial parts	Santolina alcohol (39.8-46.2%), (<i>Z</i>)-heptadeca-9,16-dien-7-one (12.3-12.7%), (<i>E</i>)- β -farnesene (3.0-5.6%)	[424]
<i>Chamaemelum nobile</i> All.	Eastern Cape, South Africa	Flowers	α -Bisabolol oxide A (50.0%), (<i>E</i>)- β -farnesene (5.4%)	[425]
<i>Chamaemelum nobile</i> All.	Southeastern Serbia	Flowers	3-Methylpentyl angelate (4.9-20.9%), artemisia ketone (4.1-15.9%), isoamyl angelate (5.5-13.8%), isoamyl tiglate (5.5-11.4%), isobutyl angelate (4.3-13.6%), camphene (1.4-12.3%), α -pinene (4.7-10.9%), octyl formate (3.5-7.9%)	[426]
<i>Chamaemelum nobile</i> All.	Khénifra, Morocco	Aerial parts	Verbenone (33.7%), pulegone (26.5%), 2-isopropyl-5-methylcyclohex-3-en-1-one (8.9%)	[427]
<i>Chamaemelum nobile</i> All.	Shoushtar, Iran	Aerial parts	Chamazulene (27.8%), β -pinene (7.9%), 1,8-cineole (7.5%), α -pinene (5.9%), α -bisabolol (5.8%)	[428]
<i>Chamaemelum nobile</i> All.	France	Flowers	Isobutyl angelate (32.1%), 2-methylbutyl angelate (16.2%), isobutyl isobutyrate (5.3%)	[429]
<i>Chamaemelum nobile</i> All.	Nitra, Slovak Republic	Flowers	Isobutyl angelate (21.6%), 2-methylbutyl angelate (14.4%), 2-methyl-2-propenyl angelate (9.1%), 3-methylamyl angelate (8.4%), isoamyl angelate (5.5%), 2-methylbutyl isobutyrate (5.2%), (<i>E</i>)-2-methyl-2-propenyl isobutyrate	[430]

3.1.15. *Dieteria* Nutt.

There are three species of *Dieteria*, which are found in western North America, *Dieteria asteroides* Torr., *Dieteria bigelovii* (A. Gray) D.R.Morgan & R.L.Hartm., and *Dieteria canescens* (Pursh) Nutt. [33]. Only *D. canescens* has been analyzed in terms of its essential oil composition [422]. The sesquiterpenoid-rich essential oil was composed largely of δ -cadinene (28.3%), *epi*-cubebol (24.4%), 1-*epi*-cubebol (10.0%), and cubenol (7.7%).

3.1.16. *Chromolaena* DC.

Chromolaena is a large genus comprising approximately 176 species, native to the Americas [33]. Two species, *Chromolaena laevigata* (Lam.) R.M. King & H. Rob. and *Chromolaena odorata* (L.) R.M. King & H. Rob. have been examined for essential oil compositions (Table 28). *Chromolaena laevigata* is native to the Neotropics, whereas *C. odorata* is native to tropical and warm temperate North, Central, and

South America, but has been introduced to tropical areas of Africa, Asia, and Australia [33].

3.1.17. *Chrysanthemum* L.

There are approximately 69 species of *Chrysanthemum* found in the northern hemisphere [33]. The volatile phytochemistry of *Chrysanthemum* has been reviewed [442-444]. Only recent aspects of the essential oil compositions of *Chrysanthemum* are included here (Table 29). The native range of *Chrysanthemum indicum* L. is to Bhutan, China, India, Japan, Korea, Nepal, Russia, and Uzbekistan [445]. *Chrysanthemum morifolium* Ramat. is common in East Asia. These two species are the main parents of commercial (florist's) chrysanthemum.

3.1.18. *Chrysothamnus* Nutt.

There are 12 recognized species of *Chrysothamnus*, all of which are found in western North America [33]. The essential oil of *Chrysothamnus viscidiflorus* Nutt. from Idaho, USA, was dominated by monoterpene

Table 28. Chemical compositions of *Chromolaena* essential oils.

<i>Chromolaena</i> species	Geographical location	Plant tissue	Major components (> 5%)	Ref.
<i>Chromolaena laevigata</i> (Lam.) R.M. King & H. Rob.	Instituto de Botânica, São Paulo, Brazil	Leaves	Laevigatin (24.2%), spathulenol (17.4%), germacrene D (8.2%), bicyclogermacrene (5.9%), β -bisabolene (5.0%)	[431]
<i>Chromolaena laevigata</i> (Lam.) R.M. King & H. Rob.	Gonzanamá, Loja Province, Ecuador	Aerial parts	Laevigatin (46.8%), germacrene D (15.4%), viridiflorol (11.4%)	[432]
<i>Chromolaena odorata</i> (L.) R.M. King & H. Rob.	Godomey, Benin	Leaves	α -Pinene (20.7%), pregeijerene (14.6%), geijerene (12.0%), β -pinene (10.3%), germacrene D (9.7%), (<i>E</i>)- β -caryophyllene (6.5%)	[433]
<i>Chromolaena odorata</i> (L.) R.M. King & H. Rob.	Jorhat, India	Aerial parts	Geijerene (26.3%), α -copaene (17.9%), (<i>E</i>)- β -caryophyllene (11.1%), δ -3-carene (10.6%), δ -cadinene (8.0%)	[434]
<i>Chromolaena odorata</i> (L.) R.M. King & H. Rob.	Belgaum, Karnataka, India	Roots	Himachalol (24.2%), 7-isopropyl-1,4-dimethyl-2-azulenol (17.6%), androencecalinol (14.1%), 2-methoxy-6-(1-methoxy-2-propenyl)naphthalene (5.6%), dodecane (5.1%)	[435]
<i>Chromolaena odorata</i> (L.) R.M. King & H. Rob.	Belgaum, Karnataka, India	Aerial parts	Pregeijerene (14.2%), <i>epi</i> -cubebol (9.8%), cubebol (8.6%), <i>cis</i> -sabinene hydrate (5.7%)	[436]
<i>Chromolaena odorata</i> (L.) R.M. King & H. Rob.	Belgaum, Karnataka, India	Flowers	Germacrene D (24.8%), geijerene (12.6%), pregeijerene (12.5%), cyperene (7.8%)	[436]
<i>Chromolaena odorata</i> (L.) R.M. King & H. Rob.	Kpalimé, Togo	Aerial parts	(<i>E</i>)- β -Caryophyllene (25.2%), germacrene D (18.8%), linalool (7.9%), (<i>Z</i>)- β -farnesene (5.7%)	[437]
<i>Chromolaena odorata</i> (L.) R.M. King & H. Rob.	Abomey-Calavi University, Bénin	Leaves	Pregeijerene (16.3-29.9%), germacrene D (13.3-21.6%), (<i>E</i>)- β -caryophyllene (7.3-14.3%), geijerene (3.5-10.1%), α -pinene (4.1-8.0%)	[438]
<i>Chromolaena odorata</i> (L.) R.M. King & H. Rob.	Epe, Lagos, Lagos state, Nigeria	Leaves	α -Pinene (42.2%), β -pinene (10.6%), germacrene D (9.7%), β -copaen-4 α -ol (9.4%), (<i>E</i>)- β -caryophyllene (5.4%)	[439]
<i>Chromolaena odorata</i> (L.) R.M. King & H. Rob.	Naresuan University, Thapho, Muang district, Phitsanulok, Thailand	Aerial parts	Pregeijerene (17.6%), germacrene D (11.1%), α -pinene (8.3%), (<i>E</i>)- β -caryophyllene (7.3%), vestitenone (6.5%), β -pinene (5.7%)	[440]
<i>Chromolaena odorata</i> (L.) R.M. King & H. Rob.	Thailand	Leaves	Pregeijerene (40.6%), dauca-5,8-diene (16.8%), α -pinene (9.7%), (<i>E</i>)- β -caryophyllene (6.1%), β -pinene (5.4%)	[25]
<i>Chromolaena odorata</i> (L.) R.M. King & H. Rob.	Côte d'Ivoire	Leaves	Germacrene D (13.9-34.5%), pregeijerene (4.2-20.8%), (<i>E</i>)- β -caryophyllene (6.0-21.3%), geijerene (3.4-11.1%), α -pinene (1.3-8.6%)	[441]
<i>Chromolaena odorata</i> (L.) R.M. King & H. Rob.	Côte d'Ivoire	Leaves	Germacrene D (15.3-20.0%), geijerene (14.1-16.9%), pregeijerene (10.7-12.3%), α -pinene (7.6-10.3%), (<i>E</i>)- β -caryophyllene (7.6-9.7%), β -pinene (4.2-5.2%)	[23]

hydrocarbons (82.6%), including (–)- β -pinene (41.3%), (+)-limonene (17.4%), (+)-sabinene (9.1%), myrcene (4.2%), and (*E*)- β -ocimene (4.2%) [453].

3.1.9. *Clibadium* F. Allam. ex L.

There are 38 recognized species of *Clibadium*, all of which are native to the Neotropics [33]. Only two have been investigated for their essential oils. *Clibadium leiocarpum* Steetz, from Monteverde, Costa Rica, was found to be rich in sesquiterpenoids, including

Table 29. Chemical compositions of *Chrysanthemum* essential oils.

<i>Chrysanthemum</i> species	Geographical location	Plant tissue	Major components (> 5%)	Ref.
<i>Chrysanthemum indicum</i> L.	China	Flowers	Camphor (36.7%), <i>iso</i> -borneol (7.6%), α -terpinene (5.7%), caryophyllene oxide (5.5%)	[446]
<i>Chrysanthemum indicum</i> L.	Shanghai, China	Leaves	(<i>E</i>)- β -Caryophyllene (20.3%), zingiberene (17.8%), germacrene D (13.2%), δ -cadinene (6.7%), β -eudesmol (5.6%), 1,8-cineole (5.5%)	[447]
<i>Chrysanthemum indicum</i> L.	Shanghai, China	Flowers	(<i>E</i>)- β -Caryophyllene (14.2%), α -bergamotene (12.2%), 1,8-cineole (9.9%), zingiberene (9.1%), δ -cadinene (7.1%), <i>ar</i> -curcumene (6.2%)	[447]
<i>Chrysanthemum morifolium</i> Ramat.	Macheng, China	Flowers	Camphor (16.9%), 1,8-cineole (10.6%), β -curcumene (9.5%), bornyl acetate (7.4%), α -zingiberene (7.0%), β -elemene (6.5%), borneol (6.24%)	[448]
<i>Chrysanthemum morifolium</i> Ramat.	Egypt	Leaves	Chrysanthenone (32.8%), borneol (15.1%), (<i>Z</i>)-anethole (9.5%), filifolone (6.3%)	[449]
<i>Chrysanthemum morifolium</i> Ramat.	Shenyang, Jiangsu Province, China	Aerial parts	(<i>E</i>)-Tibetin spiroether (20.53%), (<i>E</i>)- β -caryophyllene (8.8%), (<i>Z</i>)-tibetin spiroether (6.8%), (2 <i>E</i> ,6 <i>E</i>)-farnesyl acetate (6.5%), phytol (5.8%)	[450]
<i>Chrysanthemum morifolium</i> Ramat.	Hainoi, Vietnam	Flowers	Chrysanthenone (64.1%), camphor (9.7%), α -thujone (9.0%), γ -eudesmol (5.7%)	[451]
<i>Chrysanthemum parthenium</i> (L.) Bernh.	Debrebrhan, North Shewa, Ethiopia	Aerial parts	<i>trans</i> -Chrysanthenyl acetate (32.4%), camphor (25.6%), <i>trans</i> -chrysanthenol (9.0%)	[452]

germacrene D (21.1%), sabinene (16.0%), germacrene 4(15),5,10(14)-trien-1 α -ol (11.9%), and (*E*)- β -caryophyllene (9.2%), as well as the monoterpene β -phellandrene (7.3%) [454]. *Clibadium surinamense* L. is native to Central America and northern South America, has been introduced to Indonesia [33]. The essential oil from Padang City, West Sumatera Province, Indonesia, was dominated by (*E*)- β -caryophyllene (30.4%), along with β -sesquiphellandrene (8.5%) and δ -3-carene (8.2%) [455].

3.1.20. *Coleostephus* Cass.

The essential oil of the Mediterranean plant, *Coleostephus myconis* (L.) Rchb. f., has been studied. The floral essential oil of *C. myconis* from Beja, Tunisia, showed τ -muurolol (18.4%), *epi*- α -bisabolol (18.0%), α -cadinol (9.4%), α -bisabolol oxide B (6.7%), and elemol (5.1%) as its major components [456]. In comparison, the *C. myconis* floral essential oil from Montemarcello, Italy, was dominated by τ -cadinol (66.2%), along with valeranone (8.2%) and germacrene D (6.0%) [457]. The major components of the essential oil from the flowers of *Coleostephus*

macrotus Durand (syn. *Glossopappus macrotus* (Walp.) Briq. & Cavill.) from Zaghuan, Tunisia, were cubenol (28.3%), τ -cadinol (10.5%), α -cadinol (6.5%), and pentacosane (5.4%) [458].

3.1.21. *Conoclinium* DC.

There are only four recognized species of *Conoclinium* [33] of which only one has been examined for its essential oil. The major components of the essential oil extracted from the aerial parts of *Conoclinium coelestinum* DC. from northern Alabama were germacrene D (28.8%), (2*E*)-hexenal (9.6%), (*E*)- β -caryophyllene (7.4%), and (*Z,Z*)- α -farnesene (7.2%) [459].

3.1.22. *Conyza* Less.

There are around 152 species of *Conyza* currently recognized by the World Flora Online [33]. However, taxonomic classification is difficult and in flux. *Conyza* species are generally found in tropical and warm temperate regions [100]. The essential oil compositions of *Conyza bonariensis* (L.) Cronquist (syn. *Erigeron bonariensis* L.) [460], *Conyza canadensis* (L.) Cronquist (syn. *Erigeron canadensis* L.) [460,461], and *Conyza sumatrensis* (Retz.) E. Walker (syn. *Erigeron*

sumatrensis Retz.) [460] have been summarized; only recent studies are included in Table 30.

3.1.23. *Crassocephalum* Moench.

There are 26 recognized species of *Crassocephalum*, all of which are all native to sub-Saharan Africa [33]. Some of these (e.g., *Crassocephalum crepidioides* S. Moore) have been introduced to other tropical areas, where they are invasive weedy pests [469]. The major components of the essential oils of *Crassocephalum* spp. are summarized in Table 31.

3.1.24. *Dieteria* Nutt.

There are three recognized *Dieteria* species, *Dieteria asteroides* Torr., *Dieteria bigelovii* (A. Gray) D.R. Morgan & R.L. Hartm. and *Dieteria canescens* (Pursh) Nutt., all of which are native to western North America [33]. Only *D. canescens* from Boise, Idaho, USA, has been analyzed for its essential oil. The major components were δ -cadinene (28.3%), *epi*-cubebol (24.4%), 1-*epi*-cubenol (10.0%), and cubenol (7.7%) [422].

3.1.25. *Dittrichia* Greuter

According to the World Flora Online, there are only two species of *Dittrichia*, *Dittrichia graveolens* (L.) Greuter and *Dittrichia viscosa* (L.) Greuter. The phytochemistry and bioactivities of *D. viscosa* have been reviewed [479, 480], including a survey of essential oil compositions [481]. Mitic and co-workers have surveyed the essential oil compositions of *D. graveolens* and identified four chemotypes, (1) bornyl acetate, (2) 1,8-cineole, (3) borneol/bornyl acetate, and (4) borneol [482]. The major components of the essential oils of *D. graveolens* and *D. viscosa* are summarized in Table 32.

3.1.26. *Echinops* L.

There are approximately 194 species of *Echinops* recognized by the World Flora Online [33], which are naturally distributed from central Asia, Mongolia and north-eastern China to the Mediterranean basin, temperate regions of Eurasia, reaching to Indian subcontinent and tropical Africa [33]. The phytochemistry and biological activities of the genus have been reviewed several times [29, 493–495]. Polyacetylenes and thiophenes characterize members of the genus, but essential oils have also been characterized. Recent essential oil compositions of *Echinops* species are summarized in Table 33.

3.1.27. *Emilia* Cass.

Although there are 121 species of *Emilia* have been listed in the World Flora Online [33], only three species have been investigated for their essential oil composition. The leaf essential oil of *Emilia coccinea* G. Don was rich in α -terpinyl acetate (31.3%), whereas the root essential oil was rich in 1,8-cineole (21.4%) [506]. The major components of the leaf essential oil of *Emilia fosbergii* Nicolson from Brazil were the sesquiterpenoids, including germacrene B (23.6%), spathulenol (11.5%), *cis*-muurola-4(14),5-diene (10.3%), β -longipinene (9.4%), α -humulene (7.8%), γ -gurjunene (7.2%), and β -vetivene (5.9%) [507]. The leaf essential oil of *Emilia sonchifolia* (L.) DC., collected from southwestern Nigeria, was dominated by the sesquiterpenoids γ -himachalene (25.2%), (*E*)- β -caryophyllene (15.7%), and γ -gurjunene (8.6%), along with the fatty acid palmitic acid (5.2%) [508].

3.1.28. *Encelia* Adans.

As far as we are aware, only the essential oil of *Encelia farinosa* A. Gray ex Torr. from the Sonoran Desert in Arizona has been characterized [509]. The major components of the leaf essential oil were eupatoriocromene (20.8%), limonene (14.1%), α -pinene (11.6%), bicyclgermacrene (9.8%), sabinene (9.2%), and germacrene D (7.4%). The essential oil from the stems was dominated by α -pinene (53.5%) and bicyclgermacrene (10.7%).

3.1.29. *Erechtites* Raf.

There are approximately 19 species of *Erechtites*, which are native to the New World, but have been introduced to Africa, Asia, Australasia, Europe, and the Pacific islands [33]. The essential oils of two species, *Erechtites hieracifolius* (L.) Raf. ex DC. and *Erechtites valerianifolius* (Wolf) DC. have been analyzed [510]. *Erechtites hieracifolius* and *E. valerianifolius* essential oils from South America have shown wide variations in their chemical compositions. The essential oil of *E. hieracifolius* aerial parts from Vietnam, which showed mosquito larvicidal activity, was rich in limonene (21.4%) and caryophyllene oxide (15.1%). The essential oil of *E. valerianifolius* from Vietnam was dominated by myrcene (47.8%) and α -pinene (30.2%) [510].

3.1.30. *Ericameria* Nutt.

The essential oils of *Ericameria nauseosa* (Pursh) G. L.

Table 30. Chemical compositions of *Conyza* essential oils.

<i>Conyza</i> species	Geographical location	Plant tissue	Major components (> 5%)	Ref.
<i>Conyza aegyptiaca</i> (L.) Aiton	Giza, Egypt	Aerial parts	Limonene (48.8%), (<i>E</i>)- β -ocimene (8.7%), germacrene D (7.5%), β -pinene (6.9%), bicyclogermacrene (5.3%). (<i>Z</i>)-Lachnophyllum ester (30.0%), germacrene D (12.9%), limonene (11.2%), (<i>E</i>)- β -farnesene (12.5%), (<i>E</i>)- β -ocimene (8.4%), lachnophyllum lactone ^a (7.1%), bicyclogermacrene (5.3%)	[462]
<i>Conyza albida</i> Willd. ex Spreng.	Athens, Greece	Aerial parts	(<i>Z</i>)-Lachnophyllum ester (8.8-36.5%), limonene (10.0-21.1%), germacrene D (10.5-20.2%), (<i>E</i>)- β -ocimene (2.5-11.4%), (<i>E</i>)- β -farnesene (3.6-9.6%), bicyclogermacrene (4.2-7.6%), β -pinene (3.9-5.6%)	[463]
<i>Conyza albida</i> Willd. ex Spreng.	Athens, Greece	Aerial parts	(<i>E</i>)- β -Caryophyllene (16.2%), (<i>E</i>)- β -farnesene (15.5%), limonene (12.8%), (<i>Z</i>)-lachnophyllum ester (9.8%), germacrene D (6.8%) (<i>E</i>)- β -ocimene (5.8%), γ -cadinene (5.3%)	[464]
<i>Conyza bonariensis</i> (L.) Cronquist	Dagni Koudzragan, Togo	Leaves	(<i>Z</i>)-Lachnophyllum ester (57.2%), limonene (14.3%), β -sesquiphellandrene (7.0%)	[465]
<i>Conyza bonariensis</i> (L.) Cronquist	Paraiba, João Pessoa, Brazil	Aerial parts		[466]
<i>Conyza bonariensis</i> (L.) Cronquist	Bach Ma National Park, Thue Thien Hue, Vietnam	Aerial parts	<i>allo</i> -Aromadendrene (41.2%), (<i>E</i>)- β -caryophyllene (13.3%), caryophyllene oxide (12.2%), α -humulene (5.4%)	[460]
<i>Conyza canadensis</i> (L.) Cronquist	Al-Jubeiha, Jordan	Leaves	(2 <i>E</i> ,8 <i>Z</i>)-Matricaria ester (60.7%)	[461]
<i>Conyza canadensis</i> (L.) Cronquist	Bach Ma National Park, Thue Thien Hue, Vietnam	Aerial parts	Limonene (41.5%), β -pinene (8.8%), (<i>Z</i>)-lachnophyllum ester (5.5%)	[460]
<i>Conyza newii</i> Oliv. & Hiern	Kenya (various locations)	Leaves	Perilla aldehyde (28.6-31.9%), geraniol (16.6-30.4%), limonene (6.8-13.1%), perilla alcohol (3.1-7.1%), 1,8-cineole (4.4-5.9%)	[467]
<i>Conyza newii</i> Oliv. & Hiern	Nyanza, Kenya	Leaves	Perilla aldehyde (29.3%), limonene (10.1%), 2-methyl-5-isopropylcyclohex-2-en-1-ol (7.3%), 1,8-cineole (6.8%)	[468]
<i>Conyza sumatrensis</i> (Retz.) E. Walker	Bach Ma National Park, Thue Thien Hue, Vietnam	Aerial parts	Limonene (25.5%), (<i>Z</i>)-lachnophyllum ester (20.7%), caryophyllene oxide (5.8%), (<i>E</i>)- β -caryophyllene (5.5%), spathulenol (5.2%)	[460]

^a Correct isomer was not identified.

Table 31. Chemical compositions of *Crassocephalum* essential oils.

<i>Crassocephalum</i> species	Geographical location	Plant tissue	Major components (> 5%)	Ref.
<i>Crassocephalum biafrae</i> S. Moore	Bafoussam, Cameroon	Leaves	Germacrene D (22.6%), α -pinene (10.8%), α -muurolene (9.6%), (<i>Z</i>)- β -ocimene (6.9%), β -pinene (5.4%)	[470]
<i>Crassocephalum biafrae</i> S. Moore	Mbalmayo, Cameroon	Leaves	Germacrene D (66.7%)	[470]
<i>Crassocephalum bougheyannum</i> C.D. Adams	Bafoussam, Cameroon	Leaves	α -Phellandrene (34.9%), <i>p</i> -cymene (26.5%), α -humulene (9.2%), (<i>E</i>)- β -caryophyllene (6.3%), caryophyllene oxide (5.4%)	[470]

Table 31. (Continued).

Crassocephalum species	Geographical location	Plant tissue	Major components (> 5%)	Ref.
<i>Crassocephalum crepidioides</i> S. Moore	Costa Rica	Aerial parts	Myrcene (51.2%), (Z)- β -farnesene (11.3%), β -phellandrene (8.7%), α -copaene (5.0%)	[469]
<i>Crassocephalum crepidioides</i> S. Moore	Da Nang, Vietnam	Leaves	Myrcene (59.3%), β -phellandrene (11.9%), cryptone (6.4%)	[471]
<i>Crassocephalum crepidioides</i> S. Moore	Belgaum, Karnataka, India	Aerial parts	Myrcene (45.3%), β -phellandrene (20.2%), dauca-5,8-diene (6.9%)	[472]
<i>Crassocephalum crepidioides</i> S. Moore	Belgaum, Karnataka, India Nainital district,	Roots	(E)- β -Farnesene (30.6%), α -humulene (10.3%), (E)- β -caryophyllene (7.2%), <i>cis</i> - β -guaiene (6.1%), α -bulnesene (5.3%)	[473]
<i>Crassocephalum crepidioides</i> S. Moore	Kumaon region, Uttarakhand, India	Flowers	Myrcene (54.2%), β -phellandrene (25.9%)	[474]
<i>Crassocephalum crepidioides</i> S. Moore	Palampur, India	Aerial parts	Myrcene (65.9%), β -phellandrene (8.8%)	[475]
<i>Crassocephalum crepidioides</i> S. Moore	Fafoussam, Cameroon	Leaves	Myrcene (31.1%), limonene (20.6%), sabinene (17.6%), (E)- β -ocimene (5.6%)	[470]
<i>Crassocephalum crepidioides</i> S. Moore	Yaounde, Cameroon	Leaves	Limonene (69.7%), myrcene (14.8%),	[470]
<i>Crassocephalum mannii</i> (Hook. f.) Milne-Redh.	Bafoussam, Cameroon	Leaves	α -Pinene (32.0%), β -pinene (18.4%), germacrene D (16.6%), (E)- β -ocimene (11.0%)	[470]
<i>Crassocephalum montuosum</i> (S. Moore) Milne-Redh.	Bafoussam, Cameroon	Leaves	α -Phellandrene (87.6%), limonene (5.8%)	[470]
<i>Crassocephalum montuosum</i> (S. Moore) Milne-Redh.	Yaounde, Cameroon	Leaves	(E)- β -Ocimene (91.6%), α -pinene (5.1%)	[470]
<i>Crassocephalum rubens</i> (Jacq.) S. Moore	Akobo-Ojurin, Ibadan, Nigeria	Aerial parts	Limonene (81.1%)	[476]
<i>Crassocephalum rubens</i> (Jacq.) S. Moore	Savalou, Benin	Leaves	Limonene (48.8%), myrcene (30.7%), (E)- β -ocimene (7.4%)	[477]
<i>Crassocephalum rubens</i> (Jacq.) S. Moore	Bafoussam, Cameroon	Leaves	Limonene (34.2%), α -pinene (19.2%), (E)- β -ocimene (12.0%)	[470]
<i>Crassocephalum rubens</i> (Jacq.) S. Moore	Yaounde, Cameroon	Leaves	Limonene (44.9%), (E)- β -ocimene (36.3%), myrcene (9.4%)	[470]
<i>Crassocephalum vitellinum</i> S. Moore	Bafoussam, Cameroon	Leaves	Myrcene (24.6%), α -pinene (23.8%), β -pinene (21.2%), germacrene D (8.5%)	[470]
<i>Crassocephalum vitellinum</i> S. Moore	Dschang, Cameroon	Leaves	α -Pinene (43.3%), β -pinene (24.8%), germacrene D (5.4%), (E)- β -caryophyllene (5.3%)	[470]
<i>Crassocephalum</i> sp. (unidentified)	Gabia, Gôh region, Côte d'Ivoire	Flowers	Myrcene (87.3%)	[478]

Table 32. Chemical compositions of *Dittrichia* essential oils.

<i>Dittrichia</i> species	Geographical location	Plant tissue	Major components (> 5%)	Ref.
<i>Dittrichia graveolens</i> (L.) Greuter	Shush, Khuzestan, Iran	Aerial parts	1,8-Cineole (54.9%), <i>p</i> -cymene (16.2%), β -pinene (6.9%), borneol (5.4%)	[483]
<i>Dittrichia graveolens</i> (L.) Greuter	Bekaa, Lebanon	Aerial parts	Bornyl acetate (72.3%), τ -cadinol (13.4%)	[484]
<i>Dittrichia graveolens</i> (L.) Greuter	Sannine, Lebanon	Aerial parts	Bornyl acetate (70.6%), borneol (12.4%)	[484]
<i>Dittrichia graveolens</i> (L.) Greuter	Shushtar, Khuzestan Province, Iran	Aerial parts	Borneol (38.2%), bornyl acetate (14.9%)	[485]
<i>Dittrichia graveolens</i> (L.) Greuter	Stara Planina Mountain, Serbia	Aerial parts	Bornyl acetate (21.7%), borneol (18.7%), τ -cadinol (14.6%), caryophyllene oxide (9.6%)	[486]
<i>Dittrichia graveolens</i> (L.) Greuter	Vladimirovci, Montenegro	Aerial parts	Borneol (43.6%), bornyl acetate (38.3%)	[482]
<i>Dittrichia viscosa</i> (L.) Greuter	Fez, Morocco	Aerial parts	Isocostic acid (72.3%), juniper camphor (5.1%)	[232]
<i>Dittrichia viscosa</i> (L.) Greuter	Irbid, Jordan	Aerial parts	Fokienol (20.9%), (<i>E</i>)-nerolidol (19.8%), β -eudesm-6-en-4 α -ol (5.6%)	[487]
<i>Dittrichia viscosa</i> (L.) Greuter	Spain	Aerial parts	Fokienol (38.8%), (<i>E</i>)-nerolidol (7.1%)	[488]
<i>Dittrichia viscosa</i> (L.) Greuter	Marciana, Elba Island, Italy	Aerial parts	(<i>E</i>)- β -Caryophyllene (16.7%), limonene (15.5%), terpinen-4-ol (6.9%), β -pinene (6.2%),	[489]
<i>Dittrichia viscosa</i> (L.) Greuter	Žnjan locality, Split, Croatia	Aerial parts	1,8-Cineole (16.4%), caryophyllene oxide (15.1%), α -terpinyl acetate (13.9%), α -muurolol (13.8%), linalool (6.6%)	[490]
<i>Dittrichia viscosa</i> (L.) Greuter	Bainem Forest, Algeria	Leaves	Caryophyllene oxide (10.4%), fokienol (9.6%), α -eudesmol (7.6%), (<i>E</i>)-nerolidol (7.0%), γ -eudesmol (6.2%)	[481]
<i>Dittrichia viscosa</i> subsp. <i>revoluta</i> (Hoffmanns. & Link) P. Silva & Tutin	Algarve, Portugal	Aerial parts	3-Methoxycuminyll isobutyrate (12.0%), α -cadinol (6.3%)	[491]
<i>Dittrichia viscosa</i> (L.) Greuter subsp. <i>viscosa</i>	Ajaccio, Corsica, France	Aerial parts	Isocostic acid (43.7%), fokienol (21.1%), eudesma-4,11(13)-dien-12-oic acid (10.9%), (<i>E</i>)-nerolidol (8.6%), eudesm-6-en-4 α -ol (6.2%)	[492]

Table 33. Chemical compositions of *Echinops* essential oils.

<i>Echinops</i> species	Geographical location	Plant tissue	Major components (> 5%)	Ref.
<i>Echinops bannaticus</i> Rochel ex Schrad.	Southern Serbia	Roots	5-(3-Buten-1-ynyl)-2,2'-bithienyl (47.3%), α -terthienyl (15.5%)	[496]
<i>Echinops giganteus</i> A. Rich.	Western Cameroon	Roots	Silphiperfol-6-ene (26.9%), presilphiperfol-7(8)-ene (9.4%), (<i>E</i>)- β -caryophyllene (8.3%)	[497]
<i>Echinops graecus</i> Mill.	Prefecture Attiki, Greece	Aerial parts	Estragole (42.5%), pentacosane (9.5%), cyclopentadecanolide (7.9%), camphor (6.5%), benzyl benzoate (6.3%), heptacosane (6.1%), linalool (5.6%), (3 <i>Z</i>)-hexenyl benzoate (5.3%)	[498]

Table 33. (Continued).

Echinops species	Geographical location	Plant tissue	Major components (> 5%)	Ref.
<i>Echinops grijsii</i> Hance	Jiangsu Province, China	Roots	5-(3-Buten-1-ynyl)-2,2'-bithienyl (27.6%), α -terthienyl (15.0%), 1,8-cineole (5.6%), (Z)- β -ocimene (5.0%)	[499]
<i>Echinops ilicifolius</i> Bunge	Yazd Province, Iran	Roots	Decane (23.1%), dodecane (14.5%), silphiperfol-4,7(14)-diene (11.1%), selin-11-en-4 α -ol (9.5%), palmitic acid (7.8%), tetradecane (5.3%)	[500]
<i>Echinops ilicifolius</i> Bunge	Yazd Province, Iran	Leaves	Palmitic acid (36.3%), linalool (16.4%), geraniol (8.3%),	[500]
<i>Echinops kebericho</i> Mesfin	West Shoa region, Ethiopia	Roots	Eudesm-7(11)-en-4-ol (14.3%), caryophyllene oxide (9.7%), τ -cadinol (8.3%), (E)-nerolidol (7.2%)	[501]
<i>Echinops kebericho</i> Mesfin	Inchini, Ethiopia	Roots	Dehydrocostus lactone (41.8%), β -phellandrene (10.8%), germacrene B (5.4%)	[502]
<i>Echinops latifolius</i> Tausch	Xiaolongmen National Forest, China	Aerial parts	1,8-Cineole (19.6%), (Z)- β -ocimene (18.4%), β -pinene (15.6%)	[503]
<i>Echinops polyceras</i> Boiss.	Jordan	Flowering inflorescence	Pseudophytol (7.8%), β -bisabolene (7.5%), dolabradiene (5.5%)	[504]
<i>Echinops ritro</i> L.	Prefecture Attiki, Greece	Aerial parts	(2E)-Hexenal (21.4%), 1,8-cineole (16.3%), <i>p</i> -cymene (12.1%), linalool (9.8%)	[498]
<i>Echinops sphaerocephalus</i> L.	Southern Serbia	Roots	5-(3-Buten-1-ynyl)-2,2'-bithienyl (48.9%), α -terthienyl (13.7%)	[496]
<i>Echinops spinosus</i> L.	Southern Tunisia	Roots	δ -Cadinene (27.2%), 5-(3-buten-1-ynyl)-2,2'-bithienyl (21.3%), α -terthienyl (18.0%), caryophyllene oxide (5.2%)	[505]

Nesom & G. I. Baird and *Ericameria linearifolia* (DC.) Urbatsch & Wussow were analyzed. The major components of the essential oil from the aerial parts of *Ericameria linearifolia* (southwestern Utah, USA) were sabinene (13.2-14.3%), β -pinene (4.0-13.4%), β -phellandrene (0.3-13.9%), myrcene (6.0-12.2%), terpinen-4-ol (6.3-8.1%), limonene (1.5-15.8%), (Z)- β -ocimene (4.6-6.1%), (E)- β -ocimene (3.3-7.5%), and α -pinene (4.5-8.2%) [511]. The essential oil compositions of *E. nauseosa* showed wide variations depending on geographical location. The major components of the essential oil from Utah, USA, were β -phellandrene (20.0%), limonene (9.6%), β -pinene (9.3%), and myrcene (5.4%), the essential oil from Idaho, USA, was composed of β -phellandrene (43.6%), β -pinene (11.5%), (Z)- β -ocimene (11.5%), sabinene (6.0%), and 1,3,8-*p*-menthatriene (5.3%) [512]; whereas the major components in the essential oil from Montana, USA, were γ -decalactone (13.3%), cryptone (9.4%), and terpinen-4-ol (9.3%) [513].

3.1.31. *Eriocephalus* L.

Eriocephalus is a genus of 37 species, found naturally in southern Africa [33]. Of these, essential oils from nine species have been reported (Table 34).

3.1.32. *Eupatorium* L.

There are approximately 117 species of *Eupatorium*, which are naturally found in tropical and subtropical regions of Africa, Asia, Europe, North and South America [33]. However, the taxonomy of the genus is currently in flux. The phytochemistry, including the volatile components of *Eupatorium* was reviewed in 2015 [522] and the antimicrobial activities of *Eupatorium* species were reviewed in 2017 [523]. A summary of *Eupatorium* major essential oil components was published in 2020 [13]. Recently published essential oil data are summarized in Table 35.

3.1.33. *Flourensia* DC.

According to World Flora Online, there are 33 species of *Flourensia* [33]. However, only three species have

Table 34. Chemical compositions of *Eriocephalus* essential oils.

<i>Eriocephalus</i> species	Geographical location	Plant tissue	Major components (> 5%)	Ref.
<i>Eriocephalus africanus</i> L.	Alexandria, Egypt	Leaves	Artemisia ketone (77.9%), ledol (19.9%)	[514]
<i>Eriocephalus africanus</i> L.	Dakahlia, Egypt	Aerial parts	Artemisia ketone (41.0%), juniper camphor (14.2%), yomogi alcohol (7.1%), (<i>E</i>)- β -caryophyllene (6.3%)	[515]
<i>Eriocephalus africanus</i> L.	Medifood, Egypt	Aerial parts	Artemisia ketone (38.4%), juniper camphor (17.0%), <i>epi</i> - γ -eudesmol (5.3%)	[516]
<i>Eriocephalus africanus</i> L.	Burjassot, Spain	Aerial parts	Artemisia ketone (56.5%), intermedeol (9.6%), γ -eudesmol (5.6%)	[517]
<i>Eriocephalus africanus</i> L.	Sagunto, Spain	Aerial parts	Artemisia ketone (56.6%), intermedeol (11.6%)	[517]
<i>Eriocephalus africanus</i> L.	Valencia, Spain	Aerial parts	Artemisia ketone (56.6%), intermedeol (9.2%)	[517]
<i>Eriocephalus africanus</i> L.	Giza, Egypt	Aerial parts	Artemisia ketone (30.6%)	[518]
<i>Eriocephalus dinteri</i> S. Moore	Near Aus, Namibia	Aerial parts	Camphor (38.4%)	[519]
<i>Eriocephalus ericoides</i> Druce	Windhoek district, Namibia	Aerial parts	1,8-Cineole (39.0%), camphor (14.3%), yomogi alcohol (5.6%), 2,6-dimethyl-3,5-heptadien-2-ol (5.4%)	[519]
<i>Eriocephalus ericoides</i> Druce	Farm Hohenheim, Namibia	Aerial parts	Linalool (10.4%), linalyl acetate (5.0%)	[519]
<i>Eriocephalus klinghardtensis</i> M.A.N. Müll.	Neiaab Mountain, Namibia	Aerial parts	Chrysanthenone (24.4%), <i>p</i> -cymene (8.9%), α -pinene (7.9%), <i>trans</i> -chrysanthenyl acetate (5.6%), terpinen-4-ol (5.4%), β -eudesmol (5.3%)	[519]
<i>Eriocephalus luederitzianus</i> O. Hoffm.	Near Windhoek, Namibia	Aerial parts	α -Pinene (30.8%), (<i>E</i>)- β -caryophyllene (13.3%), β -pinene (10.3%), α -longipinene (10.3%), <i>p</i> -cymene (6.7%)	[519]
<i>Eriocephalus merxmulleri</i> M.A.N. Müll.	Buschmanberge, Namibia	Aerial parts	1,8-Cineole (17.4%), camphor (14.0%), yomogi alcohol (6.1%), chrysanthenone (5.2%)	[519]
<i>Eriocephalus pinmatus</i> O. Hoffm.	Brandberg, Namibia	Aerial parts	Isoamyl 2-methylbutyrate (7.9%), β -pinene (7.2%), isoamyl valerate (6.5%)	[519]
<i>Eriocephalus punctulatus</i> DC.	Commercial (South Africa)	Aerial parts	2-Methylbutyl isobutyrate (27.4%), isobutyl isobutyrate (14.3%), 2-methylbutyl 2-methylbutyrate (5.5%)	[520]
<i>Eriocephalus punctulatus</i> DC.	Commercial (South Africa)	Not indicated	2-Methylbutyl isobutyrate (21.5%), isobutyl isobutyrate (10.1%)	[521]
<i>Eriocephalus scariosus</i> DC.	Near Aus, Namibia	Aerial parts	1,8-Cineole (24.1%), camphor (17.2%), santolina alcohol (14.8%), borneol (5.8%)	[519]

Table 35. Chemical compositions of *Eupatorium* essential oils.

<i>Eupatorium</i> species	Geographical location	Plant tissue	Major components (> 5%)	Ref.
<i>Eupatorium adenophorum</i> Spreng.	Palampur, Himachal Pradesh, India	Aerial parts	<i>p</i> -Cymene (13.5%), τ -cadinol (16.6%), bornyl acetate (7.7%), α -phellandrene (7.5%), δ -2-carene (5.8%)	[524]
<i>Eupatorium adenophorum</i> Spreng.	Sahiya (Chakrata), Dehradun, India	Aerial parts	<i>p</i> -Cymene (12.9%), α -phellandrene (9.4%), <i>cis</i> -cadin-4-en-7-ol (7.5%), bornyl acetate (6.0%), camphene (5.8%), γ -patchoulene (5.2%)	[525]

Table 35. (Continued).

<i>Eupatorium</i> species	Geographical location	Plant tissue	Major components (> 5%)	Ref.
<i>Eupatorium adenophorum</i> Spreng.	Nanning, Guangxi Zhuang Autonomous Region, China	Whole plant	α -Muurolol (30.1%), aristolone (11.5%), α -bisabolol (9.1%), α -curcumene (7.9%), palmitic acid (5.2%)	[526]
<i>Eupatorium africanum</i> Oliv. & Hieron.	Bombo-Lumene Game reserve, Kinshasa Province, D.R. Congo	Leaves	β -Eudesmol (49.1%), 10- <i>epi</i> - γ -eudesmol (11.3%), α -humulene (8.9%), hedycaryol (8.9%), elemol (5.8%)	[527]
<i>Eupatorium betonicaeforme</i> (DC.) Baker	Acarape County, State of Ceará, Brazil	Aerial parts	(<i>E</i>)- β -Caryophyllene (41.7%), γ -murrrolene (19.0%), bicyclogermacrene (17.5%), α -humulene (11.7%)	[528]
<i>Eupatorium buniifolium</i> Hook. & Arn.	Potrero de los Funes, Argentina	Aerial parts	α -Pinene (47.4%), (<i>E</i>)- β -ocimene (8.3%), limonene (7.7%), sabinene (6.5%), δ -2-carene (6.4%)	[529]
<i>Eupatorium buniifolium</i> Hook. & Arn.	Las Brujas, Canelones, Uruguay	Aerial parts	α -Pinene (18.0%), <i>trans</i> - β -guaiene (9.0%), germacrene D (7.7%), β -pinene (7.0%), limonene (5.2%), (<i>E</i>)- β -caryophyllene (5.0%)	[530]
<i>Eupatorium buniifolium</i> Hook. & Arn.	Sauce-Canelones, Uruguay	Aerial parts	α -Pinene (22.0%), <i>trans</i> - β -guaiene (10.0%), germacrene D (7.8%), β -pinene (6.1%), sabinene (5.9%), (<i>E</i>)- β -caryophyllene (5.8%)	[9]
<i>Eupatorium fortunei</i> Turcz.	Zhengzhou City, Henan Province, China	Aerial parts	α -Phellandrene (60.5%), thymyl tiglate (9.1%) <i>p</i> -cymene (8.0%), methyl thymyl ether (5.6%)	[531]
<i>Eupatorium glutinosum</i> Lam.	Provincia Del Napo, Ecuador	Aerial parts	Carvacrol (43.6%), caryophyllene oxide (10.8%), terpinen-4-ol (7.7%), <i>p</i> -cymene (6.6%), thymol (5.5%)	[532]
<i>Eupatorium intermedium</i> DC.	Palmeira, State of Paraná, Brazil	Leaves	β -Pinene (25.9%), α -pinene (19.8%), limonene (15.0%), <i>trans</i> -muurola-4(14),5-diene (10.6%), bicyclogermacrene (9.1%)	[533]
<i>Eupatorium serotinum</i> Michx.	North Alabama, U.S.A.	Aerial parts	Cyclocolorenone (23.4%), α -copaen-11-ol (7.9%), germacrene D (6.6%), palustrol (5.3%)	[13]

been analyzed in terms of their essential oil compositions (Table 36).

3.1.34. *Grindelia* Willd.

Of the 68 species of *Grindelia* recognized by World Flora Online [33], only six have been investigated in terms of essential oil composition (reviewed in [539], Table 37).

3.1.35. *Gutierrezia* Lag.

Only three species of *Gutierrezia* have been analyzed in terms of their essential oil composition (Table 38).

3.1.36. *Helianthus* L.

There are 79 species of *Helianthus* listed in the World Flora Online [33]. The two most investigated species are *Helianthus annuus* L. (common sunflower) and *Helianthus tuberosus* L. (Jerusalem artichoke). The essential oils of these two and other *Helianthus* species are summarized in Table 39.

3.1.37. *Helichrysum* Mill.

There are approximately 580 species of *Helichrysum* recognized by World Flora Online [33]. Among these, *Helichrysum italicum* (Roth) G. Don is of commercial importance in aromatherapy [564]. However, there is a high degree of variation in the chemical compositions of *H. italicum*, and at least 10 chemotypes have been identified: (1) high neryl acetate (50.5-83.4%), (2) moderate neryl acetate (19.5-48.0%), (3) high α -pinene content (25.2-53.5%), (4) moderate α -pinene content (5.6-20.0%), (5) juniper camphor chemotype, (6) γ -selinene chemotype, (7) γ -curcumene chemotype, (8) *ar*-curcumene/ γ -curcumene chemotype, (9) neryl acetate/*ar*-curcumene chemotype, and (10) high italidiones [565]. In addition, several review articles on *Helichrysum* phytochemistry, including essential oil composition, and pharmacology have been published [565-570].

Table 36. Chemical compositions of *Flourensia* essential oils.

<i>Flourensia</i> species	Geographical location	Plant tissue	Major components (> 5%)	Ref.
<i>Flourensia campestris</i> Griseb.	Punilla Valley, Córdoba Province, Argentina	Leaves	(Z)- β -Ocimene (19.6%), germacrene A (14.6%), santolina triene (12.6%), δ -selinene (8.0%), α -pinene (6.0%)	[534]
<i>Flourensia cernua</i> DC.	Estanque de León, Coahuila de Zaragoza, Mexico	Leaves	α -Himachalene (21.5%), ledol (19.5%), β -eudesmol (13.2%), elemol (11.1%), (<i>E</i>)- β -caryophyllene (11.1%), germacrene D (8.0%)	[535]
<i>Flourensia cernua</i> DC.	Tortuga, Coahuila de Zaragoza, Mexico	Leaves	Ledol (27.7%), β -himachalene (19.4%), β -selinol (16.5%), (<i>E</i>)- β -caryophyllene (10.8%), elemol (7.8%), germacrene D (7.8%)	[535]
<i>Flourensia cernua</i> DC.	Jornada Experimental Range, New Mexico, U.S.A.	Aerial parts	β -Eudesmol (24.5%), α -eudesmol (6.9%), limonene (6.6%)	[536]
<i>Flourensia oolepis</i> S.F. Blake	El Volcan, San Luis, Argentina	Aerial parts	γ -Gurjunene (20.7%), δ -cadinene (10.3%), 2-methylene-4,8,8-trimethyl-4-vinyl-bicyclo[5.2.0]nonane ^a (10.2%), santolina triene (6.2%), τ -muurolene (6.1%)	[537]
<i>Flourensia oolepis</i> S.F. Blake	Córdoba, Argentina	Aerial parts	τ -Cadinol (10.5%), β -selinene (9.8%), linalool (8.2%), β -eudesmol (8.0%)	[538]

^a This structure is not found in the Dictionary of Natural Products [98].

Table 37. Chemical compositions of *Grindelia* essential oils.

<i>Grindelia</i> species	Geographical location	Plant tissue	Major components (> 5%)	Ref.
<i>Grindelia discoidea</i> Hook. & Arn.	Central Argentina	Aerial parts	(Z,E)-Farnesol (18.2-34.9%), (<i>E,E</i>)-farnesol (9.0-16.8%), γ -cadinene (9.4-15.6%), globulol (6.2-10.5%), (<i>E</i>)- β -caryophyllene (trace-8.6%), δ -cadinene (3.2-6.1%)	[540]
<i>Grindelia hirsutula</i> Hook. & Arn.	Targu Mures, Romania	Aerial parts	Limonene (7.0%), α -pinene (6.2%), germacrene D (4.2%), spathulenol (5.5%), 10,11-epoxycalamenene (4.1%)	[541]
<i>Grindelia humilis</i> Hook. & Arn.	Cairo, Egypt	Aerial parts	Polyacetylene isomer (22.1%), germacrene D (11.9%), polyacetylene isomer (10.5%), bornyl acetate (5.1%), α -pinene (4.9%), (<i>E</i>)-lachnophyllol acetate (4.1%)	[542]
<i>Grindelia integrifolia</i> DC.	Łodz, Poland	Leaves	Myrcene (16.9%), spathulenol (12.3%), β -eudesmol (11.9%), limonene (10.1%), α -cadinene (6.4%), α -pinene (4.6%), germacrene D (4.5%), humulene epoxide I (4.1%)	[543]
<i>Grindelia robusta</i> Nutt.	Casola Valsenio, Italy	Aerial parts	Borneol (15.0%), α -pinene (11.0%), <i>trans</i> -pinocarveol (8.2%), β -eudesmol (5.5%), bornyl acetate (4.4%), β -selinene (4.3%), limonene (4.2%),	[544]
<i>Grindelia robusta</i> Nutt.	Commercial ^a	Aerial parts	Borneol (14.8%), α -pinene (8.8%), <i>trans</i> -pinocarveol (6.1%), bornyl acetate (5.4%), limonene (4.1%), <i>p</i> -cymen-8-ol (4.1%)	[542]
<i>Grindelia robusta</i> Nutt.	Urbino, Italy	Aerial parts	Borneol (15.2%), α -pinene (10.3%), <i>trans</i> -pinocarveol (7.0%), bornyl acetate (4.5%), limonene (4.3%), β -eudesmol (4.1%)	[545]
<i>Grindelia robusta</i> Nutt.	Erlangen, Germany	Aerial parts	Germacrene D (23.3%), α -pinene (13.4%), germacrene B (8.3%), myrcene (7.2%), (<i>E</i>)- β -caryophyllene (4.1%)	[546]
<i>Grindelia squarrosa</i> (Pursh) Dunal	Commercial ^a	Aerial parts	Limonene (16.8%), α -pinene (16.1%), germacrene D (6.8%), β -pinene (5.2%), borneol (4.5%)	[542]
<i>Grindelia squarrosa</i> (Pursh) Dunal	Southwestern Idaho, USA	Aerial parts	α -Pinene (21.9%), limonene (17.1%), terpinolene (10.6%), borneol (6.5%), β -pinene (4.2%)	[539]

Table 37. (Continued).

<i>Grindelia</i> species	Geographical location	Plant tissue	Major components (> 5%)	Ref.
<i>Grindelia squarrosa</i> (Pursh) Dunal	Erlangen, Germany	Aerial parts	Limonene (16.2%), germacrene B (13.2%), α -pinene (10.4%), phytone (6.5%), bornyl isovalerate (4.3%)	[546]
<i>Grindelia squarrosa</i> (Pursh) Dunal	Southwestern Montana, USA	Aerial parts	α -Pinene (23.2%), borneol (16.6%), limonene (14.7%), p-cymen-8-ol (5.8%), bornyl acetate (5.1%)	[547]
<i>Grindelia squarrosa</i> (Pursh) Dunal	Targu Mures, Romania	Aerial parts	Bornyl acetate (10.8%), α -pinene (8.3%), limonene (8.1%), spathulenol (5.4%), caryophyllene oxide (4.9%)	[541]

^a Commercial sample, source not indicated.

Table 38. Chemical compositions of *Gutierrezia* essential oils.

<i>Gutierrezia</i> species	Geographical location	Plant tissue	Major components (> 5%)	Ref.
<i>Gutierrezia mandonii</i> (Sch.Bip.) Solbrig	Tafí del Valle, Tumucán, Argentina	Aerial parts	Limonene (13.3%), sabinene (13.1%), δ -2-carene (7.7%), (6 <i>R</i> ,7 <i>R</i>)-bisabolone (6.6%), β -pinene (6.4%),	[548, 549]
<i>Gutierrezia repens</i> Griseb.	Tafí del Valle, Tumucán, Argentina	Aerial parts	(6 <i>R</i> ,7 <i>R</i>)-Bisabolone (58.0%), β -pinene (17.8%), (<i>E</i>)- β -ocimene (7.0%)	[548, 549]
<i>Gutierrezia sarothrae</i> (Pursh) Britton & Rusby	Muskat Canyon, Utah, USA	Aerial parts	(+)- α -Pinene (12.6–22.9%), (–)- β -pinene (27.6–40.4%), (+)-limonene (7.2–13.1%), camphor (0.7–10.9%), (–)-pinocarvone (trace-11.3%), and (+)-verbenone (trace-6.0%)	[550]
<i>Gutierrezia sarothrae</i> (Pursh) Britton & Rusby	Jornada Experimental Range, south-central New Mexico, USA	Aerial parts	α -Pinene (0.4–9.4%), β -pinene 0.7–9.6%), <i>p</i> -cymene (2.5–7.9%), limonene (2.4–13.4%), cryptone (2.4–8.1%), bornyl acetate (2.8–4.5%), (<i>E</i>)- β -caryophyllene (2.3–4.8%), β -eudesmol (0.1–5.9%)	[551]
<i>Gutierrezia sarothrae</i> (Pursh) Britton & Rusby	Eunice, New Mexico, USA	Aerial parts	Geraniol (53.8%), γ -humulene (12.2%), <i>trans</i> -verbenol (6.0%)	[552]
<i>Gutierrezia sarothrae</i> (Pursh) Britton & Rusby	Owyhee Mountains, Idaho, USA	Aerial parts	(<i>Z</i>)- β -Ocimene (18.8–39.4%), limonene (1.4–25.4%), β -pinene (0.5–18.4%), α -phellandrene (2.2–11.8%), (<i>Z,E</i>)-matricaria ester (0.2–9.3%), (<i>E,Z</i>)-matricaria ester (0.1–7.5%)	[553]

Table 39. Chemical compositions of *Helianthus* essential oils.

<i>Helianthus</i> species	Geographical location	Plant tissue	Major components (> 5%)	Ref.
<i>Helianthus annuus</i> L.	Southern high plains, USA	Leaves	α -Pinene (50.5%), bornyl acetate (12.2%), camphene (8.7%), β -pinene (5.1%)	[554]
<i>Helianthus annuus</i> L.	San Diego, California, USA	Leaves	α -Pinene (47.5%), sabinene (12.5%), limonene (5.6%)	[554]
<i>Helianthus annuus</i> L.	Preston, Idaho, USA	Leaves	α -Pinene (31.4%), bornyl acetate (21.0%), limonene (7.2%), camphene (6.7%) β -pinene (5.8%)	[554]
<i>Helianthus annuus</i> L.	Redmond, Oregon, USA	Leaves	α -Pinene (28.3%), bornyl acetate (16.8%), germacrene D (8.2%), limonene (7.2%), camphene (7.2%)	[554]
<i>Helianthus annuus</i> L.	Eagle Nest, New Mexico, USA	Leaves	α -Pinene (27.3%), bornyl acetate (16.3%), germacrene D (15.6%), β -pinene (5.3%)	[554]

Table 39. (Continued).

<i>Helianthus</i> species	Geographical location	Plant tissue	Major components (> 5%)	Ref.
<i>Helianthus annuus</i> L.	Camp Verde, Arizona, USA	Leaves	Germacrene D (19.1%), α -pinene (17.4%), limonene (10.0%), β -phellandrene (6.7%)	[554]
<i>Helianthus annuus</i> L.	Ijanikin, Lagos, Nigeria	Leaves	α -Pinene (16.0%), sabinene (9.4%), germacrene D (9.0%)	[555]
<i>Helianthus annuus</i> L.	Da'an City, Jilin Province, China	Receptacles	α -Pinene (26.0%), verbenone (7.4%), calarene (5.3%)	[556]
<i>Helianthus annuus</i> L. cv. "Carlos"	Università di Pisa, Italy	Seeds	α -Pinene (56.3%), <i>cis</i> -verbenol (16.7%), β -gurjunene (7.2%)	[557]
<i>Helianthus annuus</i> L. cv. "Carlos"	Università di Pisa, Italy	Leaves	α -Pinene (28.9%), sabinene (23.2%), limonene (12.3%), germacrene D (8.8%), bornyl acetate (7.8%), camphene (5.4%)	[558]
<i>Helianthus annuus</i> L. cv. "Carlos"	Università di Pisa, Italy	Capitula	α -Pinene (70.7%), sabinene (12.1%)	[558]
<i>Helianthus annuus</i> L. cv. "Chianti"	Gurley, north Alabama, USA	Aerial parts	α -Pinene (50.7%), camphene (7.3%), limonene (7.2%), bornyl acetate (7.1%), sabinene (6.8%), β -pinene (5.8%)	[559]
<i>Helianthus annuus</i> L. cv. "Florom 350"	Università di Pisa, Italy	Seeds	α -Pinene (43.1%), β -gurjunene (13.0%), <i>cis</i> -verbenol (16.7%)	[557]
<i>Helianthus annuus</i> L. cv. "Florom 350"	Università di Pisa, Italy	Leaves	α -Pinene (28.2%), sabinene (23.5%), limonene (11.1%), germacrene D (8.2%), bornyl acetate (8.0%)	[558]
<i>Helianthus annuus</i> L. cv. "Florom 350"	Università di Pisa, Italy	Capitula	α -Pinene (74.5%), sabinene (11.2%)	[558]
<i>Helianthus annuus</i> L. cv. "LD5009"	Baicheng, Jilin Province, China	Receptacles	α -Pinene (29.9%), <i>p</i> -mentha-1,5-dien-8-ol (10.5%), campholenal (5.5%)	[560]
<i>Helianthus annuus</i> L. cv. "Mammoth"	Gurley, north Alabama, USA	Aerial parts	α -Pinene (48.9%), sabinene (17.0%), limonene (7.1%), germacrene D (6.8%)	[559]
<i>Helianthus annuus</i> L. cv. "S606"	Baicheng, Jilin Province, China	Receptacles	Desmethoxyencecalin (28.5%), γ -gurjunene (19.9%), α -pinene (10.3%)	[560]
<i>Helianthus annuus</i> L. cv. "SH363"	Baicheng, Jilin Province, China	Receptacles	Desmethoxyencecalin (15.5%), α -pinene (15.3%), γ -gurjunene (11.9%), verbenone (6.9%), <i>p</i> -mentha-1,5-dien-8-ol (6.2%), campholenal (5.3%)	[560]
<i>Helianthus petiolaris</i> Nutt.	La Pampa, Argentina	Aerial parts	α -Pinene (66%), germacrene D (16%), bornyl acetate (10%), camphene (8%)	[561]
<i>Helianthus strumosus</i> L.	Huntsville, Alabama, USA	Aerial parts	α -Pinene (58.7%), myrcene (9.8%), bornyl acetate (5.0%)	[559]
<i>Helianthus tuberosus</i> L.	Ukraine	Leaves	β -Bisabolene (70.5%), (<i>Z</i>)- α -bisabolene epoxide (12.6%)	[562]
<i>Helianthus tuberosus</i> L.	Ukraine	Tubers	β -Bisabolene (63.1%), squalene (9.8%), phenylacetaldehyde (8.3%), verbenone (6.2%), bornyl acetate (5.2%)	[562]
<i>Helianthus tuberosus</i> L.	Leskovac, southern Serbia	Tubers	β -Bisabolene (22.9%), undecanal (12.7%), α -pinene (7.6%), kauran-16-ol (6.9%), 2-pentylfuran (5.7%)	[563]

The recent data of major components of *Helichrysum* essential oils are summarized in Table 40.

3.1.38. *Heliopsis* Pers.

Apparently, there has been only one publication of an

essential oil from a *Heliopsis*, *Heliopsis helioanthoides* (L.) Sweet, cultivated in southern Alabama, USA [580]. The major components of the the essential oil extracted from the aerial parts were germacrene D

Table 40. Chemical compositions of *Helichrysum* essential oils.

<i>Helichrysum</i> species	Geographical location	Plant tissue	Major components (> 5%)	Ref.
<i>Helichrysum arenarium</i> (L.) Moench	Utena district, eastern Lithuania	Inflorescences	Palmitic acid (23.8%), myristic acid (14.9%), (<i>E</i>)- β -caryophyllene (5.4%), methyl linolenate (5.3%)	[571]
<i>Helichrysum arenarium</i> (L.) Moench	Utena district, eastern Lithuania	Leaves	Palmitic acid (18.8%), nonanal (10.4%), myristic acid (8.7%), (<i>E</i>)- β -caryophyllene (6.5%)	[571]
<i>Helichrysum arenarium</i> (L.) Moench	Alax, Inner Mongolia, China	Aerial parts	Spathulenol (20.0%), α -bisabolol (10.2%), ledol (10.0%), bicyclogermacrene (5.7%), aromadendrene (5.2%)	[572]
<i>Helichrysum arenarium</i> (L.) Moench	Yozgat Akdagmadeni district, Türkiye	Inflorescences	Oleic acid (30.3%), ethyl palmitate (20.2%), linoleic acid (18.9%)	[573]
<i>Helichrysum arenarium</i> (L.) Moench	Varna, Bulgaria	Aerial parts	α -Pinene (34.6–44.4%), sabinene (10.6–11.1%)	[569]
<i>Helichrysum benthamii</i> R. Vig. & Humbert	Ambatobe, Madagascar	Aerial parts	α -Pinene (23.1-50.8%), α -copaene (5.4-8.5%), caryophyllene oxide (1.5-6.8%), α -humulene (3.1-6.4%)	[574]
<i>Helichrysum bujerianum</i> DC.	Mount Tsiafakafokely, Madagascar	Aerial parts	(<i>E</i>)- β -Caryophyllene (16.1%), γ -curcumene (9.0%), δ -cadinene (7.6%), γ -cadinene (6.5%), aristolochene (6.2%)	[574]
<i>Helichrysum chionophilum</i> Boiss. & Balansa	Kayseri, Arslantaş plateau, Türkiye	Aerial parts	Capric acid (18.9%), myristic acid (17.0%), lauric acid (13.9%), palmitic acid (12.3%)	[575]
<i>Helichrysum cooperi</i> Harv.	Sanremo, Italy	Aerial parts	1,8-Cineole (16.4%), sabinene (14.7%), terpinen-4-ol (8.4%), himachalol (6.6%), α -thujene (5.0%)	[576]
<i>Helichrysum cymosum</i> (L.) D.Don	Bellville, South Africa	Aerial parts	α -Pinene (29.8%), (<i>E</i>)- β -caryophyllene (19.2%), 1,8-cineole (15.1%), (<i>E</i>)- β -ocimene (8.2%)	[570]
<i>Helichrysum diotoides</i> DC.	Alakamisiy kely, Madagascar	Aerial parts	(<i>E</i>)- β -Caryophyllene (15.0%), δ -cadinene (5.6%)	[574]
<i>Helichrysum dubardii</i> R. Vig. & Humbert	Ambatobe, Madagascar	Aerial parts	1,8-Cineole (26.9-35.7%), α -pinene (5.8-6.6%), α -muurolene (3.2-7.2%)	[574]
<i>Helichrysum edwardsii</i> Wild	Sanremo, Italy	Aerial parts	β -Pinene (31.2%), sabinene (22.4%), β -thujone (8.7%)	[576]
<i>Helichrysum hirtum</i> Humbert	Arivonimamo, Madagascar	Aerial parts	7- <i>epi</i> -Silphiperfol-5-en-13-oic acid (18.2-40.0%), silphiperfol-5-en-13-oic acid (4.0-10.6%), 7- <i>epi</i> -subergorgiol (7.6-14.8%) 7 β - <i>H</i> -silphiperfol-5-ene (1.8-14.8%), presilphiperfolan-9 α -ol (6.9-8.0%), β -betulenol (3.8-5.4%), α -humulene (1.1-5.1%)	[574]
<i>Helichrysum ibityense</i> R. Vig. & Humbert	Mount Ibity, Madagascar	Leaves	1,8-Cineole (69.5%)	[577]
<i>Helichrysum indutum</i> Humbert	Alaotra Mangoro, Madagascar	Aerial parts	(<i>E</i>)- β -Caryophyllene (33.1%)	[574]
<i>Helichrysum noeanum</i> Boiss.	Ankara, Bala-Kaman, Türkiye	Aerial parts	Palmitic acid (25.3%), lauric acid (17.8%), myristic acid (13.7%)	[575]
<i>Helichrysum odoratissimum</i> Sweet	Commercial essential oil, Bellville, South Africa	Not indicated	1,8-Cineole (17.4%), α -pinene (15.8%), γ -curcumene (15.8%), <i>ar</i> -curcumene (7.6%), (<i>E</i>)- β -caryophyllene (7.3%), α -terpineol (5.5%), β -pinene (5.2%)	[570]

Table 40. (Continued).

<i>Helichrysum</i> species	Geographical location	Plant tissue	Major components (> 5%)	Ref.
<i>Helichrysum odoratissimum</i> Sweet	Sanremo, Italy	Aerial parts	1,8-Cineole (25.1%), α -pinene (16.5%), <i>epi</i> -cubebol (9.0%), β -selinene (8.1%), <i>epi</i> - α -bisabolol (5.6%), 14-hydroxy-9- <i>epi</i> -(<i>E</i>)-caryophyllene (5.0%)	[576]
<i>Helichrysum pallasii</i> Ledeb.	Armutlu district of Bayburt province, Türkiye	Inflorescences	α -Springene (34.9%), <i>iso</i> -ledene (7.1%), δ -selinene (5.8%), aristolene (5.1%)	[578]
<i>Helichrysum pandurifolium</i> Schrank	Sanremo, Italy	Aerial parts	Viridiflorol (60.3%), δ -cadinene (7.5%), α -pinene (5.8%)	[576]
<i>Helichrysum petiolare</i> Hilliard & B.L.Burtt	Bellville, South Africa	Aerial parts	Faurinone (20.7%), (<i>E</i>)- β -ocimene (17.2%), β -pinene (10.5%), 1,8-cineole (9.9%), α -pinene (7.5%), <i>allo</i> -ocimene (6.7%)	[570]
<i>Helichrysum thianschanicum</i> Regel	Khorugh, Badakhshon Province, Tajikistan	Aerial parts	Pentylcurcumene (21.6%), β -selinene (6.4%)	[579]
<i>Helichrysum trilineatum</i> DC.	Sanremo, Italy	Aerial parts	Sandaracopimarinol (17.7%), α -pinene (11.5%), bicyclogermacrene (10.7%), spathulenol (7.2%), abieta-7,13-diene (6.1%), germacrene D (5.5%)	[576]

(42.4%) and 4-vinylguaicol (5.5%).

3.1.39. *Heteromera* Pomel

The leaf essential oil of *Heteromera fuscata* Pomel (syn. *Chrysanthemum fuscatum* Desf.) from Gafsa, Tunisia, was largely composed of limonene (20.6%), germacrene D (10.4%), and β -phellandrene (6.5%) [581]. The major components of the floral essential oil, on the other hand, were limonene (12.9%), geranyl isovalerate (9.3%), geranyl 2-methylbutyrate (7.0%), and α -muurolol (5.5%).

3.1.40. *Launaea* Endl.

The major components in the essential oil from the aerial parts of *Launaea nudicaulis* (L.) Hook.f. from Algeria were palmitic acid (17.3%), β -selinene (9.9%), (*E*)- β -caryophyllene (7.9%), (*E*)- β -farnesene (7.6%), and α -cadinol (5.9%) [582]. The leaf essential oil of *Launaea taraxacifolia* (Willd.) Amin ex C. Jeffrey from Ipara, Badagry, Nigeria, was dominated by limonene (48.8%) along with sabinene (18.8%) and citronellal (11.0%) [583].

3.1.41. *Liatris* Gaertn. ex Schreb.

The aerial parts of *Liatris spicata* (L.) Willd., cultivated in southern Alabama, yielded an essential oil with germacrene D (23.7%), myrcene (13.7%), α -pinene (8.1%), and caryophyllene oxide (5.9%) as the major

components [580].

3.1.42. *Matricaria* L.

Chamomile (*Matricaria chamomilla* L., syn. *Matricaria recutita* L.) is the most important species of the genus, and its phytochemistry and pharmacology have been reviewed several times [584–589]. At least six chemotypes of chamomile, based on essential oil composition, have been described: (1) (*E*)- β -farnesene, (2) bisabolone oxide A, (3) α -bisabolol oxide A/ α -bisabolol oxide B/*cis*-bicycloether, (4) α -bisabolol oxide B/ α -bisabolol oxide A/chamazulene, (5) α -bisabolol, and (6) α -bisabolol oxide A (Fig. 5) [590]. The essential oil compositions of *Matricaria aurea* (Loefl.) Sch.Bip. have also been reviewed recently [30]. The common constituents of *M. aurea* essential oil are bisabolol oxide, α -bisabolol, and farnesene. *Matricaria decipiens* K. Koch from Taleghan, Iran, produced an essential oil from its aerial parts, composed of (*Z,Z*)-matricaria ester (33.3%), 1,8-cineole (10.5%), (*Z,E*)-matricaria ester (8.6%), camphor (6.5%), (*E,Z*)-matricaria ester (6.0%), and (*E*)- β -farnesene (5.6%) [591]. The major components in the essential oil of *Matricaria sevanensis* (Manden.) Rauschert aerial parts from Osmaniye Province, Türkiye, were bisabolone oxide A (50.3%), (*Z*)- β -farnesene (24.2%), and α -bisabolol oxide A (8.1%) [592].

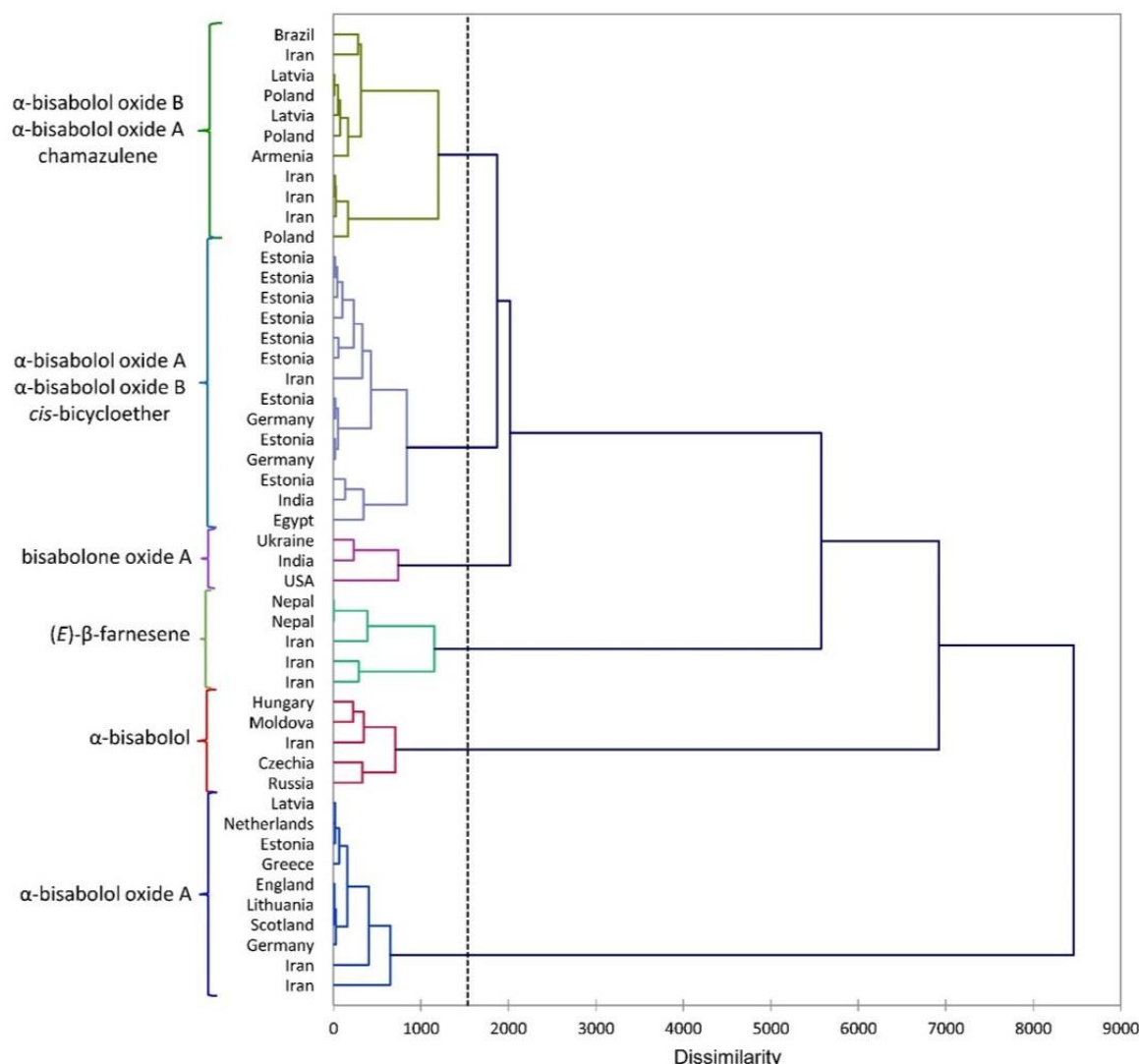


Figure 5. Dendrogram based on hierarchical cluster analysis of *Matricaria chamomilla* essential oil compositions.

3.1.43. *Maurantherum* Vogt & Oberpr.

The floral essential oil of *Maurantherum paludosum* (Poir.) Vogt & Oberpr. from Rades, Tunisia, was largely composed of pentacosane (26.9%), palmitic acid (19.1%), caryophyllene oxide (7.6%), and tricosane (5.2%) [581].

3.1.44. *Mikania* Willd.

Although 456 species of *Mikania* [33] have been recognized, only a few have been examined for their essential oil content. The pharmacology and phytochemistry of *Mikania* species have been previously reviewed [593–596]. Recent reports on the chemical composition of *Mikania* species are summarized in Table 41.

3.1.45. *Montanoa* Cerv.

There are 29 species of *Montanoa* distributed in the

Neotropics [33]. The essential oils of several species have been characterized (Table 42).

3.1.46. *Neomirandea* R.M. King & H. Rob.

The *Neomirandea* genus comprises 32 Neotropical species [33]. Only *Neomirandea angularis* (B.L. Rob.) R.M. King & H. Rob. from Monteverde, Costa Rica, has been investigated for its essential oil composition. The leaf essential oil was dominated by the sesquiterpene hydrocarbons germacrene D (83.2%) and β -selinene (10.5 %) [611].

3.1.47. *Ormenis* (Cass.) Cass. (syn. *Cladanthus* Cass.)

The most important species in terms of essential oil is *Ormenis mixta* (L.) Dumort. (syn. *Cladanthus mixtus* (L.) Chevall.), also known as Moroccan chamomile. The essential oil compositions and biological activities of *Ormenis* (*Cladanthus*) have been reviewed [612–614].

Table 41. Chemical compositions of *Mikania* essential oils.

<i>Mikania</i> species	Geographical location	Plant tissue	Major components (> 5%)	Ref.
<i>Mikania cordifolia</i> (L.f.) Willd.	State of Paraná, Brazil	Aerial parts	Limonene (19.2%), β -pinene (17.8%), α -pinene (16.0%), myrcene (13.3%), bicyclogermacrene (8.8%), (<i>E</i>)- γ -bisabolene (5.4%)	[597]
<i>Mikania glomerata</i> Spreng.	Ribeirão Preto, State of São Paulo, Brazil	Leaves	Coumarin (7.3-28.3%), spathulenol (17.3-20.8%), caryophyllene oxide (8.0-10.9%)	[598]
<i>Mikania glomerata</i> Spreng.	Paulinia, State of São Paulo, Brazil	Leaves	Germacrene D (46.0%), (<i>E</i>)- β -caryophyllene (20.4%), bicyclogermacrene (5.8%)	[599]
<i>Mikania involucreta</i> Hook. & Arn.	Penha, Santa Catarina, Brazil	Leaves	Caryophyllene oxide (27.7%), limonene (12.7%), spathulenol (8.2%), (<i>E</i>)- β -caryophyllene (6.8%), 1-epi-cubanol (5.4%)	[600]
<i>Mikania laevigata</i> Sch.Bip. ex Baker	Oratórios, Minas Gerais, Brazil	Leaves	Germacrene D (44.4%), bicyclogermacrene (15.2%), (<i>E</i>)- β -caryophyllene (12.8%), α -pinene (6.1%),	[601]
<i>Mikania laevigata</i> Sch.Bip. ex Baker	Oratórios, Minas Gerais, Brazil	Leaves	Germacrene D (40.3-35.3%), bicyclogermacrene (15.7-19.7%), (<i>E</i>)- β -caryophyllene (8.0-9.0%), α -pinene (5.9-10.3%), spathulenol (4.9-8.9%)	[602]
<i>Mikania laevigata</i> Sch.Bip. ex Baker	Paulinia, State of São Paulo, Brazil	Leaves	Germacrene D (40.8%), (<i>E</i>)- β -caryophyllene (14.3%), bicyclogermacrene (10.6%), β -pinene (8.1%), α -pinene (7.9%)	[599]
<i>Mikania micrantha</i> Kunth	Vietnam	Leaves	β -Cubebene (11.3%), germacrene D (11.0%), α -zingiberene (10.8%)	[603]
<i>Mikania micrantha</i> Kunth	Vietnam	Stems	Limonene (17.0%), β -pinene (7.9%), α -zingiberene (7.3%)	[603]
<i>Mikania micrantha</i> Kunth	Assam, India	Flowers	Isolatedene (16.0%), δ -cadinene (11.2%), debromofiliformin (9.4%), (<i>E</i>)- β -caryophyllene (9.1%), β -bisabolene (7.4%), germacrene-D (5.8%), zingiberene (5.3%)	[604]
<i>Mikania scandens</i> (L.) Willd.	Muksudpur, Gopalganj, Bangladesh	Leaves	(<i>E</i>)- β -Caryophyllene (17.0%), δ -cadinene (12.2%), α -cubebene (11.3%), caryophyllene oxide (7.7%)	[605]

Table 42. Chemical compositions of *Montanoa* essential oils.

<i>Montanoa</i> species	Geographical location	Plant tissue	Major components (> 5%)	Ref.
<i>Montanoa bipinnatifida</i> (Kunth) K. Koch	Doqqi, Giza Governorate, Egypt	Leaves	Germacrene D (37.2%), (<i>E</i>)- β -caryophyllene (30.7%)	[606]
<i>Montanoa guatemalensis</i> B.L. Rob. & Greenm.	Monteverde, Costa Rica	Leaves	Cyclocolorenone (14.5-27.5%), limonene (8.1-21.3%), α -selinene (0.0-21.2%), <i>trans</i> -muurola-4(14),5-diene (0.0-16.8%), β -cadinene (0.0-13.3%), β -selinene (0.0-14.8%), α -pinene (3.2-8.6%), selina-3,7(11)-diene (3.6-7.7%)	[607]
<i>Montanoa quadrangularis</i> Sch.Bip.	Mérida, Venezuela	Flowers	Limonene + β -phellandrene (27.8%), <i>trans</i> -sabinol (23.5%), myrcene (13.5%), (<i>E</i>)- β -caryophyllene (5.9%)	[608]
<i>Montanoa quadrangularis</i> Sch.Bip.	Mérida, Venezuela	Leaves	Myrcene (26.2%), limonene + β -phellandrene (16.1%), (<i>E</i>)- β -caryophyllene (14.7%), sabinene (8.9%), 1,8-cineole (5.7%), α -thujene (5.2%)	[608]

Table 42. (Continued).

Montanoa species	Geographical location	Plant tissue	Major components (> 5%)	Ref.
<i>Montanoa quadrangularis</i> Sch.Bip.	Mérida, Venezuela	Stems	Sabionene (22.3%), myrcene (13.6%), limonene + β -phellandrene (12.2%), β -pinene (9.9%), α -thujene (9.2%), terpinen-4-ol (5.8%), germacrene D (5.7%)	[608]
<i>Montanoa speciosa</i> K. Koch	Mérida, Yucatan, México	Flowers	(<i>E</i>)- β -Caryophyllene (17.9%), δ -cadinene (9.3%), caryophyllene oxide (8.7%), germacrene D (5.8%)	[609]
<i>Montanoa speciosa</i> K. Koch	Mérida, Yucatan, México	Leaves	(<i>E</i>)- β -Caryophyllene (20.7%), δ -cadinene (9.9%), caryophyllene oxide (9.5%), germacrene D (6.9%)	[609]
<i>Montanoa tomentosa</i> Cerv.	Guanajuato, Mexico	Leaf glandular trichomes	β -Eudesmol (26.8-56.1%), valencene (25.3-45.0%)	[610]

The essential oil yields and chemical compositions vary widely and are strongly dependent on geographical location (Table 43) [612, 615].

3.1.48. *Parthenium* L.

Of the 12 recognized species of *Parthenium* [33], only two have been examined for their essential oils. Commercially, *Parthenium argentatum* A. Gray (guayule) is the most important species as an alternative source of rubber [624]. *Parthenium hysterophorus* L. is a noxious weed outside its natural range, but it has also shown medicinal potential [31]. The major essential oil components of *P. argentatum* and *P. hysterophorus* are summarized in Table 44.

3.1.49. *Phania* DC.

Phania is a small genus comprising six species restricted to the Caribbean (Cuba and Dominican Republic) [33]. The essential oil of *Phania cajalbanica* Borhidi & O. Muñiz from Cuba was dominated by δ -elemene (25.9%) and 1,7-di-*epi*- β -cedrene (20.8%) [630]. The major components of *Phania matricarioides* Griseb. essential oil from Cuba, were contained lavandulyl acetate (40.1%), thymyl isobutyrate (13.9%), 8,9-dehydrothymul isobutyrate (5.9%), and lavandulol (5.5%) [631].

3.1.50. *Polymnia* Kalm.

As far as we are aware, the essential oils have been reported from only two species of *Polymnia*. There are two reports of *Polymnia canadensis* L. essential oils from north Alabama, USA. The major components were germacrene D (63.6%), (*E*)- β -caryophyllene (15.9%), and bicyclgermacrene (5.4%) from Monte Sano, Alabama [632]; germacrene D (44.5%), (*E*)- β -

caryophyllene (14.8%), and kauran-16 β -ol (5.4%) from Blue Spring, Alabama [632]; and α -phellandrene (28.3%), α -pinene (19.7%), and germacrene D (11.4%) from Hampton Cove, Alabama [13]. The essential oil from the tubers of *Polymnia sonchifolia* Poepp. was rich in α -pinene (33.5%), *neo*-abienol (15.7%), *cis*-abienol (15.4%), and *trans*-abienol (7.0%) [633].

3.1.51. *Porophyllum* Guett

The genus *Porophyllum* comprises of 32 species, which are native to the New World [33]. The phytochemical and pharmacological properties of *Porophyllum* species have been reviewed [634]. The essential oils of *Porophyllum* species are summarized in Table 45.

3.1.52. *Pulicaria* Gaertn.

The compositions and biological activities of *Pulicaria* essential oils was reviewed in 2021 [646]. Essential oil compositions of *Pulicaria* species recently reported are summarized in Table 46.

3.1.53. *Rudbeckia* L.

Of the 27 species of *Rudbeckia* recognized by the World Flora Online [33], only three species have been examined in terms of essential oils, *Rudbeckia fulgida* Aiton, *Rudbeckia hirta* L., and *Rudbeckia laciniata* L. (Table 47).

3.1.54. *Santolina* L.

There are around 21 species of *Santolina*, which are native to Europe, North Africa, and the Caucasus [33]. D’Auria and co-workers presented a summary of *Santolina chamaecyparissus* L. essential oil compositions in 2023 [665], while Sarri and co-authors reviewed the essential oil compositions of *Santolina rosmarinifolia* L. until 2021 [666]. A summary of the

Table 43. Chemical compositions of *Ormenis* (*Cladanthus*) essential oils.

<i>Ormenis</i> species	Geographical location	Plant tissue	Major components (> 5%)	Ref.
<i>Ormenis eriolepis</i> Coss. ex Maire	Morocco	Aerial parts	Isobutyl angelate (22.0-22.4%), isobutyl isobutyrate (20.8-21.2%), α -pinene (5.8-9.2%), 2-methylbutyl angelate (7.2-7.7%), 2-methylbutyl isobutyrate (5.7-5.8%), 2-methylallyl isobutyrate (5.3-5.5%)	[616]
<i>Ormenis mixta</i> Dumort.	Morocco	Flowers	Camphor (14.4-29.0%), 2-tridecanone (21.5%), (<i>E</i>)- β -farnesene (8.3%)	[617]
<i>Ormenis mixta</i> Dumort.	Morocco	Leaves	(<i>E</i>)-Nerolidol (44.1%), camphor (11-33%), myrcene (12.4%)	[617]
<i>Ormenis mixta</i> Dumort.	Maâmoura region, Morocco	Aerial parts	Santolina alcohol (37.5%), (<i>E</i>)- β -farnesene (6.2%), τ -muurolol (6.0%)	[618]
<i>Ormenis mixta</i> Dumort.	Souk Had, Morocco	Aerial parts	1,8-Cineole (20.8%), α -pinene (16.1%)	[619]
<i>Ormenis mixta</i> Dumort.	Sidi Slimane, Morocco	Aerial parts	(<i>E</i>)-Nerolidol (13.9%), farnesa-1,7(14),10-triene (5.8%), 6,9-epoxyfarnesa-1,7(14),10-trien-3-ol (5.4%)	[619]
<i>Ormenis mixta</i> Dumort.	Bouznika, Morocco	Aerial parts	2-Methyl-2-(<i>E</i>)-butenyl methacrylate ^a (32.0-35.2%), <i>ar</i> -curcumene (13.0-14.0%)	[620]
<i>Ormenis mixta</i> Dumort.	Oujda, Morocco	Aerial parts	(<i>E</i>)- β -Farnesene (35.5-50.5%)	[620]
<i>Ormenis mixta</i> Dumort.	Taounate region, Morocco	Aerial parts	Germacrene D (11.5%), 1,8-cineole (10.3%), (<i>Z</i>)-methyl isoeugenol (9.0%), butyric acid (8.5%), δ -elemene (5.5%)	[621]
<i>Ormenis mixta</i> Dumort. subsp. <i>multicaulis</i> Maire	Kénitra, Morocco	Aerial parts	Santolina alcohol (24.1-47.6%), τ -muurolol (5.5%), α -cadinol (5.4%)	[622]
<i>Ormenis mixta</i> Dumort. subsp. <i>multicaulis</i> Maire	Salé, Morocco	Aerial parts	Santolina alcohol (44.7-55.1%), τ -muurolol (5.7%), α -cadinol (5.2%)	[622]
<i>Ormenis multicaulis</i> Braun-Blanq. & Maire	Commercial, Morocco	Flowers	α -Pinene (24.9%), santolina alcohol (15.2%), 1,8-cineole (7.2%), δ -elemene ^b (6.7%), limonene (6.0%)	[520]
<i>Ormenis scariosa</i> Litard. & Maire	Tizi n'Ticha, Morocco	Aerial parts	Germacrene D (13.2%), α -pinene (11.9%), sabinene (10.2%), terpinen-4-ol (8.8%), <i>p</i> -cymene (8.5%), α -phellandrene (5.2%)	[614]
<i>Ormenis scariosa</i> Litard. & Maire	Ait M'hamed, Morocco	Aerial parts	<i>p</i> -Cymene ^c (11.3%), caryophyllene oxide (9.9%), γ -terpinene (8.3%), sabinene (7.1%), elemol (6.5%), terpinolene (5.6%), spathulenol (5.0%)	[623]
<i>Ormenis scariosa</i> Litard. & Maire	Azilal, Morocco	Aerial parts	Sabinene (15.6-23.8%), α -pinene (12.2-17.7%), terpinen-4-ol (4.6-11.0%)	[615]

^a This compound is not found in the Dictionary of Natural Products [98]; its identification may be incorrect. ^b Isomer was not identified, but RI is consistent with δ -elemene.

Table 44. Chemical compositions of *Parthenium* essential oils.

<i>Parthenium</i> species	Geographical location	Plant tissue	Major components (> 5%)	Ref.
<i>Parthenium argentatum</i> A. Gray	Tehran, Iran	Flowers	α -Pinene (27.2%), β -phellandrene (17.0%), γ -eudesmol (11.3%), β -pinene (10.0%), β -eudesmol (9.0%)	[625]
<i>Parthenium argentatum</i> A. Gray	CIRAD, Montpellier, France	Aerial parts	α -Pinene (22.5-37.0%), sabinene (12.5-14.0%), limonene (8.1-9.1%), bornyl acetate (4.3-7.0%)	[626]
<i>Parthenium argentatum</i> A. Gray	Riverside, California, USA	Leaves	α -Pinene (16.7%), β -pinene (13.6%), terpinolene (9.2%), sabinene (6.5%), limonene (5.9%)	[627]

Table 44. (Continued).

<i>Parthenium</i> species	Geographical location	Plant tissue	Major components (> 5%)	Ref.
<i>Parthenium hysterophorus</i> L.	Lavras, Minas Gerais state, Brazil	Leaves	Germacrene D (35.9%), (<i>E</i>)- β -ocimene (8.5%)	[628]
<i>Parthenium hysterophorus</i> L.	Nghe An Province, Vietnam	Aerial parts	Germacrene D (23.2%), myrcene (14.4%), (<i>E</i>)- β -caryophyllene, (12.6%),	[629]

Table 45. Chemical compositions of *Porophyllum* essential oils.

<i>Porophyllum</i> species	Geographical location	Plant tissue	Major components (> 5%)	Ref.
<i>Porophyllum angustissimum</i> Gardner	Balneário Pinhal, Rio Grande do Sul state, Brazil	Aerial parts	β -Pinene (37.7%), limonene (14.6%), myrcene (12.0%), (<i>E</i>)- β -ocimene (10.2%), (3 <i>Z</i>)-undecene (5.5%)	[635]
<i>Porophyllum curticeps</i> Malme	Porto Alegre, Rio Grande do Sul state, Brazil	Aerial parts	Limonene (28.2%), myrcene (22.6%), (2 <i>E</i>)-dodecadial (14.7%), decanal (11.5%), β -pinene (10.6%)	[635]
<i>Porophyllum gracile</i> Benth.	Ottawa, Ontario, Canada	Leaves	Myrcene (40.6%), sabinene (20.5%), β -cubebene (9.1%)	[636]
<i>Porophyllum lanceolatum</i> DC.	Barão do Triunfo, Rio Grande do Sul state, Brazil	Aerial parts	Decanal (60.2%), (2 <i>E</i> ,6 <i>Z</i>)-dodecadial (12.1%)	[635]
<i>Porophyllum linaria</i> (Cav.) DC.	Santa Cruz Xoxocotlán, Oaxaca, México	Leaves	Myrcene (41.9%), limonene (20.3%), estragole (20.0%), 1-undecene (8.0%)	[637]
<i>Porophyllum linaria</i> (Cav.) DC.	San Andrés Cholula, Puebla, Mexico	Aerial parts	Linoleic acid (29.5%), phytol (25.5%), palmitic acid (18.4%)	[638]
<i>Porophyllum ruderales</i> (Jacq.) Cass.	Viçosa, Minas Gerais state, Brazil	Flowers	β -Phellandrene (44.9%), (<i>Z</i>)- β -ocimene (9.6%), α -pinene (6.3%)	[639]
<i>Porophyllum ruderales</i> (Jacq.) Cass.	Viçosa, Minas Gerais state, Brazil	Leaves	β -Phellandrene (56.9%), α -pinene (8.0%), (<i>Z</i>)- β -ocimene (6.7%)	[639]
<i>Porophyllum ruderales</i> (Jacq.) Cass.	Cochabamba valley, Bolivia	Aerial parts	Sabinene (64.1%), terpinen-4-ol (10.3%)	[640]
<i>Porophyllum ruderales</i> (Jacq.) Cass.	Barão do Triunfo, Rio Grande do Sul state, Brazil	Aerial parts	(<i>E</i>)- β -Ocimene (51.3%), myrcene (9.8%), perillene (6.1%)	[635]
<i>Porophyllum ruderales</i> (Jacq.) Cass.	Mérida, Venezuela	Aerial parts	Limonene + β -phellandrene (50.3%), sabinene (20.2%)	[641]
<i>Porophyllum ruderales</i> (Jacq.) Cass.	Bingerville, Côte d'Ivoire	Aerial parts	Myrcene (35.5%), γ -terpinene (26.4%), β -pinene (21.7%), limonene (9.3%)	[642]
<i>Porophyllum ruderales</i> (Jacq.) Cass. subsp. <i>macrocephalum</i> (DC.) R.R.Johnson	São Paulo, Brazil	Aerial parts	Limonene (83.5%), 1-undecene (5.4%)	[643]
<i>Porophyllum ruderales</i> (Jacq.) Cass. subsp. <i>macrocephalum</i> (DC.) R.R.Johnson	São Paulo, Brazil	Aerial parts	1-Undecene (29.0%), limonene (27.4%), α -isocomene (5.7%)	[644]

Table 45. (Continued).

Porophyllum species	Geographical location	Plant tissue	Major components (> 5%)	Ref.
<i>Porophyllum ruderale</i> (Jacq.) Cass. subsp. <i>macrocephalum</i> (DC.) R.R.Johnson	Cajamarca, Perú	Aerial parts	Limonene (63.9%), 1-undecene (10.2%) and (<i>E</i>)- β -caryophyllene (5.1%)	[645]
<i>Porophyllum ruderale</i> (Jacq.) Cass. subsp. <i>runderale</i>	São Paulo, Brazil	Aerial parts	(<i>E</i>)- β -Ocimene (54.9%), limonene (25.2%), 1- β -pinene (10.1%)	[643]
<i>Porophyllum ruderale</i> (Jacq.) Cass. subsp. <i>runderale</i>	São Paulo, Brazil	Aerial parts	(<i>E</i>)- β -Ocimene (58.6%), limonene (17.4%), 1-undecene (13.7%)	[644]

Table 46. Chemical compositions of *Pulicaria* essential oils.

<i>Pulicaria</i> species	Geographical location	Plant tissue	Major components (> 5%)	Ref.
<i>Pulicaria arabica</i> Cass.	M'sala, Algeria	Aerial parts	τ -Cadinol (23.9%), δ -cadinene (21.1%), α -cadinol (19.8%), germacrene D-4-ol (8.4%)	[187]
<i>Pulicaria arabica</i> Cass.	Bordj Bou Arreridj, Algeria	Aerial parts	α -Cadinol (35.1%), δ -cadinene (22.5%), τ -muurolol (12.6%), τ -cadinol (11.8%), α -muurolene (5.9%)	[647]
<i>Pulicaria arabica</i> Cass.	Riyadh city, Saudi Arabia	Aerial parts	Carvotanacetone (36.9%), carvomenthone (27.2%)	[648]
<i>Pulicaria arabica</i> Cass.	Al-shadeeda, Alkharj province, Saudi Arabia	Aerial parts	τ -Cadinol (38.6%), carvotanacetone (10.3%), caryophyllene oxide (5.3%), palmitic acid (5.3%)	[649]
<i>Pulicaria burchardii</i> Hutch. subsp. <i>burchardii</i>	Chichaoua, Morocco	Aerial parts	1-Oxobisabolone (65.1%), 1,8-cineole (13.9%)	[650]
<i>Pulicaria crispa</i> Sch. Bip.	Riyadh, Saudi Arabia	Aerial parts	Caryophyllene oxide (34.0%), modheph-2-ene (23.3%), geranyl isovalerate (6.7%)	[651]
<i>Pulicaria crispa</i> Sch. Bip.	Dead Sea region, Jordan	Flowers	Chrysanthenone (34.7%), <i>p</i> -cymen-8-ol (24.6%)	[652]
<i>Pulicaria crispa</i> Sch. Bip.	Dead Sea region, Jordan	Leaves	Chrysanthenone (29.2%), <i>p</i> -cymen-8-ol (19.4%), vanillin (10.9%), 7- <i>epi</i> - α -eudesmol (9.8%)	[652]
<i>Pulicaria crispa</i> Sch. Bip.	Kenadsa, Algeria	Aerial parts	(<i>E</i>)- β -Caryophyllene (40.1%), caryophyllene oxide (11.1%)	[653]
<i>Pulicaria crispa</i> Sch. Bip.	Al-henniya, Alkharj province, Saudi Arabia	Aerial parts	τ -Cadinol (53.5%), (<i>E</i>)- β -caryophyllene (10.8%)	[649]
<i>Pulicaria dysenterica</i> (L.) Bernh.	Paklenik, Karaula, Olovo Municipality, Bosnia and Herzegovina	Aerial parts	Caryophyllene oxide (14.9%), (<i>E</i>)-nerolidol (9.2%), nerol (5.9%)	[14]
<i>Pulicaria dysenterica</i> (L.) Bernh.	Skrapež, Serbia	Aerial parts	3-Methoxycuminyll isobutyrate (31.1%), neryl isobutyrate (22.1%), (<i>E</i>)- β -caryophyllene (5.6%), neryl 2-methylbutyrate (5.5%)	[654]
<i>Pulicaria dysenterica</i> (L.) Bernh.	Niš, Serbia	Aerial parts	3-Methoxycuminyll isobutyrate (25.5%), neryl isobutyrate (16.4%), (<i>E</i>)- β -caryophyllene (8.2%)	[654]
<i>Pulicaria gnaphaloides</i> (Vent.) Boiss.	Dalfard, Kerman province, Iran	Aerial parts	1,8-Cineole (17.7%), α -terpineol (7.9%), eudesma-4(15),7-dien-1 β -ol (7.2%), terpinen-4-ol (5.7%)	[655]

Table 46. (Continued).

<i>Pulicaria</i> species	Geographical location	Plant tissue	Major components (> 5%)	Ref.
<i>Pulicaria gnaphaloides</i> (Vent.) Boiss.	Khabr, Kerman province, Iran	Aerial parts	Terpinen-4-ol (20.3%), 1,8-cineole (11.8%), α -terpineol (9.0%), cedr-8(15)-en-9 α -ol (7.5%), eudesma-4(15),7-dien-1 β -ol (7.1%)	[655]
<i>Pulicaria gnaphaloides</i> (Vent.) Boiss.	Koohpayeh, Kerman province, Iran	Aerial parts	1,8-Cineole (22.8%), terpinen-4-ol (11.2%), α -terpineol (11.2%), eudesma-4(15),7-dien-1 β -ol (5.5%), geraniol (5.2%)	[655]
<i>Pulicaria gnaphaloides</i> (Vent.) Boiss.	Mayduk, Kerman province, Iran	Aerial parts	1,8-Cineole (24.0%), α -terpineol (11.5%), cedr-8(15)-en-9 α -ol (11.1%), geraniol (7.5%)	[655]
<i>Pulicaria gnaphaloides</i> (Vent.) Boiss.	Sarcheshmeh, Kerman province, Iran	Aerial parts	Citronellyl acetate (23.5%), <i>cis</i> -chrysanthenyl acetate (19.9%), α -terpineol (8.7%), terpinen-4-ol (5.6%)	[655]
<i>Pulicaria incisa</i> (Lam.) DC.	Neve Zonar, Israel	Aerial parts	<i>cis</i> -Chrysanthenol (52.7%), xanthoxylin (15.4%), carvotanacetone (11.7%)	[656]
<i>Pulicaria incisa</i> (Lam.) DC. subsp. <i>candolleana</i> E. Gamal-Eldin	Jabal Al-Lawz, Tabuk province, Saudi Arabia	Aerial parts	Linalool (33.0%), chrysanthenone (10.3%), eugenol (8.9%) <i>cis</i> -chrysanthenol (8.0%), (<i>Z</i>)-jasmone (5.7%)	[657]
<i>Pulicaria jaubertii</i> E. Gamal-Eldin	Sana'a, Yemen	Aerial parts	Carvotanacetone (20.7%), linolenic acid (9.6%), 1-hexacosanol (5.6%), palmitic acid (5.1%)	[658]
<i>Pulicaria mauritanica</i> Batt.	Kasr Igoudman Aghbalou N'Kerdous, Morocco	Aerial parts	Carvotanacetone (67.9%)	[659]
<i>Pulicaria odora</i> (L.) Rchb.	Peloritani mountains, Sicily	Aerial parts	(2 <i>E</i>)-Hexenal (14.8%), thymyl isobutyrate (11.4%), α -cadinol (5.7%)	[660]
<i>Pulicaria petiolaris</i> Jaub. & Spach	Sana'a, Yemen	Aerial parts	(10 <i>E</i> ,12 <i>Z</i>)-Linoleic acid (10.2%), palmitic acid (6.2%), piperitone (5.8%), linoleic acid (5.5%)	[658]
<i>Pulicaria somalensis</i> O. Hoffm.	Al-senaiyya, Alkharj province, Saudi Arabia	Aerial parts	Intermedeol (15.9%), α -cadinol (9.7%), γ -eudesmol (9.1%), α -eudesmol (5.2%)	[649]
<i>Pulicaria undulata</i> (L.) C.A. Mey.	Wadi Alsahbaa, Alkharj, Riyadh region, Saudi Arabia	Aerial parts	β -Pinene (21.1%), γ -terpinene (7.7%), <i>iso</i> -shyobunone (7.7%), 6- <i>epi</i> -shyobunol (6.5%), α -pinene (5.1%)	[661]
<i>Pulicaria undulata</i> (L.) C.A. Mey.	Wadi Hagoul, Eastern Desert, Egypt	Aerial parts	Spathulenol (30.9%), hexahydrofarnesyl acetone (18.1%), α -bisabolol (6.3%)	[661]
<i>Pulicaria undulata</i> (L.) C.A. Mey.	Ardestan, Isfahan province, Iran	Aerial parts	1,8-Cineole (26.0%), α -pinene (12.5%), camphor (8.4%), camphene (5.0%)	[662]

Table 47. Chemical compositions of *Rudbeckia* essential oils.

<i>Rudbeckia</i> species	Geographical location	Plant tissue	Major components (> 5%)	Ref.
<i>Rudbeckia fulgida</i> Aiton	Huntsville, Alabama, USA	Aerial parts	Germacrene D (30.1%), δ -cadinene (17.8%), (<i>E</i>)- β -caryophyllene (10.0%), γ -muurolene (8.9%), (<i>E</i>)- β -ocimene (6.2%), (2 <i>E</i>)-hexenal (6.0%)	[663]
<i>Rudbeckia hirta</i> L.	Bucharest, Romania	Flowers	β -Phellandrene (26.0%), germacrene D (21.6%), α -pinene (16.3%), sabinene (12.0%)	[664]
<i>Rudbeckia hirta</i> L.	Huntsville, Alabama, USA	Aerial parts	Germacrene D (23.6%), (2 <i>E</i>)-hexenal (20.2%), δ -cadinene (16.2%), (<i>E</i>)- β -ocimene (15.2%), γ -muurolene (8.9%)	[663]
<i>Rudbeckia laciniata</i> L.	Monte Sano, Alabama, USA	Aerial parts	Limonene (58.9%), α -pinene (10.2%), β -pinene (9.2%), myrcene (5.3%),	[13]

essential oil compositions of *Santolina* species is presented in Table 48.

3.1.55. *Saussurea* DC.

Currently, 436 species of *Saussurea* have been recognized [33]. The essential oil compositions of several species of *Saussurea* have been reviewed [672], including *Saussurea costus* (Falc.) Lipsch. [673–675], *Saussurea lappa* (Decne.) Sch. Bip. [676–678], *Saussurea medusa* Maxim. [679], *Saussurea involucrata* (Kar. & Kir.) Sch. Bip., *Saussurea obovata* (DC.) Edgew. [680], as well as *Saussurea controversa* DC., *Saussurea latifolia* Ledeb., *Saussurea parviflora* (Poir.) DC., and *Saussurea salicifolia* DC. [681]. Recent reports on the essential oil compositions of *Saussurea* species are summarized in Table 49.

3.1.56. *Schizogyne* Cass.

There are only three species of *Schizogyne*, all of which are endemic to the Canary Islands: *Schizogyne glaberrima* DC., *Schizogyne obtusifolia* Cass., and *Schizogyne sericea* (L.f.) DC. [33]. The major essential oil components of *S. glaberrima* and *S. sericea* are summarized in Table 50. To date, the essential oil composition of *S. obtusifolia* has not been reported.

3.1.57. *Smallanthus* Mack.

Currently, the World Flora Online recognizes 21 species of *Smallanthus* [33]. Of these, the essential oils of five species have been reported (Table 51).

3.1.58. *Solidago* L.

Solidago is a large genus comprising 156 species [33]. Of these, *Solidago canadensis* L. seems to be the most important with respect to essential oil characterization, which has been reviewed [13, 699]. The essential oil compositions of *S. canadensis* and other *Solidago* species are summarized in Table 52.

3.1.59. *Sphaeranthus* L.

The phytochemistry and biological activities of *Sphaeranthus indicus* L. have been reviewed [725, 726]. The major essential oil components of *Sphaeranthus* species are summarized in Table 53.

3.1.60. *Sphagneticola* O. Hoffm.

There are only four species of *Sphagneticola* (syn. *Thelechitonina*), namely *Sphagneticola brachycarpa* (Baker) Pruski, *Sphagneticola calendulacea* (L.) Pruski, *Sphagneticola gracilis* (Rich.) Pruski, and *Sphagneticola trilobata* (L.) Pruski [33]. Apparently, only *S. trilobata*

has been investigated for its essential oil composition (Table 54). The phytochemistry and pharmacology of *S. trilobata* have been reviewed [732].

3.1.61. *Symphotrichum* Nees

There are around 100 species of *Symphotrichum* [33], but the essential oils of only *Symphotrichum novae-angliae* (L.) G.L. Nesom (syn. *Aster novae-angliae* L.) and *Symphotrichum squamatum* (Spreng.) G.L. Nesom (syn. *Aster squamatus* Hieron.) have been reported. The leaf essential oil of *S. novae-angliae* from north Alabama, USA, was largely composed of (2E)-hexenal (31.0%), germacrene D (25.5%), α -pinene (16.4%), δ -cadinene (14.3%), and γ -muurolene (5.4%) [663]. The essential oils of *S. squamatum* aerial parts were obtained from an inland population (Mansoura, Egypt) and a Mediterranean coastal population (Gamsa City, Al-Dakahlia Governorate, Egypt) [736]. The major components of the coastal sample were humulene epoxide I (18.5%), spathulenol (15.5%), caryophyllene oxide (14.4%), germacrene D (5.9%), and α -humulene (5.5%). On the other hand, the inland sample, showed α -pinene (24.2%), germacrene D (8.6%), α -humulene (7.4%), α -muurolene (6.8%), humulene epoxide I (6.3%), and caryophyllene oxide (6.0%) as the major components.

3.1.62. *Tagetes* L.

Tagetes (marigolds), is a genus of approximately 50 species native to southern North America, Central America, and South America [33]. The phytochemistry and biological activities of this genus have been extensively studied, and there are several reviews on *Tagetes* [737–740], including *Tagetes erecta* L. (Mexican marigold) [741–746], *Tagetes minuta* L. (southern marigold) [747, 748], and *Tagetes patula* L. (French marigold) [749]. The representative essential oil compositions of *Tagetes* species are summarized in Table 55.

3.1.63. *Tanacetum* L.

The chemical compositions and biological activities of the members of the genus *Tanacetum* have been previously reviewed [775–779]. Of the 192 species of *Tanacetum* [33], the most important in terms of ethnopharmacological uses and biological activities are *Tanacetum parthenium* (L.) Sch. Bip. (feverfew), *Tanacetum vulgare* L. (tansy), and *Tanacetum balsamita* L. (costmary) [778]. The phytochemical and

Table 48. Chemical compositions of *Santolina* essential oils.

<i>Santolina</i> species	Geographical location	Plant tissue	Major components (> 5%)	Ref.
<i>Santolina africana</i> Jord. & Fourr.	El Krib Sud region, Tunisia	Stems	Artemisia ketone (44.3%), iso-borneol (26.6%)	[667]
<i>Santolina africana</i> Jord. & Fourr.	Taounate Province, Morocco	Stems	Artemisia ketone (35.4%), santolina alcohol (16.2%), iso-borneol (6.1%), β -oplophenone (5.1%)	[667]
<i>Santolina chamaecyparissus</i> L.	Siedlce, Poland	Aerial parts	Artemisia ketone (25.9%), β -phellandrene (18.7%), vulgarone B (11.6%), myrcene (9.2%), β -pinene (6.1%)	[4]
<i>Santolina chamaecyparissus</i> L.	Commercial, Spain	Aerial parts	Artemisia ketone (26.6%), β -phellandrene (21.7%), myrcene (9.7%), sabinene (7.2%), β -pinene (6.9%), longiverbenone (5.9%)	[520]
<i>Santolina chamaecyparissus</i> L.	Osmaniye province, Türkiye	Aerial parts	Artemisia ketone (39.8%), camphor (17.7%), β -phellandrene (8.0%) and β -bisabolene (7.3%).	[668]
<i>Santolina etrusca</i> (Lacaita) Marchi & D'Amato	Acquapendente, Italy	Aerial parts	Viridiflorol (24.0%), 1,8-cineole (9.2%), β -pinene (8.8%), terpinen-4-ol (8.1%), pinocarveol (6.3%)	[665]
<i>Santolina impressa</i> Hoffmanns. & Link	Portugal	Aerial parts	β -Pinene (12.6%), β -phellandrene (10.4%), yomogi alcohol (8.8%), limonene (8.1%), camphor (7.1%), 1,8-cineole (6.2%), myrcene (6.0%)	[669]
<i>Santolina insularis</i> (Gennari ex Fiori) Arrigoni	Nebida, Sardinia, Italy	Aerial parts	β -Phellandrene (22.6%), myrcene (11.4%), artemisia ketone (7.6%), <i>ar</i> -curcumene (7.1%), β -pinene (5.4%), γ -curcumene (5.0%)	[670]
<i>Santolina rosmarinifolia</i> L.	Palmela, Setúbal, Portugal	Aerial parts	β -Pinene (29.6%), borneol (16.9%), myrcene (15.4%), limonene (5.7%)	[671]
<i>Santolina rosmarinifolia</i> L.	Hodna area, Algeria	Aerial parts	Capillene (32.8%), 1,8-cineole (15.1%), myrcene (14.0%)	[666]

Table 49. Chemical compositions of *Saussurea* essential oils.

<i>Saussurea</i> species	Geographical location	Plant tissue	Major components (> 5%)	Ref.
<i>Saussurea amara</i> (L.) DC.	Qianshan, China	Aerial parts	Caryophyllene oxide (12.4%), δ -selinene (9.5%), <i>trans</i> - β -elemene (8.8%), (<i>E</i>)- β -caryophyllene (7.6%), β -selinene (5.6%), δ -guaiene (5.1%)	[682]
<i>Saussurea costus</i> (Falc.) Lipsch.	Not reported	Roots	1,8,11,14-Heptadecatetraene (40.9%), <i>trans</i> - β -elemene (9.3%), (<i>E</i>)- β -caryophyllene (7.2%),	[683]
<i>Saussurea costus</i> (Falc.) Lipsch.	Lahaul & Spiti, Himachal Pradesh, India	Roots	Linoleic acid (24.7%), valerenol (11.8%), erementhin (10.7%), α -costol (6.6%), germacrene B (6.7%), (<i>Z</i>)- <i>trans</i> - α -bergamotyl acetate (6.7%), γ -costol (5.5%)	[684]
<i>Saussurea lappa</i> (Decne.) Sch. Bip.	Cairo, Egypt (market)	Roots	Velleral (22.5%), eremanthin (23.7%), α -selinene (9.7%), dehydrosaussurea lactone (6.9%), costunolide (6.9%)	[685]
<i>Saussurea lappa</i> (Decne.) Sch. Bip.	Dronagiri village, Uttarkhand, India	Roots	Dehydrocostus lactone (68.8%), dihydrodehydrocostus lactone (20.4%)	[686]
<i>Saussurea lappa</i> (Decne.) Sch. Bip.	Bordj Bou Arreridj, Algeria (market)	Roots	Dehydrocostus lactone (55.4%), costunolide (8.9%), dehydrosaussurea lactone (5.6%)	[687]
<i>Saussurea nivea</i> Turcz.	Beijing, China	Aerial parts	Limonene (15.5%), caryophyllene oxide (7.6%), linalool (7.2%), α -pinene (6.4%), β -pinene (5.7%), spathulenol (5.0%)	[688]
<i>Saussurea pulchella</i> (Fisch.) Fisch.	Primorsky Krai, Shkotovsky District, Russia	Aerial parts	Caryophyllene oxide (30.8%), germacrene D (24.3%), (<i>E</i>)- β -caryophyllene (9.1%)	[689]

Table 50. Chemical compositions of *Schizogyne* essential oils.

<i>Schizogyne</i> species	Geographical location	Plant tissue	Major components (> 5%)	Ref.
<i>Schizogyne glaberrima</i> DC.	Barranco de Mogán, Gran Canaria	Aerial parts	<i>p</i> -Cymene (64.9%), limonene (25.2%), α -phellandrene (5.2%)	[690]
<i>Schizogyne sericea</i> (L.f.) DC.	La Barranquera, Tenerife	Aerial parts	<i>p</i> -Cymene (34.0%), isobornyl acetate (11.5%)	[691]
<i>Schizogyne sericea</i> (L.f.) DC.	Palm Mar, Tenerife	Aerial parts	<i>p</i> -Cymene (48.0%), limonene (5.6%)	[692]
<i>Schizogyne sericea</i> (L.f.) DC.	Fasnia, Tenerife	Aerial parts	<i>p</i> -Cymene (43.0%), β -pinene (5.3%)	[692]
<i>Schizogyne sericea</i> (L.f.) DC.	La Barranquera, Tenerife	Aerial parts	<i>p</i> -Cymene (57.0%), isobornyl acetate (5.1%)	[692]
<i>Schizogyne sericea</i> (L.f.) DC.	Montaña de Guaza, Tenerife	Aerial parts	<i>p</i> -Cymene (45.0%), β -pinene (6.0%), isobornyl acetate (5.3%)	[693]
<i>Schizogyne sericea</i> (L.f.) DC.	Palm Mar, Tenerife	Aerial parts	<i>p</i> -Cymene (48.0%), isobornyl acetate (11.0%), limonene (5.6%)	[694]
<i>Schizogyne sericea</i> (L.f.) DC.	Los Roques, Tenerife	Aerial parts	<i>p</i> -Cymene (43.0%), β -pinene (5.3%)	[694]
<i>Schizogyne sericea</i> (L.f.) DC.	La Barranquera, Tenerife	Aerial parts	<i>p</i> -Cymene (57.0%), isobornyl acetate (5.1%)	[694]

Table 51. Chemical compositions of *Smallanthus* essential oils.

<i>Smallanthus</i> species	Geographical location	Plant tissue	Major components (> 5%)	Ref.
<i>Smallanthus maculatus</i> (Cav.) H. Rob.	San José, Costa Rica	Leaves	α -Pinene (32.9%), germacrene D (13.7%), (<i>E</i>)- β -caryophyllene (10.7%), β -pinene (7.1%), camphene (5.4%)	[695]
<i>Smallanthus parviceps</i> (S.F. Blake) H. Rob.	Ayacucho, Peru	Leaves	α -Phellandrene (18.3%), (<i>E</i>)- β -caryophyllene (8.7%), <i>p</i> -cymene (8.1%), β -curcumene (7.3%)	[696]
<i>Smallanthus quichensis</i> (J.M. Coult.) H. Rob.	Turrialba Volcano, Costa Rica	Aerial parts	α -Pinene (35.5%), <i>p</i> -cymene (11.5%), β -phellandrene (9.2%), α -phellandrene (9.0%), limonene (5.8%)	[697]
<i>Smallanthus quichensis</i> (J.M. Coult.) H. Rob.	Turrialba Volcano, Costa Rica	Aerial parts	α -Pinene (64.5%), 1,8-cineole (9.7%)	[697]
<i>Smallanthus sonchifolius</i> (Poepp.) H. Rob.	Duitama, Colombia	Leaves	Sabinene (40.8%), germacrene D (15.4%), (<i>E</i>)- β -caryophyllene (9.9%), terpinen-4-ol (5.5%)	[698]
<i>Smallanthus uvedalia</i> (L.) Mack.	Monte Sano, Alabama, USA	Leaves	(<i>E</i>)- β -Caryophyllene (24.5%), caryophyllene oxide (19.8%), 14-hydroxy-9- <i>epi</i> -(<i>E</i>)-caryophyllene (8.9%), 14-hydroxy-9- <i>epi</i> -(<i>Z</i>)-caryophyllene (8.2%)	[632]
<i>Smallanthus uvedalia</i> (L.) Mack.	Blue Spring, Alabama, USA	Leaves	(<i>E</i>)- β -Caryophyllene (16.5%), caryophyllene oxide (14.2%), spathulenol (7.5%), 14-hydroxy-9- <i>epi</i> -(<i>E</i>)-caryophyllene (6.2%)	[632]
<i>Smallanthus uvedalia</i> (L.) Mack.	Monte Sano, Alabama, USA	Aerial parts	α -Pinene (65.6%), limonene (11.4%), β -pinene (6.0%)	[13]
<i>Smallanthus uvedalia</i> (L.) Mack.	Caesars Head, South Carolina, USA	Aerial parts	α -Pinene (23.9%), (<i>E</i>)- β -caryophyllene (16.9%), perillene (14.5%), germacrene D (12.2%), limonene (6.1%)	[580]

Table 52. Chemical compositions of *Solidago* essential oils.

<i>Solidago</i> species	Geographical location	Plant tissue	Major components (> 5%)	Ref.
<i>Solidago caesia</i> L.	Göttingen, Germany	Aerial parts	β-Cubebene (22.6%), α-pinene (8.7%), α-cadinol (7.7%), δ-cadinene (6.3%), (E)-β-caryophyllene (5.1%)	[700]
<i>Solidago canadensis</i> L.	Bhimtal, Kumaon, India	Aerial parts	Germacrene D (56.7-75.5%), limonene (0.2-12.5%)	[701]
<i>Solidago canadensis</i> L.	L'ubotice, Slovakia	Aerial parts	Germacrene D (34.9%), limonene (12.5%), α-pinene (11.6%), <i>trans</i> -β-elemene (7.1%), bornyl acetate (6.3%)	[702]
<i>Solidago canadensis</i> L.	El-Mansoureya, Giza, Egypt	Aerial parts	Germacrene D (9.86-29.47%), α-pinene (3.38-29.17%), γ-cadinene (0.39-20.36%), myrcene (2.98-13.74%), limonene (4.81-11.47%)	[703]
<i>Solidago canadensis</i> L.	Hampton Cove, Alabama, USA	Aerial parts	Myrcene (20.3%), bornyl acetate (14.4%), sabinene (14.3%), α-pinene (13.9%), germacrene D (10.7%)	[13]
<i>Solidago canadensis</i> L.	Ljubljana, Slovenia	Flowers	α-Pinene (33.1%), limonene (21.5%), germacrene D (10.4%)	[704]
<i>Solidago canadensis</i> L.	Szentlőrinc, Hungary	Flowers	α-Pinene (29.5%), bornyl acetate (12.2%), limonene (5.1%)	[705]
<i>Solidago canadensis</i> L.	Bucharest, Romania	Flowers	α-Pinene (27.9%), germacrene D (13.2%), limonene (12.3%), bornyl acetate (5.8%)	[706]
<i>Solidago canadensis</i> L.	Vilnius, Lithuania	Flowers	α-Pinene (18.1%), <i>trans</i> -verbenol (13.1%), bornyl acetate (11.9%), germacrene D (8.1%)	[707]
<i>Solidago canadensis</i> L.	Moscow, Russia	Flowers	α-Pinene (61.2%), limonene (13.7%), bornyl acetate (8.5%)	[708]
<i>Solidago canadensis</i> L.	Vilnius, Lithuania	Flowers	α-Pinene (18.8%), germacrene D (8.4%), bornyl acetate (6.0%)	[709]
<i>Solidago canadensis</i> L.	Ljubljana, Slovenia	Leaves	Germacrene D (48.7%), cyclocolorenone (7.6%), bornyl acetate (5.5%)	[704]
<i>Solidago canadensis</i> L.	Szentlőrinc, Hungary	Leaves	Bornyl acetate (13.4%), germacrene D (11.0%), cyclocolorenone (8.8%), eudesma-4(15).7-dien-1β-ol (7.1%)	[705]
<i>Solidago canadensis</i> L.	Bhimtal, India	Leaves	Germacrene D (64.1%)	[710]
<i>Solidago canadensis</i> L.	Vilnius, Lithuania	Leaves	Carvacrol (23.3%), β-cubebene (21.3%), germacrene D (19.6%), bornyl acetate (18.7%), α-pinene (8.6%)	[707]
<i>Solidago canadensis</i> L.	Moscow, Russia	Leaves	Bornyl acetate (29.8%), germacrene D (16.6%)	[708]
<i>Solidago canadensis</i> L.	Vilnius, Lithuania	Leaves	Germacrene D (19.5%), bornyl acetate (7.1%)	[709]
<i>Solidago canadensis</i> L.	Szentlőrinc, Hungary	Roots	Limonene (32.7%), β-pinene (31.3%)	[705]
<i>Solidago canadensis</i> L.	Bhimtal, India	Roots	Thymol (20.3%), α-copaene (6.3%), carvacrol (5.5%)	[711]
<i>Solidago chilensis</i> Meyen	Pérez, Rosario, Argentina	Flowers	Limonene (13.4%), pumiloxide (12.7%), γ-cadinene (8.2%)	[712]
<i>Solidago chilensis</i> Meyen	Pérez, Rosario, Argentina	Leaves	Pumiloxide (15.3%), γ-cadinene (5.6%)	[712]
<i>Solidago decurrens</i> Lour.	Tonglu county, Zhejiang province, China	Leaves	δ-Elemene (30.8%), (E)-β-caryophyllene (15.4%), ledene oxide II (13.1%), β-elemene (6.4%)	[713]

Table 52. (Continued).

<i>Solidago</i> species	Geographical location	Plant tissue	Major components (> 5%)	Ref.
<i>Solidago gigantea</i> Aiton	Warsaw, Poland	Aerial parts	Germacrene D (21.6%), cyclocolorenone (8.1%), α -pinene (7.0%), α -gurjunene (6.1%)	[714]
<i>Solidago gigantea</i> Aiton	Łódź, Poland	Aerial parts	Cyclocolorenone (32.4%), germacrene D (23.5%)	[714]
<i>Solidago glomerata</i> Michx.	Göttingen, Germany	Aerial parts	β -Cubebene (16.4%), α -pinene (14.4%), limonene (9.2%),	[700]
<i>Solidago gigantea</i> Aiton	Ljubljana, Slovenia	Flowers	Germacrene D (20.8%), α -pinene (7.6%)	[704]
<i>Solidago gigantea</i> Aiton	Szentlőrinc, Hungary	Flowers	Bornyl acetate (11.4%), germacrene D (9.0%), α -pinene (8.1%), cyclocolorenone (6.4%)	[705]
<i>Solidago gigantea</i> Aiton	Vilnius, Lithuania	Flowers	Germacrene D (11.2%), <i>p</i> -cymene (10.9%), α -pinene (10.7%), bornyl acetate (10.4%), isospathulenol (6.1%), spathulenol (5.0%)	[707]
<i>Solidago gigantea</i> Aiton	Vilnius, Lithuania	Flowers	Germacrene D (16.7%)	[709]
<i>Solidago gigantea</i> Aiton	Ljubljana, Slovenia	Leaves	Germacrene D (33.8%), bornyl acetate (9.1%)	[704]
<i>Solidago gigantea</i> Aiton	Szentlőrinc, Hungary	Leaves	Cyclocolorenone (15.6%), bornyl acetate (13.7%), germacrene D (6.3%)	[705]
<i>Solidago gigantea</i> Aiton	Vilnius, Lithuania	Leaves	Bornyl acetate (22.4%), β -cubebene (14.1%), spathulenol (6.7%), isospathulenol (6.3%), epoxyazulene (6.1%), germacrene D (5.9%)	[707]
<i>Solidago gigantea</i> Aiton	Vilnius, Lithuania	Leaves	Germacrene D (15.5%), bornyl acetate (12.7%),	[709]
<i>Solidago gigantea</i> Aiton	Szentlőrinc, Hungary	Roots	Germacrene D (14.4%), 1-nonene (13.1%)	[705]
<i>Solidago graminifolia</i> (L.) Salisb.	Opole, Lower Silesia, Poland	Aerial parts	β -Phellandrene (23.1%), sabinene (18.3%), β -pinene (10.3%)	[715]
<i>Solidago litoralis</i> Savi	Lucca, Tuscany, Italy	Aerial parts	Myrcene (65.1%), α -pinene (13.3%), (<i>E</i>)- β -caryophyllene (7.4%)	[716]
<i>Solidago nemoralis</i> Aiton	Göttingen, Germany	Aerial parts	Germacrene D (25.5%), α -pinene (9.5%), limonene (8.7%), β -phellandrene (6.1%), sabinene (5.9%), myrcene (5.5%)	[700]
<i>Solidago odora</i> Aiton	Worton, Maryland, USA	Flowers	Methyl chavicol (70.8%), myrcene (12.5%), methyl eugenol (5.8%)	[717]
<i>Solidago puberula</i> Nutt.	Saint-Ludger-de-Milot, Québec, Canada	Aerial parts	α -Phellandrene (53.0%), (<i>E,E</i>)- α -farnesene (10.7%), α -pinene (9.4%), γ -terpinene ^a (6.0%), α -phellandrene (5.7%)	[718]
<i>Solidago rugosa</i> Mill.	Göttingen, Germany	Aerial parts	Germacrene D (41.8%), sabinene (8.3%), terpinen-4-ol 7.0%	[700]
<i>Solidago tortifolia</i> Elliott	Göttingen, Germany	Aerial parts	Sabinene (18.3%), β -pinene (12.2%), β -cubebene (8.3%), α -calacorene (7.5%) α -pinene (6.6%), limonene (5.6%)	[700]
<i>Solidago virga-aurea</i> L. var. <i>asiatica</i> Nakai	Koheung, Jeolanamdo, Korea	Aerial parts	Palmitic acid (29.2%), 7-hexyl eicosane (9.1%), spathulenol (7.7%), 3,8-dimethyl decane (6.5%)	[719]

Table 52. (Continued).

Solidago species	Geographical location	Plant tissue	Major components (> 5%)	Ref.
<i>Solidago virga-aurea</i> L. var. <i>asiatica</i> Nakai	Seoguipo, Jejudo, Korea	Aerial parts	δ-2-Carene (41.0%), α-copaene (10.8%), α-muurolene (5.8%)	[720]
<i>Solidago virgaurea</i> L.	Almora, Uttarakhand, India	Aerial parts	Limonene (25.6%), α-humulene (12.2%), <i>trans</i> -dehydroxylinalool oxide (8.7%), benzyl salicylate (6.4%), 1,4-cineole (6.2%), humulene epoxide II (5.9%)	[721]
<i>Solidago virgaurea</i> L.	Łódź, Poland	Aerial parts	α-Pinene (32.5%), myrcene (17.9%), limonene (14.1%), germacrene D (8.2%), β-pinene (5.4%)	[722]
<i>Solidago virgaurea</i> L.	Warsaw, Poland	Aerial parts	α-Pinene (34.1%), germacrene D (17.0%), myrcene (9.0%), β-pinene (7.5%)	[722]
<i>Solidago virgaurea</i> L.	Kielce, Poland	Aerial parts	α-Pinene (27.4%), germacrene D (13.5%), sabinene (11.8%), myrcene (7.8%), β-pinene (7.5%)	[722]
<i>Solidago virgaurea</i> L.	Čačak, Serbia	Aerial parts	Cyclocolorenol (18.0-29.5%), germacrene D (7.7-9.4%), germacra-4(15),5,10(14)-trien-1α-ol (5.8-6.8%), spathulenol (4.8-5.9%), gymnomitrol (4.3-5.0%), bornyl acetate (3.1-5.2%)	[723]
<i>Solidago virgaurea</i> L.	Zasavje, Slovenia	Flowers	α-Pinene (28.5%), germacrene D (8.4%)	[704]
<i>Solidago virgaurea</i> L.	Vilnius, Lithuania	Flowers	α-Pinene (28.6%), β-copaene (12.2%), spathulenol (8.5%), <i>trans</i> -verbenol (6.6%)	[707]
<i>Solidago virgaurea</i> L.	Novo-Mikhaylovskoe, Russia	Flowers	α-Pinene (36.5%), myrcene (14.8%), (<i>E</i>)-β-caryophyllene (10.5%), germacrene D (8.2%), limonene (6.4%)	[724]
<i>Solidago virgaurea</i> L.	Vilnius, Lithuania	Flowers	Caryophyllene oxide (9.2%), humulene epoxide II (6.8%), germacrene D (6.7%), <i>trans</i> -verbenol (6.4%)	[709]
<i>Solidago virgaurea</i> L.	Zasavje, Slovenia	Leaves	α-Pinene (13.1%), caryophyllene oxide (10.2%), humulene epoxide II (6.7%), spathulenol (6.5%), germacrene D (6.3%)	[704]
<i>Solidago virgaurea</i> L.	Vilnius, Lithuania	Leaves	<i>trans</i> -Verbenol (24.6%), α-pinene (16.0%), caryophyllene oxide (9.0%), verbenone (7.3%)	[707]
<i>Solidago virgaurea</i> L.	Vilnius, Lithuania	Leaves	Caryophyllene oxide (9.0%), <i>trans</i> -verbenol (6.3%), spathulenol (5.9%), humulene epoxide II (5.7%), α-pinene (5.2%)	[709]

Table 53. Chemical compositions of *Sphaeranthus* essential oils.

<i>Sphaeranthus</i> species	Geographical location	Plant tissue	Major components (> 5%)	Ref.
<i>Sphaeranthus africanus</i> L.	Diên Lãm Commune, Pù Huèng Natural Reserve, Nghe An Province, Vietnam	Aerial parts	1-Decen-3-ol (36.9%), α-pinene (21.0%), τ-cadinol (7.5%), 3-octyl propionate (5.6%), (<i>E</i>)-β-caryophyllene (5.5%)	[629]
<i>Sphaeranthus amaranthoides</i> Burm.f.	Tirunelveli District, Tamil Nadu, India	Leaves	Carvone (89.7%), 2-cyclohexen-1-ol (6.7%)	[727]
<i>Sphaeranthus cyathuloides</i> O. Hoffm.	Carnivore, Nairobi, Kenya	Leaves	<i>trans</i> -Dihydrocarvone (67.4%), <i>cis</i> -dihydrocarvone (26.2%)	[728]
<i>Sphaeranthus indicus</i> L.	Calicut University, Kerala, India	Aerial parts	Thymohydroquinone dimethylether (27.0%), τ-cadinol (12.5%), β-eudesmol (9.1%), α-eudesmol (7.0%)	[729]

Table 53. (Continued).

<i>Sphaeranthus</i> species	Geographical location	Plant tissue	Major components (> 5%)	Ref.
<i>Sphaeranthus indicus</i> L.	Hyderabad, India	Aerial parts	Thymohydroquinone dimethylether (18.2%), selin-11-en-4 α -ol (12.7%), α -agarofuran (11.8%), (<i>E</i>)- β -caryophyllene (5.4%)	[730]
<i>Sphaeranthus indicus</i> L.	Calicut University, Kerala, India	Flowers	β -Eudesmol (21.4%), thymohydroquinone dimethylether (16.2%), (<i>E</i>)- β -caryophyllene (7.8%), τ -cadinol (7.2%), caryophyllene oxide (6.9%)	[729]
<i>Sphaeranthus indicus</i> L.	Calicut University, Kerala, India	Roots	Thymohydroquinone dimethylether (28.3%), τ -cadinol (25.3%), (<i>Z</i>)-arteannuic alcohol (10.1%), <i>iso</i> -Pinocamphone (33.5%), thymohydroquinone dimethylether (16.1%), α -pinene (10.6%), 1,8-cineole (6.6%), <i>p</i> -cymene (6.3%)	[729]
<i>Sphaeranthus suaveolens</i> DC.	Tanta, Egypt	Leaves		[731]

Table 54. Chemical compositions of *Sphagneticola trilobata* (L.) Pruski (syn. *Thelechitonia trilobata* (L.) H. Rob. & Cuatrec.) essential oils.

Geographical location	Plant tissue	Major components (> 5%)	Ref.
Federal University of Viçosa, Minas Gerais state, Brazil	Leaves	Germacrene D (11.9-35.8%), α -phellandrene (1.4-28.5%), α -pinene (7.3-23.8%), (<i>E</i>)- β -caryophyllene (4.6-19.0%), bicyclgermacrene (6.0-17.0%), limonene (1.8-15.1%), α -humulene (4.0-11.6%)	[733]
University of Zululand, Kwa-Zulu Natal Province, South Africa	Leaves	α -Pinene (21.6%), α -phellandrene (21.0%), limonene (12.8%), germacrene D (7.5%)	[734]
Pantnagar, Uttarakhand, India	Aerial parts	α -Pinene (78.6–83.3%)	[735]

Table 55. Chemical compositions of *Tagetes* species essential oils.

<i>Tagetes</i> species	Geographical location	Plant tissue	Major components (> 5%)	Ref.
<i>Tagetes argentina</i> Cabrera	Sierras Grandes, Córdoba, Argentina Pampa de Achala, El	Aerial parts	(<i>E</i>)-Tagetenone (28.8%), (<i>Z</i>)-tagetenone (17.9%), (<i>E</i>)-tagetone (11.8%), (<i>Z</i>)-tagetone (9.4%), dihydrotagetone (6.4%)	[750]
<i>Tagetes argentina</i> Cabrera	Condor, Córdoba Province, Argentina	Flowers	(<i>Z</i>)-Tagetenone (44.0%), (<i>E</i>)-tagetenone (38.3%)	[751]
<i>Tagetes coronopifolia</i> Willd.	Santa María Tecuanulco, Texcoco, Mexico Chupaca	Aerial parts	Verbenone (30.7%), dihydrotagetone ^a (14.5%), <i>cis</i> -verbenol ^b (13.3%), (<i>Z</i>)- β -ocimene (9.5%), (<i>E</i>)-tagetone (9.4%)	[752]
<i>Tagetes elliptica</i> Sm.	Province, Junín Region, Peru Chupaca	Leaves	(<i>Z</i>)-Tagetenone (37.3%), (<i>E</i>)-tagetenone (18.8%), dihydrotagetone (14.4%), (<i>E</i>)-tagetone (5.2%)	[753]
<i>Tagetes elliptica</i> Sm.	Province, Junín Region, Peru Chupaca	Leaves	(<i>Z</i>)-Tagetenone (34.2%), (<i>E</i>)-tagetenone (15.0%), (<i>Z</i>)-myroxide (14.5%), dihydrotagetone (13.9%), (<i>E</i>)-tagetone (5.8%)	[754]
<i>Tagetes erecta</i> L.	Po Valley, Italy	Flowers	Piperitone (28.9%), terpinolene (5.8%)	[737]

Table 55. (Continued).

Tagetes species	Geographical location	Plant tissue	Major components (> 5%)	Ref.
<i>Tagetes erecta</i> L.	Miyaneh county, East Azerbaijan Province, Iran	Fruit	2-Isopropyl-5-methyl-3-cyclohexen-1-one (20.0%), palmitic acid (19.1%), limonene (12.8%), terpinolene (11.6%)	[755]
<i>Tagetes erecta</i> L.	Mérida Municipio Libertador, Mérida State, Venezuela	Leaves	Piperitone (35.9%), terpinolene (22.2%), limonene (8.8%), (<i>E</i>)- β -ocimene (7.0%)	[756]
<i>Tagetes erecta</i> L.	Po Valley, Italy	Leaves	Terpinolene (28.8%), piperitone (24.2%), limonene (15.6%)	[737]
<i>Tagetes filifolia</i> Lag.	Tucumán, Argentina	Aerial parts	(<i>E</i>)-Anethole (76.9%), estragole (19.3%)	[10]
<i>Tagetes filifolia</i> Lag.	Sierra de Los Gigantes, Córdoba province, Argentina	Aerial parts	(<i>E</i>)-Anethole (74.8%), estragole (23.7%)	[757]
<i>Tagetes filifolia</i> Lag.	Occopa, Santiago District, Cuzco, Peru	Aerial parts	(<i>E</i>)-Anethole (85.0%), estragole (12.9%)	[758]
<i>Tagetes filifolia</i> Lag.	Alta Gracia, Córdoba Province, Argentina	Flowers	(<i>E</i>)-Anethole (67.0%), estragole (30.3%)	[751]
<i>Tagetes filifolia</i> Lag.	Mérida Municipio Libertador, Mérida State, Venezuela	Leaves	(<i>E</i>)-Anethole (87.5%), estragole (10.7%)	[756]
<i>Tagetes filifolia</i> Lag.	Po Valley, Italy	Leaves	Estragole (90.4%), (<i>E</i>)-anethole (5.5%)	[737]
<i>Tagetes filifolia</i> Lag.	Cerro Villonaco, Loja Province, Ecuador	Leaves	(<i>E</i>)-Anethole (55.6%), 1-tridecene (8.7%), estragole (5.8%)	[759]
<i>Tagetes lacera</i> Brandegee	La Paz y Los Cabos, Baja California Sur, México	Aerial parts	(<i>E</i>)-Tagetone (26.2%), verbenone (22.1%), α -thujene (20.5%), chrysanthenone (24.8%)	[760]
<i>Tagetes laxa</i> Cabrera	Salta Province, La Caldera, Yacones, Argentina	Aerial parts	(<i>E</i>)-Tagetenone (31.4%), (<i>Z</i>)-tagetone (26.2%), (<i>Z</i>)- β -ocimene (24.1%)	[761]
<i>Tagetes laxa</i> Cabrera	Yacones and Quebrada del Toro, Salta Province, Argentina	Flowers	(<i>E</i>)-Tagetenone (33.2%), (<i>Z</i>)-tagetone (27.1%), (<i>Z</i>)- β -ocimene (15.8%), (<i>E</i>)- β -ocimene (8.7%), dihydrotagetone (6.2%), (<i>Z</i>)-tagetone (5.6%)	[751]
<i>Tagetes lemmonii</i> A. Gray	Sierra de Mazatlán, Sonora, Mexico	Aerial parts	Dihydrotagetone ^a (35.2%), (<i>E</i>)-tagetone (21.8%), (<i>Z</i>)- β -ocimene (11.5%), (<i>Z</i>)-tagetone (7.5%)	[752]
<i>Tagetes lemmonii</i> A. Gray	Dover, Delaware, USA	Aerial parts	Dihydrotagetone (42.5%), (<i>E</i>)-tagetone (16.1%), (<i>E</i>)-tagetone (14.2%)	[762]
<i>Tagetes lucida</i> Cav.	San Pablo Ixayoc, Texcoco, Mexico	Aerial parts	Estragole (36.0%), (<i>E</i>)-anethole (17.2%), (<i>E</i>)- β -ocimene (9.0%)	[752]
<i>Tagetes lucida</i> Cav.	Havana, Cuba	Aerial parts	Estragole (97%)	[763]
<i>Tagetes lucida</i> Cav.	Po Valley, Italy	Flowers	Estragole (93.8%)	[737]
<i>Tagetes lucida</i> Cav.	Po Valley, Italy	Leaves	Estragole (78.2%), (<i>E</i>)- β -caryophyllene (9.4%)	[737]

Table 55. (Continued).

Tagetes species	Geographical location	Plant tissue	Major components (> 5%)	Ref.
<i>Tagetes mandonii</i> Sch. Bip. ex Klatt	Sacsayhuman National Park, Cusco District, Peru	Aerial parts	(E)- β -Ocimene (15.2%), (Z)- β -ocimene (11.8%), (Z)-anethole (9.2%), (E)-tagetenone (8.6%), (E)-tagetone (8.5%), spathulenol (6.9%)	[764]
<i>Tagetes mendocina</i> Phil.	Bauchaceta district, San Juan Province, Argentina	Aerial parts	(E)- β -Ocimene (28.6%), (Z)-tagetone (28.0%), (E)-tagetone (11.7%), (Z)-tagetenone (7.3%), α -pinene (5.5%)	[765]
<i>Tagetes minuta</i> L.	Tucumán, Argentina	Aerial parts	(Z)-Tagetone (62.4%), (E)- β -ocimene (16.2%), dihydrotagetone (10.3%)	[10]
<i>Tagetes minuta</i> L.	Po Valley, Italy	Flowers	(E)-Tagetone (58.0%), (Z)- β -ocimene (25.5%)	[737]
<i>Tagetes minuta</i> L.	Highlands near São Joaquim, Santa Catarina, Brazil	Flowers	(Z)-Tagetone (62.7%), (Z)- β -ocimene (21.3%), dihydrotagetone (5.6%)	[766]
<i>Tagetes minuta</i> L.	Dhamar Province, Yemen	Leaves	(E)-Tagetenone (34.8%), (Z)-tagetenone (15.9%), (Z)- β -ocimene (8.3%)	[767]
<i>Tagetes minuta</i> L.	Po Valley, Italy	Leaves	Dihydrotagetone (61.1%), (E)-tagetone (9.7%), limonene (8.8%), camphor (5.7%), (Z)- β -ocimene (5.1%)	[737]
<i>Tagetes multiflora</i> Kunth	Andahuaylas Province, Peru	Leaves	(Z)-Tagetone (29.1%), (E)- β -ocimene (20.3%), dihydrotagetone (7.9%), terpinolene (7.4%)	[768]
<i>Tagetes nelsonii</i> Greenm.	San Cristóbal de las Casas, Mexico	Leaves	(Z)-Tagetenone (25.0%), (E)-tagetone (15.3%), dihydrotagetone (12.7%), (Z)-tagetone (10.3%), <i>cis</i> -muurolo-4(14),5-diene (5.8%)	[769]
<i>Tagetes parryi</i> A.Gray	Villa de Zaragoza, San Luis Potosí State, Mexico	Aerial parts	Verbenone (33.4%), dihydrotagetone (26.9%), (Z)-tagetone (20.8%)	[770]
<i>Tagetes patula</i> L.	Siedlce district, Poland	Aerial parts	Terpinolene (15.8%), limonene (12.5%), piperitone (9.8%), piperitenone (8.4%), (Z)- β -ocimene (7.9%)	[4]
<i>Tagetes patula</i> L.	La Culata, Mérida State, Venezuela	Flowers	(E)- β -Caryophyllene (23.7%), terpinolene (15.6%), (Z)- β -ocimene (15.5%), piperitenone (8.4%), (Z)-tagetenone (8.7%), limonene (6.8%), (E)-tagetenone (5.1%)	[756]
<i>Tagetes patula</i> L.	Po Valley, Italy	Flowers	(E)- β -Caryophyllene (18.2%), (E)- β -ocimene (15.0%), terpinolene (14.6%), (Z)- β -ocimene (11.8%), limonene (6.1%)	[737]
<i>Tagetes patula</i> L.	La Culata, Mérida State, Venezuela	Leaves	Terpinolene (20.9%), piperitenone (14.0%), (E)-tagetenone (9.5%), limonene (8.4%), (Z)- β -ocimene (8.1%), piperitone (7.8%), (Z)-tagetenone (7.3%), (E)- β -caryophyllene (5.8%)	[756]
<i>Tagetes patula</i> L.	Po Valley, Italy	Leaves	Terpinolene (22.6%), (E)- β -ocimene (16.5%), limonene (13.4%), piperitone (7.2%), (Z)- β -ocimene (6.5%)	[737]
<i>Tagetes pusilla</i> Kunth	Guayaquil, Ecuador	Aerial parts	(E)-Anethole (68.0%), estragole (24.5%)	[771]
<i>Tagetes pusilla</i> Kunth	El Valle, Mérida, Venezuela	Leaves	(E)-Anethole (70.0%), estragole (30.0%)	[772]
<i>Tagetes riojana</i> M. Ferraro	Catamarca Province, Argentina	Leaves	(E)-Tagetone (40.3%), (Z)-tagetenone (23.2%), dihydrotagetone (15.4%), (E)- β -ocimene (7.5%)	[773]

Table 55. (Continued).

Tagetes species	Geographical location	Plant tissue	Major components (> 5%)	Ref.
<i>Tagetes rupestris</i> Cabrera	Tucumán, Argentina	Aerial parts	(E)-Tagetenone (39.3%), (E)-tagetone (24.4%), (Z)- β -ocimene (6.1%), (Z)-tagetenone (5.9%)	[10]
<i>Tagetes subulata</i> Cerv.	Mérida Municipio Libertador, Mérida State, Venezuela	Leaves	Terpinolene (26.0%), piperitenone (13.1%), limonene (10.8%), (Z)- β -ocimene (9.5%), (E)-tagetenone (9.5%), (E)- β -caryophyllene (6.0%), (Z)-tagetenone (5.5%), piperitone (5.4%)	[756]
<i>Tagetes tenuifolia</i> Cav.	Po Valley, Italy	Flowers	(E)-Tagetenone (24.7%), dihydrotagetone (20.2%), (Z)- β -ocimene (17.0%), (E)-tagetone (11.5%)	[737]
<i>Tagetes tenuifolia</i> Cav.	Po Valley, Italy	Leaves	(E)-Tagetenone (41.6%), dihydrotagetone (12.6%), (E)-tagetone (9.8%), (Z)- β -ocimene (5.9%)	[737]
<i>Tagetes terniflora</i> Kunth	Tucumán, Argentina	Aerial parts	(Z)-Tagetone (31.0%), (Z)- β -ocimene (15.4%), (E)-tagetenone (15.4%), (Z)-tagetenone (14.5%), (E)-tagetone (10.3%), dihydrotagetone (6.5%)	[10]
<i>Tagetes terniflora</i> Kunth	Los Altos de Chiapas, Mexico	Aerial parts	(E)-Tagetone (28.7%), dihydrotagetone ^a (20.5%), (Z)- β -ocimene (19.3%), <i>cis</i> -verbenol ^b (13.8%)	[752]
<i>Tagetes terniflora</i> Kunth	Salta Province, La Caldera, Yacones, Argentina	Aerial parts	(Z)-Tagetone (67.8%), (Z)- β -ocimene (18.0%), (E)-tagetenone (7.6%)	[761]
<i>Tagetes terniflora</i> Kunth	Tafi, Tucumán Province, Argentina	Flowers	Dihydrotagetone (68.2%), (Z)- β -ocimene (15.0%), (E)-tagetenone (5.5%)	[751]
<i>Tagetes verticillata</i> Lag. & Rod.	Mérida Municipio Libertador, Mérida State, Venezuela	Leaves	(E)-Tagetenone (64.3%), (Z)-tagetone (13.7%), dihydrotagetone (7.4%), (Z)-tagetenone (6.7%)	[756]
<i>Tagetes zypaquirensis</i> Bonpl.	Pasto, Colombia	Aerial parts	Dihydrotagetone (42.2%), (E)-tagetone (22.9%), (E)-tagetenone (20.8%), (Z)-tagetenone (5.6%)	[774]

^a Labeled as 4-ethyl-4-methyl-1-hexene, but that compound is not found in the Dictionary of Natural Products [98], the retention time is more consistent with dihydrotagetone. ^b Labeled as *cis*-verbenone, but this must be a misspelling.

pharmacological properties of *T. parthenium* [780, 781], *T. vulgare* [32, 782], and *T. balsamita* [783] have been reviewed. The essential oil compositions of several *Tanacetum* species are presented in Table 56.

3.1.64. *Tarchonanthus* L.

Tarchonanthus is a relatively small genus comprising six species scattered in southern Africa, eastern Africa, and the Arabian Peninsula [33]. Two species of *Tarchonanthus*, *Tarchonanthus camphoratus* L. and *Tarchonanthus trilobus* DC., have been examined in terms of their essential oil composition and listed in Table 57.

3.1.65. *Tithonia* Desf. ex Juss

World Flora Online currently recognizes 13 species of *Tithonia* [33]. The phytochemical compositions and biological activities of *Tithonia* have been reviewed [809]. The most important member of the genus in

terms of phytochemical investigation is *Tithonia diversifolia* (Hemsl.) A. Gray (Mexican sunflower), and this species has been reviewed [810–812]. This species is native to Mexico and Central America, but it has become naturalized in many other tropical countries, where it is an invasive pest. The essential oils of *T. diversifolia* have been extensively studied in its current geographical locations (Table 58), showing wide variations in composition.

3.1.66. *Verbesina* L.

The genus *Verbesina* is very large, with 340 species [33]. Nevertheless, the genus is relatively understudied in terms of essential oil chemistry [828, 829] (Table 59).

3.1.67. *Vernonia* Schreb.

Vernonia is another large genus with 724 species [33]. Of these, *Vernonia amygdalina* Delile, *Vernonia cinerea* (L.) Less. (syn. *Cyanthillium cinereum* (L.) H. Rob.), and

Table 56. Chemical compositions of *Tanacetum* essential oils.

<i>Tanacetum</i> species	Geographical location	Plant tissue	Major components (> 5%)	Ref.
<i>Tanacetum annuum</i> L.	Beni Aerousse region, Tanger-Tétouan-Al Hoceima province, Morocco	Aerial parts	Chamazulene (17.7%), sabinene (14.4%), camphor (14.2%), 3,6-dihydrochamazulene (7.0%), <i>p</i> -cymene (8.9%), β -pinene (5.3%), α -phellandrene (5.1%)	[784]
<i>Tanacetum annuum</i> L.	Ben Karrich, Tetouan province, Morocco	Aerial parts	Camphor (16.7%), α -pinene (12.4%), bornyl acetate (12.0%), borneol (6.3%)	[785]
<i>Tanacetum balsamita</i> L.	Türkiye	Aerial parts	Carvone (51.0%), β -thujone (20.8%)	[786]
<i>Tanacetum balsamita</i> L.	Ovčar-Kablar Gorge, Serbia	Flowers	Carvone (54.2%), <i>trans</i> -dihydrocarvone (7.7%), β -thujone (6.4%)	[787]
<i>Tanacetum balsamita</i> L.	Ovčar-Kablar Gorge, Serbia	Leaves	Carvone (52.1%), α -thujone (11.4%), 1,8-cineole (5.9%)	[787]
<i>Tanacetum corymbosum</i> (L.) Sch. Bip.	Chisinau, Moldova	Aerial parts	Germacrene D (47.5%), 1-octadecanol (9.7%), (<i>Z</i>)- β -farnesene (8.6%), γ -elemene (5.2%)	[788]
<i>Tanacetum dolichophyllum</i> (Kitam.) Kitam.	Khaliya, Munsyari, Uttarakhand, India	Flowers	γ -Eudesmol (24.5%), (<i>E</i>)- β -farnesene (7.2%), linalool (5.6%)	[789]
<i>Tanacetum dolichophyllum</i> (Kitam.) Kitam.	Khaliya, Munsyari, Uttarakhand, India	Leaves	γ -Eudesmol (20.3%), (<i>E</i>)- β -farnesene (13.4%), (<i>E</i>)- β -caryophyllene (10.9%)	[789]
<i>Tanacetum fisherae</i> Aitch. & Hemsl.	Kerman, Iran	Flowers	<i>cis-p</i> -Menth-2-en-1-ol (11.2%), <i>trans-p</i> -menth-2-en-1-ol (10.7%), <i>trans</i> -piperitol (7.8%), 1,8-cineole (6.1%)	[790]
<i>Tanacetum fisherae</i> Aitch. & Hemsl.	Kerman, Iran	Leaves	1,8-Cineole (16.7%), <i>cis-p</i> -menth-2-en-1-ol (14.6%), <i>trans-p</i> -menth-2-en-1-ol (10.4%), <i>trans</i> -piperitol (12.8%), α -terpineol (5.4%)	[790]
<i>Tanacetum fruticosum</i> C. Sm.	Karaj, Iran	Aerial parts	Camphor (16.8%), bornyl acetate (14.3%), borneol (11.8%), camphene (11.1%)	[791]
<i>Tanacetum lingulatum</i> (Boiss.) Bornm.	Urmia Province, Iran	Aerial parts	1,8-Cineole (18.8%), camphor (15.0%), linalyl propionate (8.5%), α -terpineol (8.0%), sabinene (5.8%), terpinen-4-ol (5.8%)	[792]
<i>Tanacetum macrophyllum</i> Sch. Bip.	Tsigov Chark, Batak, Bulgaria	Flowers	1,8-Cineole (23.7%), camphor (22.8%), borneol (5.9%)	[793]
<i>Tanacetum parthenium</i> (L.) Sch. Bip.	Kashan, Iran	Aerial parts	Camphor (43.8%), camphene (9.4%), bornyl acetate (6.8%)	[794]
<i>Tanacetum parthenium</i> (L.) Sch. Bip.	Brezovica, Serbia	Aerial parts	Camphor (44.8%), <i>trans</i> -chrysanthenyl acetate (29.0%), camphene (8.1%)	[795]
<i>Tanacetum parthenium</i> (L.) Sch. Bip.	Southern Bulgaria	Aerial parts	Camphor (45.5%), <i>trans</i> -chrysanthenyl acetate (21.7%), camphene (9.5%), (<i>Z</i>)- <i>iso</i> -geraniol (5.4%)	[796]
<i>Tanacetum parthenium</i> (L.) Sch. Bip.	Chormaghzak village, Yovon region, Tajikistan	Aerial parts	Camphor (69.7%), camphene (12.2%), bornyl acetate (8.7%)	[797]
<i>Tanacetum parthenium</i> (L.) Sch. Bip.	Tsigov Chark, Rhodope Mountains, Bulgaria	Flowers	Camphor (50.9%), camphene (16.1%), bornyl acetate (6.1%)	[796]
<i>Tanacetum parthenium</i> (L.) Sch. Bip.	Gabrovo, Balkan Mountains, Bulgaria	Flowers	Camphor (45.5%), <i>trans</i> -chrysanthenyl acetate (13.9%), camphene (13.0%), <i>trans</i> -verbanyl acetate (8.9%)	[796]

Table 56. (Continued).

Tanacetum species	Geographical location	Plant tissue	Major components (> 5%)	Ref.
<i>Tanacetum parthenium</i> (L.) Sch. Bip.	Wola Zadybska, Poland	Leaves	Camphor (40.1%), <i>trans</i> -chrysanthenyl acetate (22.2%), camphene (7.1%)	[798]
<i>Tanacetum polycephalum</i> Sch. Bip.	Urmia Province, Iran	Aerial parts	1,8-Cineole (15.7%), camphor (10.9%), α -pinene (5.4%), sabinene (5.1%)	[792]
<i>Tanacetum sinaicum</i> (Fresen.) Delile ex K. Bremer & Humphries	Wadi Jibaal, St. Katherine Protectorate, South Sinai, Egypt	Aerial parts	Thymol (17.0%), <i>cis</i> -verbenol (12.2%), 3-thujan-2-one (6.3%), 1,8-cineole (5.9%), eudesm(4(14)en-4-ol (5.5%)	[15]
<i>Tanacetum sinaicum</i> (Fresen.) Delile ex K. Bremer & Humphries	South Sinai, Egypt	Aerial parts	<i>trans</i> -Chrysanthenyl acetate (33.7%), α -thujone (28.9%), verbenol ^a (9.1%), 1,8-cineole (5.4%)	[799]
<i>Tanacetum vulgare</i> L.	Chicoutimi, Quebec, Canada	Aerial parts	Camphor (30.5%), borneol (14.8%), 1,8-cineole (10.8%), camphene (7.3%), bornyl acetate (5.5%)	[800]
<i>Tanacetum vulgare</i> L.	Siedlce district, Poland	Aerial parts	α -Thujone (26.9%), 1,8-cineole (16.8%), bornyl acetate (8.9%), camphor (8.4%), β -thujone (7.6%), borneol (7.2%)	[4]
<i>Tanacetum vulgare</i> L.	Košice, Slovakia	Aerial parts	Borneol (13.6%), umbellulone (11.7%), artemisia ketone (9.3%), <i>cis</i> -chrysanthenol (6.9%), camphor (5.9%), terpinen-4-ol (5.5%), α -pinene (5.0%)	[801]
<i>Tanacetum vulgare</i> L.	Aleksinac, Serbia	Aerial parts	β -Thujone (49.8%), <i>trans</i> -chrysanthenyl acetate (22.3%), camphor (8.2%)	[795]
<i>Tanacetum vulgare</i> L.	Rhodope Mountains, Tsigov Chark, Batak, Bulgaria	Flowers	Camphor (25.2%), <i>trans</i> -chrysanthenyl acetate (18.4%), <i>cis</i> -verbenol (10.9%), 1,8-cineole (6.0%), α -campholenal (6.0%)	[802]
<i>Tanacetum vulgare</i> L.	Wohyń Commune, Radzyń Poviast, Lubelskie Voivodeship, Poland	Flowers	<i>trans</i> -Chrysanthenyl acetate (0.1-76.1%), camphor (1.3-31.2%), <i>trans</i> -dihydrocarvone (0.1-20.6%), 1,8-cineole (2.7-7.9%)	[803]

^a Correct isomer was not indicated.

Table 57. Chemical compositions of *Tarchonanthus camphoratus* L. and *Tarchonanthus trilobus* DC. essential oils.

Tarchonanthus species	Geographical location	Plant tissue	Major components (> 5%)	Ref.
<i>Tarchonanthus camphoratus</i> L.	Kenya	Aerial parts	α -Pinene (16.9%), 1,8-cineole (13.1%), <i>exo</i> -fenchol (10.8%)	[804]
<i>Tarchonanthus camphoratus</i> L.	Alselw district, Taiz province, Yemen	Leaves	<i>endo</i> -Fenchol (21.2%), <i>trans</i> -pinene hydrate (8.8%), caryophyllene oxide (7.5%), α -terpineol (6.4%), τ -cadinol (6.4%), α -cadinol (5.2%)	[805]
<i>Tarchonanthus camphoratus</i> L.	Njoro, Nakuru, Rift Valley, Kenya	Leaves	<i>endo</i> -Fenchol (15.9%), 1,8-cineole (14.3%), α -terpineol (13.2%), α -pinene (6.9%), <i>trans</i> -pinene hydrate (6.5%), β -eudesmol (5.8%)	[806]
<i>Tarchonanthus camphoratus</i> L.	Sangoyana, Kwa-Zulu Natal province, South Africa	Leaves	α -Cadinol (9.4%), 1,8-cineole (9.2%), δ -cadinene (6.9%), butanal (6.1%)	[807]
<i>Tarchonanthus trilobus</i> DC. var. <i>galpinii</i> (Hutch. & E. Phillips) Paiva	Ubombo, Kwa-Zulu Natal province, South Africa	Leaves	(<i>E</i>)- β -Caryophyllene (30.4%), δ -cadinene (8.0%), γ -muurolene (5.8%), γ - <i>neo</i> -clovene (5.8%), longifolene (5.6%)	[808]

Table 58. Chemical compositions of *Tithonia diversifolia* (Hemsl.) A. Gray and *Tithonia rotundifolia* S.F. Blake essential oils.

<i>Tithonia</i> species	Geographical location	Plant tissue	Major components (> 5%)	Ref.
<i>Tithonia diversifolia</i> (Hemsl.) A. Gray	Bungoma County, Western Kenya	Aerial parts	α -Pinene (63.6%), β -pinene (15.0%), (<i>E</i>)- β -caryophyllene (7.6%)	[813]
<i>Tithonia diversifolia</i> (Hemsl.) A. Gray	Uyo, Nigeria	Flowers	Germacrene D (32.5%), α -pinene (7.5%) (<i>E</i>)- β -caryophyllene (6.6%), <i>p</i> -cymene (5.4%)	[814]
<i>Tithonia diversifolia</i> (Hemsl.) A. Gray	uMhlathuze district, KwaZulu-Natal Province, South Africa	Flowers	α -Pinene (72.8%), β -pinene (9.5%)	[815]
<i>Tithonia diversifolia</i> (Hemsl.) A. Gray	Yaounde region, Cameroon	Flowers	α -Pinene (61.0%), (<i>Z</i>)- β -ocimene (15.5%), limonene (6.4%)	[816]
<i>Tithonia diversifolia</i> (Hemsl.) A. Gray	Olanbiwonu Village, Iwo, Osun State, Nigeria	Flowers	Germacrene D (20.3%), (<i>E</i>)- β -caryophyllene (20.1%), bicyclogermacrene (8.0%), α -pinene (6.8%), 1,8-cineole (5.7%)	[817]
<i>Tithonia diversifolia</i> (Hemsl.) A. Gray	Gagnoa, Côte d'Ivoire	Flowers	α -Pinene (42.0%), limonene (40.1%), α -cubebene (11.3%)	[818]
<i>Tithonia diversifolia</i> (Hemsl.) A. Gray	Dschang, Cameroon	Flowers	α -Pinene (13.7%), limonene (7.6%), <i>cis</i> -chrysanthenol (6.2%)	[819]
<i>Tithonia diversifolia</i> (Hemsl.) A. Gray	Pires do Rio, Goiás, Brazil	Flowers	α -Pinene (44.3%), <i>cis</i> -chrysanthenol (10.7%), α -copaene (8.2%)	[820]
<i>Tithonia diversifolia</i> (Hemsl.) A. Gray	Ribeirão Preto, São Paulo, Brazil	Flowers	β -Pinene (37.1%), α -pinene (33.8%), α -copaene (6.0%)	[820]
<i>Tithonia diversifolia</i> (Hemsl.) A. Gray	Ribeirão Preto, São Paulo, Brazil	Flowers	α -Pinene (68.1%), β -pinene (21.9%)	[821]
<i>Tithonia diversifolia</i> (Hemsl.) A. Gray	Nainital, Uttarakhand, India	Leaves	α -Pinene (33.6%), β -pinene (8.6%), germacrene D (8.1%), δ -cadinene (5.1%)	[822]
<i>Tithonia diversifolia</i> (Hemsl.) A. Gray	Fazenda São Jorge, Itaguaçu, Espírito Santo, Brazil	Leaves	β -Pinene (32.7%), α -pinene (24.7%), limonene (22.7%), (<i>E</i>)- β -ocimene (5.6%), sabinene (5.0%)	[823]
<i>Tithonia diversifolia</i> (Hemsl.) A. Gray	Huong Son district, Ha Tinh Province, Vietnam	Leaves	α -Pinene (30.7%), (<i>E</i>)- β -caryophyllene (5.1%)	[824]
<i>Tithonia diversifolia</i> (Hemsl.) A. Gray	Yaoundé, Cameroon	Leaves	α -Terpineol (20.3%), 1,8-cineole (14.6%), camphor (20.3%), α -pinene (13.5%), ledol (5.7%), pinocarveol (5.1%)	[825]
<i>Tithonia diversifolia</i> (Hemsl.) A. Gray	Uyo, Nigeria	Leaves	Germacrene D (46.0%), (<i>E</i>)- β -caryophyllene (12.2%), estragole (9.8%), α -humulene (6.5%)	[814]
<i>Tithonia diversifolia</i> (Hemsl.) A. Gray	Fazendinha, Amapá, Brazil	Leaves	Piperitone (11.7%), spathulenol (10.8%), α -pinene (9.9%), limonene (5.4%)	[16]
<i>Tithonia diversifolia</i> (Hemsl.) A. Gray	Ile-Ife, Nigeria	Leaves	(<i>E</i>)- β -Ocimene (43.7%), α -pinene (28.6%), limonene (12.0%)	[39]
<i>Tithonia diversifolia</i> (Hemsl.) A. Gray	Yaoundé region, Cameroon	Leaves	(<i>Z</i>)- β -Ocimene (40.2%), α -pinene (25.0%), limonene (13.9%), (<i>E</i>)- β -ocimene (5.8%)	[826]
<i>Tithonia diversifolia</i> (Hemsl.) A. Gray	uMhlathuze district, KwaZulu-Natal Province, South Africa	Leaves	α -Pinene (60.9%), β -pinene (10.7%)	[815]
<i>Tithonia diversifolia</i> (Hemsl.) A. Gray	Olanbiwonu Village, Iwo, Osun State, Nigeria	Leaves	α -Pinene (32.9%), (<i>E</i>)- β -caryophyllene (20.8%), germacrene D (12.6%), β -pinene (10.9%), 1,8-cineole (9.1%)	[817]

Table 58. (Continued).

<i>Tithonia</i> species	Geographical location	Plant tissue	Major components (> 5%)	Ref.
<i>Tithonia diversifolia</i> (Hemsl.) A. Gray	Gagnoa, Côte d'Ivoire	Leaves	Limonene (44.1%), (<i>E</i>)- β -ocimene (27.0%), α -pinene (16.8%)	[818]
<i>Tithonia diversifolia</i> (Hemsl.) A. Gray	Pires do Rio, Goiás, Brazil	Leaves	α -Pinene (41.9%), limonene (8.6%), camphene (7.6%)	[820]
<i>Tithonia diversifolia</i> (Hemsl.) A. Gray	Ribeirão Preto, São Paulo, Brazil	Leaves	β -Pinene (49.4%), α -pinene (26.2%)	[820]
<i>Tithonia diversifolia</i> (Hemsl.) A. Gray	Ribeirão Preto, São Paulo, Brazil	Leaves	α -Pinene (45.0%), β -pinene (34.0%)	[821]
<i>Tithonia diversifolia</i> (Hemsl.) A. Gray	Fokoue Village, Dschang, Menoua Division, Cameroon	Leaves	Limonene (20.1%), α -copaene (10.3%), <i>p</i> -cymene (10.0%), 1-pentadecanol (8.8%), (<i>E</i>)- β -caryophyllene (8.4%), α -pinene (7.7%)	[827]
<i>Tithonia rotundifolia</i> S.F. Blake	Awo village, Osun State, Nigeria	Leaves	Germacrene D (33.0%), (<i>E</i>)- β -caryophyllene (25.8%), bicyclogermacrene (8.7%), <i>neo</i> -phytadiene (6.5%)	[39]

Table 59. Chemical compositions of *Verbesina* essential oils.

<i>Verbesina</i> species	Geographical location	Plant tissue	Major components (> 5%)	Ref.
<i>Verbesina diversifolia</i> DC.	Fortaleza and Ubajara, Ceara, Brazil	Leaves	γ -Muurolene (30.5%), γ -elemene (24.6%), α -pinene (7.9%), <i>trans</i> - β -elemene (5.8%), β -pinene (5.3%)	[410]
<i>Verbesina diversifolia</i> DC.	Pico Alto, Guarimiranga Mountain, State of Ceará, Brazil	Leaves	Bicyclogermacrene (23.2%), germacrene D-4-ol (14.1%), (<i>E</i>)- β -caryophyllene (7.4%), β -phellandrene (5.4%)	[830]
<i>Verbesina macrophylla</i> (Cass.) S.F. Blake	Ilhéus, Bahia, Brazil	Leaves	Germacrene D (37.3%), germacrene D-4-ol (17.0%), (<i>E</i>)- β -caryophyllene (5.9%), δ -cadinene (5.7%), bicyclogermacrene (5.3%)	[831]
<i>Verbesina macrophylla</i> (Cass.) S.F. Blake	Camocim de São Félix, Pernambuco, Brazil	Leaves	Germacrene D (25.5%), germacrene D-4-ol (18.8%), bicyclogermacrene (11.3%), (<i>E</i>)- β -caryophyllene (9.9%)	[832]
<i>Verbesina negrensis</i> Steyerl.	Pueblo Hondo, Aldea Llanetes, Táchira State, Venezuela	Aerial parts	α -Pinene (43.1%), α -humulene (13.8%), δ -cadinene (8.1%)	[833]
<i>Verbesina turbacensis</i> Kunth	Pueblo Llano, Municipio Miranda, Mérida State, Venezuela	Leaves	Germacrene D (56.2%), bicyclogermacrene (8.2%), (<i>E</i>)- β -caryophyllene (8.1%), α -pinene (6.2%), α -eudesmol (6.1%)	[834]
<i>Verbesina turbacensis</i> Kunth	Monteverde, Costa Rica	Leaves	Germacrene D (29.1-36.9%), δ -elemene (21.7-22.1%), β -pinene (12.8-15.6%), α -pinene (11.1-13.9%), limonene (8.4-9.6%)	[835]

Vernonia anthelmintica (L.) Willd. (syn. *Baccharoides anthelmintica* (L.) Moench) have received the most attention [17,836]. The biological properties, medicinal potential, and phytochemical constituents of *V. amygalina* [837–843], *V. cinerea* [844], and *V. anthelmintica* [845] have been reviewed. The nomenclature of the genus seems to be in flux and there have been several changes (Table 60).

Sesquiterpenoids are often the dominant components of the essential oils of *Vernonia* species (Table 60).

3.1.68. *Xanthium* L.

Currently, the World Flora Online recognizes nine species of *Xanthium* [33]. The phytochemistry and pharmacology of *Xanthium* have been reviewed [867–870] and their major essential oil components are summarized in Table 61.

Table 60. Chemical compositions of *Vernonia* essential oils.

<i>Vernonia</i> species	Geographical location	Plant tissue	Major components (> 5%)	Ref.
<i>Vernonia albicans</i> DC.	Shiroda, Maharashtra, India	Aerial parts	(<i>E</i>)- β -Caryophyllene (34.3%), γ -amorphene (19.5%), 9- <i>epi</i> -(<i>E</i>)- β -caryophyllene (6.9%), α -pinene (6.9%)	[846]
<i>Vernonia amygdalina</i> Delile	Umdike, Nigeria	Leaves	1,8-Cineole (25.1%), β -pinene (14.5%), myrtenal (6.5%), <i>trans</i> -pinocarveol (6.2%)	[847]
<i>Vernonia amygdalina</i> Delile	Tho Xuan district, Thanh Hoa province, Vietnam	Leaves	Caryophyllene oxide (29.5%), (<i>E</i>)- β -caryophyllene (20.0%), α -humulene (8.5%), humulene epoxide II (5.7%)	[848]
<i>Vernonia amygdalina</i> Delile	Iwo, Nigeria	Leaves	α -Muurolol (45.7%)	[849]
<i>Vernonia amygdalina</i> Delile	Ibadan, Nigeria	Leaves	Thymol (27.0%), (<i>E</i>)-phytol (15.7%), <i>p</i> -cymene ^a (12.7%), β -selinene (8.1%)	[850]
<i>Vernonia brasiliana</i> (L.) Druce	Sobral, Brazil	Leaves	(<i>E</i>)- β -Caryophyllene (36.7%), germacrene D (35.5%), α -humulene (11.7%), α -copaene (5.2%)	[851]
<i>Vernonia brasiliana</i> (L.) Druce	Monte Alegre de Minas, Minas Gerais state, Brazil	Leaves	Germacrene D (10.2%), (<i>E</i>)- β -caryophyllene (8.7%), bicyclgermacrene (5.8%), spathulenol (5.2%)	[24]
<i>Vernonia brasiliana</i> (L.) Druce	Santa Luzia, Maranhão State, Brazil	Leaves	(<i>E</i>)- β -Caryophyllene (21.5%), germacrene D (14.6%), caryophyllene oxide (10.3%), α -humulene (8.9%), α -copaene (5.2%)	[852]
<i>Vernonia chalybaea</i> Mart. ex DC.	Meruoca Mountain, Ceará, Brazil	Aerial parts	β -Pinene (30.6%), (<i>E</i>)- β -caryophyllene (12.1%), α -pinene (9.7%), bicyclgermacrene (8.6%)	[853]
<i>Vernonia chalybaea</i> Mart. ex DC.	Alcântaras, Ceará, Brazil	Aerial parts	(<i>E</i>)- β -Caryophyllene (39.1%), bicyclgermacrene (19.7%), caryophyllene oxide (8.7%), <i>trans</i> - β -elemene (8.3%), spathulenol (6.8%)	[854]
<i>Vernonia cinerea</i> (L.) Less.	Belgaum, Karnataka, India	Aerial parts	(<i>E</i>)- β -Caryophyllene (23.2%), δ -cadinene (10.3%), γ -amorphene (7.5%), <i>cis</i> - β -guaiene (6.8%), premnaspirodiene (6.3%)	[855]
<i>Vernonia colorata</i> Drake	Kolakani, Mali	Aerial parts	Palmitic acid (14.8%), hexahydrofarnesyl acetone (12.2%), tetradecane-2-one (8.3%)	[856]
<i>Vernonia condensata</i> Baker	Caatinga biome, Pernambuco, Brazil	Leaves	(<i>E</i>)- β -Caryophyllene (18.4%), γ -muurolene (16.4%), α -humulene (6.0%)	[857]
<i>Vernonia crotonoides</i> Sch. Bip.	Ouro Preto, Minas Gerais, Brazil	Aerial parts	α -Cadinol (14.1%), spathulenol (9.8%), eugenol (6.8%), (<i>E</i>)- β -caryophyllene (6.3%), caryophyllene oxide (5.9%), τ -cadinol (5.3%)	[858]
<i>Vernonia migeodii</i> S. Moore	Isanlu-Isin, Kwara State, Nigeria	Leaves	Germacrene D (26.8%), (<i>E</i>)- β -caryophyllene (16.4%), caryophyllene oxide (6.0%), α -humulene (5.6%), 1-octen-3-one (5.1%)	[859]
<i>Vernonia nigriflora</i> Oliv. & Hiern	Kolakani, Mali	Aerial parts	τ -Cadinol (9.7%), phytol (8.7%), (<i>E,E</i>)- α -farnesol (7.8%), hexahydrofarnesyl acetone (7.5%)	[856]
<i>Vernonia patula</i> Merr.	Pu Hoat Nature Reserve, Nghe An Province, Vietnam	Leaves	(<i>E</i>)- β -Caryophyllene (28.5%), caryophyllene oxide (16.6%), α -copaene (9.0%), α -humulene (7.1%)	[860]
<i>Vernonia perrottetii</i> Sch. Bip. ex Walp.	Isanlu-Isin, Kwara State, Nigeria	Leaves	Germacrene D (34.5%), (<i>E</i>)- β -caryophyllene (28.1%)	[861]
<i>Vernonia polyanthes</i> Less.	Lavras, Brazil	Leaves	Germacrene D (42.2%), bicyclgermacrene (17.2%), (<i>E</i>)- β -caryophyllene (13.6%), α -humulene (7.8%), spathulenol (5.2%)	[862]

Table 60. (Continued).

Vernonia species	Geographical location	Plant tissue	Major components (> 5%)	Ref.
<i>Vernonia polyanthes</i> Less.	Brazil	Leaves	Myrcene (34.3%), zerumbone (15.8%), bicyclogermacrene (8.9%)	[863]
<i>Vernonia remotiflora</i> Rich.	Crato, Ceará, Brazil	Leaves	(<i>E</i>)- β -Caryophyllene (42.2%), bicyclogermacrene (20.0%), α -humulene (7.9%)	[851]
<i>Vernonia scorpioides</i> (Lam.) Cass.	Guaramiranga mountain, Ceará, Brazil	Aerial parts	(<i>E</i>)- β -Caryophyllene (30.6%), germacrene D (27.3%), bicyclogermacrene (8.5%), δ -cadinene (5.2%)	[864]
<i>Vernonia solanifolia</i> Benth.	Pu Hot Nature Reserve, Nghe An Province, Vietnam	Leaves	Sabinene (49.2%), δ -cadinene (10.9%), (<i>E</i>)- β -caryophyllene (7.8%)	[865]
<i>Vernonia volkameriifolia</i> DC.	Pu Luong Nature Reserve, Thanh Hoa Province, Vietnam	Leaves	β -Bisabolene (25.2%), β -pinene (19.1%), germacrene D (13.1%), <i>trans</i> - β -elemene ^b (11.4%)	[866]

^a Reported as *o*-cymene, but the retention index is more consistent with *p*-cymene. ^b Reported as *cis*- β -elemene, but the retention index is more consistent with *trans*- β -elemene.

Table 61. Chemical compositions of *Xanthium* essential oils.

Xanthium species	Geographical location	Plant tissue	Major components (> 5%)	Ref.
<i>Xanthium brasiliicum</i> Vell.	Tehran, Iran	Aerial parts	Borneol (28.9%), fenchone (21.1%), isobornyl acetate (9.1%)	[871]
<i>Xanthium cavanillesii</i> Schouw ex Didr.	Las Piedras, Entre Rios province, Argentina	Aerial parts	Limonene (43.6%), β -pinene (5.4%), bornyl acetate (5.1%)	[872]
<i>Xanthium italicum</i> Moretti	Corsica, France	Aerial parts	Limonene (30.4%), germacrene D (8.9%), sabinene (6.1%)	[873]
<i>Xanthium italicum</i> Moretti	Urumqi city, Xinjiang Uygur autonomous region, China	Aerial parts	Limonene (51.6%), germacrene B (7.0%), δ -cadinol (5.9%), β -pinene (5.6%), α -humulene (5.1%)	[874]
<i>Xanthium sibiricum</i> Patrín ex Widder	Urumqi, Xinjiang Uygur Autonomous Region, China	Aerial parts	Limonene (56.9%), myrcene (26.2%)	[875]
<i>Xanthium italicum</i> Moretti	Temaska village, near Pirot city, Serbia	Fruit	Germacrene B (28.7%), shyobunol (16.7%), α -humulene (8.4%)	[876]
<i>Xanthium spinosum</i> L.	Corsica, France	Aerial parts	Eudesma-4(14),7-dien-1 β -ol (18.7%), germacrene D (8.1%), β -elemol (5.7%), humulene epoxide II (5.6%), cadalene (5.5%)	[873]
<i>Xanthium strumarium</i> L.	Hampton Cove, Alabama, USA	Aerial parts	Limonene (48.0%), myrcene (14.3%), germacrene D (13.9%), (2 <i>E</i>)-hexenal (5.8%)	[13]
<i>Xanthium strumarium</i> L.	Sari, Taberestan, Iran	Fruit	Methyl linoleate (40.6%), methyl oleate (13.1%), methyl palmitate (12.4%), <i>neo</i> -intermedeol (9.7%)	[877]

Table 61. (Continued).

<i>Xanthium</i> species	Geographical location	Plant tissue	Major components (> 5%)	Ref.
<i>Xanthium strumarium</i> L.	El-Salhia region, Al-Sharkia Province, Egypt	Leaves	1,5-Dimethyltetralin (14.3%), α -eudesmol (10.6%), spathulenol (7.5%), borneol (6.6%), ledene alcohol (6.5%), caryophyllene oxide (5.4%), 7,8-dehydro-8 α -hydroxyisolongifolene (5.1%)	[878]
<i>Xanthium strumarium</i> L.	Khoramabad, Province, Lurestan, Iran	Leaves	Limonene (24.7%), borneol (10.6%), β -cubebene (6.3%), bornyl acetate (5.9%)	[879]
<i>Xanthium strumarium</i> L.	Lahore, Pakistan	Leaves	(<i>E</i>)- β -Caryophyllene (17.5%), α -cadinol (6.7%), spathulenol (6.1%), limonene (5.7%)	[880]
<i>Xanthium strumarium</i> L.	Campinas, São Paulo, Brazil	Leaves	β -Guaiene (79.6%)	[881]
<i>Xanthium strumarium</i> L.	Yozgat, Türkiye	Leaves	α -Cadinol (12.4%), caryophyllene oxide (11.9%), borneol (9.2%), <i>iso</i> -aromadendrene epoxide (8.7%), cubebol (8.6%), hexahydrofarnesyl acetone (8.1%), τ -cadinol (6.8%), α -bisabolene epoxide (5.0%)	[882]
<i>Xanthium strumarium</i> L.	Zabol, Sistan and Baluchestan Province, Iran	Leaves	<i>cis</i> - β -Guaiene (34.2%), limonene (20.3%), borneol (11.6%)	[883]

4. Conclusions

The Asteraceae (Compositae) family is one of the largest and most diverse plant families, with many species that produce essential oils that contribute to fragrance, flavor, aroma, and biological activities. Asteraceae essential oils are dominated by mono- and sesquiterpenoids, and the particular group of major components vary by genus and species. The essential oil compositions are strongly influenced by environmental factors, including soil type, climate, altitude, and seasonality, which leads to chemotypes with the same species.

We hope that this review will provide information for researchers, aromatherapists, medicinal chemists, horticulturists, and other essential oil enthusiasts, who are interested in the compositions and biological activities of Asteraceae essential oils. However, the intraspecific variability in Asteraceae essential oils poses challenges for the standardization and reproducibility of their biological activities. Thus, essential oils intended for therapeutic, cosmetic, or food use should undergo safety assessments (e.g., toxicity, dermal irritation, sensitization) and regulatory compliance (e.g., labeling, concentrations).

Disclaimer (artificial intelligence)

Authors hereby state that no generative AI tools such as Large Language Models (ChatGPT, Copilot, etc.) and text-to-image generators were utilized in the preparation or editing of this manuscript.

Authors' contributions

Conceptualization, W.N.S. and A.E.; data curation, W.N.S.; writing—original draft preparation, W.N.S. and A.E.; writing—review and editing, A.E. and F.S.; project administration, W.N.S.

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Availability of data and materials

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Conflicts of interest

The authors declare no conflict of interest.

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