Chemical Compositions and Biological Activities of *Scutellaria* Genus Essential Oils (Lamiaceae)

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Abstract

**Context:** Essential oils are secondary metabolites with versatile organic structures that, due to their compounds, have useful medicinal properties. There are about 250 species of the genus of *Scutellaria* perennial flowering plants from the Lamiaceae family. Its application for the treatment of allergy, inflammatory, hyperlipidemia, arteriosclerosis, hypertension, and hepatitis has a long history.

**Evidence Acquisition:** Various studies on the chemical compounds of the *Scutellaria* genus have identified several compounds, especially essentials oils. The current review is based on the evidence found in Chemical Abstract, Science Direct, Scopus, PubMed, Web of Knowledge, and Google Scholar databases.

**Results:** Many studies on the chemical components of essential oils from the *Scutellaria* genus have identified several compounds. We summarized the chemical compositions and biological activities of *Scutellaria* essential oils. Hexadecanoic acid, germacrene D, β-caryophyllene, linalool, β-farnesene, and eugenol are the main compounds in essential oils of this genus. Despite many reports about essential oils of *Scutellaria* species (more than 38), a large number of species have not been studied yet. Therefore, several studies should be conducted on the chemical compounds and biological activities of unstudied *Scutellaria* essential oils.

**Conclusions:** This review has summarized reports on the chemistry and biological activities of *Scutellaria* essential oils, such as antioxidant, antimicrobial, antifeedant, phytotoxic, and acaricidal toxicities, based on the recent literature.

**Keywords:** *Scutellaria*, Lamiaceae, Essential Oils, Chemical Composition, Biological Activities

1. Context

The *Scutellaria* genus that can be found in East Asia, the United States, and Europe include perennial flowering plants in the Lamiaceae (mint) family, which contains 350 species (1, 2). There are about 300 species of this genus in Asia (3-6). In Iran, the *Scutellaria* genus is represented by 27 species, which 12 of them are endemic (7). *Scutellaria* genus has been used for the treatment of hyperlipidemia, allergy, inflammatory, arteriosclerosis, hepatitis, and hypertension for hundreds of years (8). It’s about 2000 years that Asian medicine, especially Chinese medicine, is using *Scutellaria* for the treatment of fevers, colds, diphtheria, and high blood pressure (9). The genus of *Scutellaria* has several therapeutic properties such as antitumor, hepatoprotective, antioxidant, anti-inflammatory, anticonvul- sant, antibacterial, and antiviruses activities (8). Also, *Scutellaria* species are useful in treating nervous system problems, including anxiety, insomnia, and hysteria (2). More than 295 compounds have been isolated from this genus (10, 11), such as flavonoids (12), phenylethanoid glycosides, and terpenes (Iridoid glycosides, monoterpenes, diterpenes, and triterpenoids) (13). Flavonoids (almost flavones) are common bioactive compounds of the *Scutellaria* genus (14).

Essential oils are secondary metabolites with versatile organic structures that have useful medicinal properties (15). They can be extracted from plants using classical and advanced techniques (16). There are various methods to extract essential oils, such as hydrodistillation, steam distillation, microwave, organic solvent extraction, supercritical CO₂, and ultrasonic and high-pressure solvent extraction (17, 18). Various factors affect the compositions of the essential oils, including geographical and climatic conditions, harvesting time, physiological age, plant storages, extraction methods, kind of drying. Besides, it should be noted that various parts of the plant contain different compositions (19-22). The major essential oil compounds are terpenoids, which are classified as monoter-
Monoterpene Hydrocarbons (%)

Sesquiterpene Hydrocarbons (%)

| Monoterpene Hydrocarbons (%) | Sesquiterpene Hydrocarbons (%) |
|-------------------------------|--------------------------------|
| 0                             | 0                              |
| 5                             | 10                             |
| 10                            | 15                             |
| 15                            | 20                             |
| 20                            | 25                             |

2. Evidence Acquisition

The recent literature about the essential oils of different species of Scutellaria was reviewed (26-32). Although some review studies are conducted on the Scutellaria genus (8, 13) but evidence about the Scutellaria essential oils is not sufficient. Therefore this review was focused on the chemical compounds and biological activities of the Scutellaria genus essential oils.

3. Results

3.1. Chemical Compositions of Scutellaria Genus Essential Oils

Many studies have shown variations in the chemical compounds of Scutellaria genus essential oils. Several factors affect the variations in the essential oil compositions, including harvesting time, soil PH, drying conditions, geographic location, kind of subspecies, part of the plant, and extraction method (19-22).

The oils extracted from different Scutellaria species have similar compounds (Table 1). The compositions of essential oils are classified in Figures 1 to 4; the sesquiterpenes are the most common compound of the Scutellaria essential oils. Hexadecanoic acid, Germacrene D, β-caryophyllene, Linalool, β-Farnesene, and Eugenol are the main compounds of the essential oils of this genus. The structures of these compounds are shown in Figure 5. Several hydrocarbons and oxygenated terpenoid compounds have been identified from Scutellaria species (Figures 2 to 5). Hexadecanoic acid is a saturated fatty acid in plants, animals, and microorganisms (33). Germacrene D is a precursor of various sesquiterpenes such as cadinenes and selinenes (34, 35). Germacrene D has insecticidal activity against mosquitoes (36), aphids (37), and ticks (38). β-caryophyllene is a natural sesquiterpene with dietary phytocannabinoid that has therapeutic potential for anxiety, neuropathic pain, ulcerative colitis, endometriosis, and renal protection (39-42). Linalool is a monoterpenic compound that is found in many plants; it is effective against several bacteria and fungi and possesses anti-inflammatory, antinociceptive, and antihyperalgesic activities (43). β-Farnesene is a strong pheromone in most aphid species (44).

Despite the many reports about essential oils of Scutellaria species (more than 38), a large number of species have not been studied yet. Therefore, more studies on the chemical composition of unstudied Scutellaria essential oils are needed for a better understanding of the potential medicinal properties of these essential oils.
3.2. Antioxidant Activity

There are reports on the biological activities of Scutellaria genus essential oils, and most of the studies have investigated the antimicrobial activity of essential oils from this genus. The antimicrobial activity of these oils could be due to the components such as linalool, eugenol, and other long-chain alcohols (73). Moreover, other compounds such as thymol and alpha-terpineol could also contribute to the antimicrobial activity of the essential oil (74, 75). Yu et al. (2004) investigated the antibacterial activities of S. barbata essential oils against 17 microorganisms (Enterococcus faecalis, Staphylococcus aureus, Serratia marcescens, Escherichia coli, Stenotrophomonas maltophilia, Pseudomonas aeruginosa, Staphylococcus hemolyticus, Staphylococcus epidermidis, Candida tropicalis, Staphylococcus simulans, Citrobacter freundii, Salmonella paratyphi-A, Shigella flexneri, Klebsiella pneumoniae, Salmonella typhi, Serratia liquefaciens, and Candida albicans) using the disc diffusion and broth microdilution methods. According to their results, the essential oil demonstrated a strong bactericidal effect; S. epidermidis was the most sensitive microorganism (29 mm inhibition zone and 0.77 mg/mL MBC), and C. albicans was the most resistant to the extract (7 - 9 mm inhibition zone and 1.5 mg/mL MBC) (69). Based on the results reported by Zhu et al. (2016), the essential oils from S. strigillosa had higher antimicrobial effects on gram-positive bacteria than gram-negative bacteria and fungus (53). Another study by Pant et al. (2012) demonstrated that the essential oils of S. grossa had significant antibacterial activity against B. subtilis, E. faecalis, K. pneumonia, and S. entherica (65). Skaltsa (2005) reported a moderate activity against S. aureus and B. cereus for the essential oils of S. rupestris and S. sieberi that were collected from Greece (28). In a study by Skaltsa et al. (2000), it was revealed that the essential oil of S. albid subsp albid was moderately active against E. coli, S. aureus, B. subtilis, P. aeruginosa, and S. cerevisiae, which can be recommended.

3.2.1. Antioxidant Activity

compared to the results on the antioxidant activity of Scutellaria extracts (70-72), the essential oils of Scutellaria species only have moderate antioxidant activity (57). Zokirjonovna et al. (2016) evaluated the antioxidant activity of essential oils of three Uzbek Scutellaria species (i.e., S. imaculata, S. ramosissima, and S. schchristanica). The Scutellaria essential oils of these species exhibited moderate antioxidant activity due to the presence of eugenol, thymol, and carvacrol, but it was weaker than ascorbic acid (57).

Figure 3. Relative abundance of oxygenated sesquiterpene in the essential oils of Scutellaria species. 1: S. Albida (27); 2: S. albid subsp albid (47); 3: S. albid subsp colchica (47); 4: S. albid subsp condensata (47); 5: S. albid subsp velenovskiy (47); 6: S. barbata (69); 7: S. barbata (50); 8: S. baikalensis (Chinese Medicinal Plants) (52); 9: S. baicalensis (UC Berkeley Botanical Gardens) (52); 10: S. baikalensis (Horizon Herbs) (52); 11: S. cypria var. elatior (59); 12: S. cypria var. aureus, B. subtilis, P. aeruginosa, S. epidermidis, K. pneumonia, and S. entherica (65). Skaltsa (2005) reported a moderate activity against S. aureus and B. cereus for the essential oils of S. rupestris and S. sieberi that were collected from Greece (28). In a study by Skaltsa et al. (2000), it was revealed that the essential oil of S. albid subsp albid was moderately active against E. coli, S. aureus, B. subtilis, P. aeruginosa, and S. cerevisiae, which can be recommended.

Figure 4. Relative abundance of oxygenated monoterpenes in the essential oils of Scutellaria species. 1: S. Albida (27); 2: S. albid subsp albid (47); 3: S. albid subsp colchica (47); 4: S. albid subsp condensata (47); 5: S. albid subsp velenovskiy (47); 6: S. barbata (69); 7: S. barbata (50); 8: S. baikalensis (Chinese Medicinal Plants) (52); 9: S. baikalensis (UC Berkeley Botanical Gardens) (52); 10: S. baikalensis (Horizon Herbs) (52); 11: S. cypria var. elatior (59); 12: S. cypria var. aureus, B. subtilis, P. aeruginosa, S. epidermidis, K. pneumonia, and S. entherica (65). Skaltsa (2005) reported a moderate activity against S. aureus and B. cereus for the essential oils of S. rupestris and S. sieberi that were collected from Greece (28). In a study by Skaltsa et al. (2000), it was revealed that the essential oil of S. albid subsp albid was moderately active against E. coli, S. aureus, B. subtilis, P. aeruginosa, and S. cerevisiae, which can be recommended.

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be attributed to high levels of linalool and nerolidol content (27). Dereboylu et al. (2012) investigated the antimicrobial activities of the volatile compounds of S. sibthorpii, S. cypria var. cypria, and S. cypria var. elatior against 7 bacteria and one fungus (S. aureus, B. subtilis, S. typhimurium, E. faecalis, E. coli, P. aeruginosa, K. pneumonia, and C. albicans) and reported that S. aureus was the most sensitive microorganism (58). The antibacterial activity of S. repens essential oil was tested on S. aureus, E. faecalis, A. tumefaciens, E. chrysanthemi, X. phaseoli, E. coli, S. enterica, K. pneumoniae, and P. multocida (67), and according to the results, the essential oil showed a high level of antibacterial activity. The maximum zone of inhibition was 23 mm for E. coli, 18 mm for E. faecalis, 15 mm for K. pneumonia, and 12 mm for B. subtilis (67). The antimicrobial activities of Scutellaria essential oils are summarized in Table 2.

3.2.3. Antifeedant Activity

In the study performed by Formisano et al. (2013), the essential oils of three Scutellaria species (S. brevibracteata, S. hastifolia and S. orientalis ssp. alpina) are studied against the feeding and egg-laying behavior of Spodoptera littoralis. The results of the insect assays showed that the essential oil of S. hastifolia was the only oil that could deter Spodoptera littoralis larvae from feeding on treated discs, whereas both S. brevibracteata and S. hastifolia could deter female moths from laying eggs on papers treated with their extracts (47). In another study, Rosselli et al. (2007) reported that essential oil of S. rubicunda subsp. linnaeana has antifeedant activity against Spodoptera littoralis (26). In their study, the essential oil of plant stimulated a dose-dependent positive feeding response from larvae of S. littoralis (feeding index (FI) 50% = 925 ppm; FI at 100 ppm = 44.85). A study on S. rubicunda subsp. linnaeana revealed that aerial parts of the plant that contains scutecyprol B, scutalbin C, and scutecyprol B had antifeedant activity against larvae of five
Table 2. Antibacterial and Antifungal Activities of Scutellaria Species

| Microorganism          | S. barbata | S. strigillosa | S. grossa | S. rupestris sp. adenotricha | S. sieberi | S. albida sp. albida | S. cypria var. cypria | S. sibthorpis | S. repens |
|------------------------|------------|----------------|-----------|------------------------------|------------|---------------------|-----------------------|---------------|-----------|
| S. aureus              | √          | √              | -         | -                            | √          | -                   | -                     | -             | -         |
| E. coli                | √          | -              | -         | -                            | √          | √                   | -                     | -             | √         |
| P. aeruginosa          | √          | √              | -         | -                            |       -    | -                   | -                     | -             | √         |
| S. epidermidis         | √          | -              | -         | -                            | -          | -                   | -                     | -             | -         |
| S. heamalyticus        | -          | -              | -         | -                            | -          | -                   | -                     | -             | -         |
| S. simulans            | -          | -              | -         | -                            | -          | -                   | -                     | -             | -         |
| E. faecalis            | √          | -              | -         | -                            | -          | -                   | -                     | -             | √         |
| C. freundii            | √          | -              | -         | -                            | -          | -                   | -                     | -             | -         |
| K. pneumoniae          | √          | -              | -         | -                            | -          | -                   | -                     | -             | √         |
| S. flexneri            | √          | -              | -         | -                            | -          | -                   | -                     | -             | -         |
| S. paratyphi           | -          | -              | -         | -                            | -          | -                   | -                     | -             | -         |
| S. liquefaciens        | √          | -              | -         | -                            | -          | -                   | -                     | -             | -         |
| S. marcescens          | √          | -              | -         | -                            | -          | -                   | -                     | -             | -         |
| S. malthophilia        | √          | -              | -         | -                            | -          | -                   | -                     | -             | -         |
| C. albicans            | √          | √              | -         | -                            | -          | -                   | -                     | -             | -         |
| C. tropicalis          | √          | -              | -         | -                            | -          | -                   | -                     | -             | -         |
| B. subtilis            | -          | -              | -         | √                            | -          | -                   | -                     | -             | √         |
| S. cerevisiae          | -          | -              | -         | -                            | √          | -                   | -                     | -             | -         |
| S.enterica             | -          | -              | -         | -                            | -          | -                   | -                     | -             | -         |
| B. cereus              | -          | -              | -         | √                            | √          | -                   | -                     | -             | -         |
| M. flavus              | -          | -              | -         | -                            | -          | -                   | -                     | -             | -         |
| P. mirabilis           | -          | -              | -         | -                            | -          | -                   | -                     | -             | -         |
| S. thypihimium         | -          | -              | -         | -                            | -          | -                   | -                     | -             | √         |
| X. phaseoli            | -          | -              | -         | -                            | -          | -                   | -                     | -             | -         |
| E.chrysanthemi         | -          | -              | -         | -                            | -          | -                   | -                     | -             | √         |
| A.tumefaciens          | -          | -              | -         | -                            | -          | -                   | -                     | -             | √         |
| P. multocida           | -          | -              | -         | -                            | -          | -                   | -                     | -             | -         |

*aMicroorganism was not tested or essential oil had little activity or it was inactive.

3.2.4. Phytotoxic Effect

The phytotoxic effect of S. strigillosa essential oil was evaluated by conducting bioassays against amaranth and bluegrass (amaranthus is a cosmopolitan genus of annual or short-lived perennial plants, and bluegrass refers to several species of grasses of the genus Poa). 3 µL/mL of essential oil could completely inhibit amarathus seedling growth and caused a significant inhibitory effect on bluegrass (53).

3.2.5. Acaricidal Toxicities Activity

The acaricidal activity of S. barbata essential oil was higher than the activity observed in the positive controls (benzyl benzoate), which was evaluated via fumigant and contact toxicity bioassays against Dermatophagoides farinae, D. pteronyssinus, and Tyrophagus putrescentiae (45).
4. Conclusions

*Scutellaria* is a genus in the Lamiaceae family and for thousands of years, has been used as a medicine (76, 77). In recent years, many studies are performed on the essential oils of different species of *Scutellaria* (8, 13, 26-32). However, many species of the *Scutellaria* genus are not investigated, and therefore many studies can be performed on the components and biological activities of uninvestigated *Scutellaria* essential oils.

In the current review, chemical compositions of essential oils and biological activities (antioxidant, antimicrobial, anti-feedant, phytotoxic, and acaridical activities) of the *Scutellaria* genus are summarized. Hexadecanoic acid, germacrene D, β-caryophyllene, linalool, β-farnesene, and eugenol were the main compounds. (several compounds of these oils have medicinal properties). This review can serve as a reference for natural products and ethnopharmacology fields.

Footnotes

Authors’ Contribution: This work was performed by the collaboration of all authors. Ameneh Mohammadi contributed to the study design, data collection, assessment of documents, data analysis, writing the first draft, and managing the research. Jamal Kasaian was a supervisor of the research project and contributed with original data, critical editing, and reviewing the manuscript. Peiman Alesheikh was the second supervisor of the research project and cooperated in the clinical process, assessment of neonates, critical editing, and reviewing the manuscript. All authors read and approved the final manuscript.

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Table 1. Major Essential Oil Components (> 10%) of Scutellaria Species

| Compound          | Scutellaria species | Origin       | Amount (%) | Ref. |
|-------------------|---------------------|--------------|------------|------|
| **Hexadecanoic acid** |                     |              |            |      |
|                   | S. barbata          | Korea        | 58.52      | (45) |
|                   | S. albida subsp albida | Turkey     | 15.6       | (46) |
|                   | S. albida subsp colchica | Turkey    | 12.9       | (46) |
|                   | S. albida subsp velenovskyi | Turkey  | 17.3       | (46) |
|                   | S. brevibracteata    | Lebanon      | 12.6       | (47) |
|                   | S. diffusa           | Turkey       | 29.9       | (48) |
|                   | S. heterophylla      | Turkey       | 16.0       | (49) |
|                   | S. barbata           | China        | 28.6       | (50) |
| **Hydroxynaphthalene** |                     |              |            |      |
|                   | S. barbata           | Korea        | 12.22      | (51) |
|                   | S. volubilis         | United States| 20.4       | (52) |
|                   | S. baikalesensis     | United States| 12.4       | (53) |
|                   |                     | United States| 27.5       | (54) |
|                   |                     | United States| 13.0       | (55) |
|                   | S. irwinowii         | Iran         | 16.9       | (56) |
|                   | S. strigillosa       | China        | 37.78      | (57) |
|                   | S. salvifisca        | Turkey       | 40.0       | (58) |
|                   | S. laeteviolacea     | Japan        | 21.87      | (59) |
|                   | S. orientalis subsp alpina | Iran | 19.7       | (60) |
|                   | S. orientalis subsp Virens | Iran | 16.5       | (61) |
|                   | S. ramosissima       | Uzbekistan   | 23.96      | (62) |
|                   | S. sitothorpsi       | Turkey       | 42.01      | (63) |
|                   | S. heterophylla      | Turkey       | 21         | (64) |
|                   | S. pinnatifida subsp alpina | Iran | 20.7       | (65) |
| **Germacrene D**   |                     |              |            |      |
|                   | S. volubilis         | Ecuador      | 17.5       | (66) |
|                   | S. baikalesensis     | US           | 22.3       | (67) |
|                   | S. baikalesensis     | US           | 23.1       | (68) |
|                   | S. baikalesensis     | US           | 41.5       | (69) |
|                   | S. californica       | US           | 56.6       | (70) |
|                   | S. albida subsp albida | Turkey     | 14.2       | (71) |
|                   | S. albida subsp velenovskyi | Turkey | 20        | (72) |
|                   | S. sieberti          | Greece       | 14.2       | (73) |
|                   | S. salvifisca        | Turkey       | 11         | (74) |
|                   | S. orientalis subsp alpina | Iran | 15        | (75) |
|                   | S. orientalis subsp Virens | Iran | 13.4       | (76) |
|                   | S. ramosissima       | Uzbekistan   | 11.99      | (77) |
|                   | S. sitothorpsi       | Turkey       | 22.58      | (78) |
|                   | S. brevibracteata    | Lebanon      | 14.4       | (79) |
|                   | S. hastifolia        | Lithuania    | 12.9       | (80) |
| Compound                        | Country     | Percent | Ref. |
|---------------------------------|-------------|---------|------|
| **α-Humulene**                  |             |         |      |
| S. havanensis Jacq.             | Cuba        | 11.6    | 63   |
| S. volubilis                    | Ecuador     | 14.7    | 50   |
| **Linalool**                    |             |         |      |
| S. albid subsp. albida          | Turkey      | 20.4    | 46   |
| S. albid subsp. condensata      | Turkey      | 28.5    | 46   |
| S. sieberi                      | Greece      | 22.7    | 28   |
| S. rupestris                    | Greece      | 38.8    | 28   |
| S. schachristanica              | Uzbekistan  | 26.98   | 57   |
| S. cypria var. elatior          | Turkey      | 10.92   | 58   |
| S. rubicunda                    | Italy       | 27.8    | 26   |
| **Nerolidol**                   |             |         |      |
| S. albid subsp. condensata      | Turkey      | 16.8    | 46   |
| **Tetradecanoic acid**          |             |         |      |
| S. albid subsp. velenovskyi     | Turkey      | 10.2    | 46   |
| **Cadinene**                   |             |         |      |
| S. lateriflora                  | Iran        | 27.0    | 64   |
| S. orientalis subsp. virens     | Turkey      | 19.92   | 59   |
| **Calamenene**                  |             |         |      |
| S. lateriflora                  | Iran        | 15.2    | 64   |
| S. litwinowii                   | Iran        | 20.3    | 52   |
| **β-Farnesene**                 |             |         |      |
| S. galericulata                 | Canada      | 17.0    | 60   |
| S. parvula                      | Canada      | 17.0    | 60   |
| S. Wightiana bonii              | India       | 22.07   | 63   |
| **Bicyclo-germacrene**          |             |         |      |
| S. salvifolia                   | Turkey      | 14.0    | 46   |
| **Hexahydro farnesy acetone**   |             |         |      |
| S. orientalis subsp. alpina     | Lebanon     | 11.7    | 47   |
| **1-octen-3-ol**                |             |         |      |
| S. laeteviolacea                | Japan       | 27.72   | 54   |
| S. grossa Wall ex Benth         | India       | 32.0    | 65   |
| **Terpinolene**                 |             |         |      |
| S. orientalis subsp. virens     | Iran        | 15.6    | 56   |
| **Acetophenone**                |             |         |      |
| S. immaculata                   | Uzbekistan  | 30.39   | 57   |
| S. schachristanica              | Uzbekistan  | 34.74   | 57   |
| **Eugenol**                     |             |         |      |
| S. immaculata                   | Uzbekistan  | 20.61   | 57   |
| S. schachristanica              | Uzbekistan  | 20.67   | 57   |
| S. cypria var. cypria           | Turkey      | 23.05   | 58   |
| S. cypria var. cypria           | Turkey      | 20.04   | 57   |
| **Thymol**                      |             |         |      |
| S. immaculata                   | Uzbekistan  | 10.04   | 57   |
| **Palmitic acid**               |             |         |      |
| S. cypria var. cypria           | Turkey      | 27.0    | 57   |
| S. cypria var. elatior          | Turkey      | 46.76   | 57   |
| **Phytol**                      |             |         |      |
| S. brevibracteata               | Lebanon     | 10.7    | 47   |
| **4-vinylguaiacol**             |             |         |      |
| S. brevibracteata               | Lebanon     | 10.2    | 47   |
| Ingredient                  | Plant Species                     | Location | Percentage | Reference |
|-----------------------------|-----------------------------------|----------|------------|-----------|
| β-Isabolol                  | *S. galericulata*                 | Canada   | 20.6       | (60)      |
|                             | *S. parvula*                      | Canada   | 20.6       | (60)      |
| Bergamotene                 | *S. galericulata*                 | Canada   | 13.4       | (60)      |
|                             | *S. parvula*                      | Canada   | 13.4       | (60)      |
| Methyl chavicol             | *S. pinnatifida A. Hamilt Subsp. pinnatifida* | Iran     | 81.9       | (66)      |
| Aromadendrene               | *S. repens*                       | India    | 0.3        | (60)      |
| β-Funebrene                 | *S. repens*                       | India    | 15.0       | (60)      |
| 1,4-Benzenediol-2,5-dimethyl| *S. Wightiana benth*              | India    | 21.53      | (13)      |
| Pipertone oxide             | *S. Wightiana benth*              | India    | 16.23      | (13)      |
| α-Humulene                  | *S. havanensis Jacq*              | Cuba     | 11.8       | (60)      |
| Limonene                    | *S. angustifolia*                 | Laos     | 30.3       | (60)      |
| Fenchone                    | *S. angustifolia*                 | Laos     | 26.7       | (60)      |
| Alpha-pinene                | *S. angustifolia*                 | Laos     | 31.3       | (60)      |