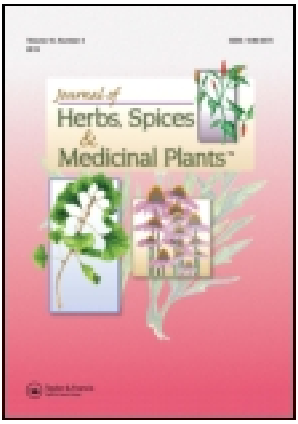

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Chemical Compositions of Essential Oils of Selected Medicinal Plants from Thùa Thiên-Huế Province, Vietnam

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Essential oils from selected plants of Vietnam were analyzed by gas chromatography (GC-FID) and gas chromatography/mass spectrometry (GC-MS). The results showed that one group contains aromatic and terpenoid components namely Friesodielsia filipes *(stem: benzyl benzoate, α-pinene);* Meiogyne virgata *(stem; α-humulene, benzyl benzoate, bicyclogermacrene); and* P. sessiliflora *(stem: eugenol, limonene, α-phellandrene), while the second group producing terpenoid oils includes* F. filipes *(leaf: α-pinene, β-caryophyllene, caryophyllene oxide);* M. virgata *(leaf: α-humulene, bicyclogermacrene, β-caryophyllene, bicycloelemene);* Polyalthia sessiliflora *(leaf: limonene, β-caryophyllene, β-cubebene);* Pseuduvaria indochinensis *(leaf: α-copaene, α-pinene; stem: limonene, α-phellandrene, β-caryophyllene); and* O. hirsuta *(leaf: cis-ρ-mentha-2,4(8)-diene, germacrene D, bicyclogermacrene).*

KEYWORDS Friesodielsia filipes*,* Meiogyne virgata*,* Orophea hirsuta*,* Polyalthia sessiliflora*,* Pseuduvaria indochinensis*, terpenes, annonaceae*

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INTRODUCTION

The *Annonaceae* and all woody plants of the *Magnoliales* are sources of terpenoids, alkaloids, steroids, polyphenols, and flavonoids (15).

The chemical compositions of volatile oils of some *Annonaceae* flora of Vietnam have been reported (4–6). In this study, the volatile constituents of 10 essential oils from different parts of five Annonaceous plants namely *Friesodielsia filipes, Meiogyne virgata , Orophea hirsute, Polyalthia sessiliflora*, and *Pseuduvaria indochinensis* from Vietnam were studied. Ethnomedically, the plants are used to reduce fever, treat symptoms of flu, treat sores and wounds, reduce constipation and inflammation, and serve as a general tonic and bath (15).

Phytochemical investigations revealed the characterization of alkaloids from *Pseuduvaria* species (12,16,29) as well as diterpenes from *P. indochinensis* (22,30); alkaloids (11,25), and lactones (2) from *M. virgata* and other species; alkaloids from *Orophea* species (14,23,26); sesquiterpenes and flavonoids (9,19) from *Friesodielsia* species; diterpenes and triterpens (20,21) and alkaloids (16,28) from *Polyalthia* species. The essential oils of some *Polyalthia* (5) and *Pseuduvaria* (4) have been reported in the literature.

MATERIALS AND METHODS

Plant Collection

Samples of *F. filipes, M. virgata, O. hirsuta, P. sessiliflora*, and *P. indochinensis* were collected from Bạch Mã National Park, Thùa Thiên–Huế Province, Vietnam, in August 2011. Voucher specimens DND 240, DND 247, DND 248, DND 268, and DND 271, respectively, were deposited at the Botany Museum, Vinh University, Vietnam. Plant samples were air-dried prior to extraction.

Extraction of Oils

Aliquots of 500 g of pulverized plant samples were subjected to hydrodistillation for 4 h under normal pressure, according to the Vietnamese Pharmacopoeia (27). The plant samples yielded a low content of essential oils: 0.12 and 0.15% (v. w^{-1}); *F. filipes* (leaf and stem bark); 0.15, 0.10 and 0.20% (v. w^{-1}); *P. indochinensis* (leaf, stem bark and root bark); 0.1% (v. w^{-1}); *O. hirsuta*; (leaf); 0.10 and 0.12% (v. w^{-1}); *P. sessiliflora*; (leaf and stem bark); and 0.12 and 0.10% (v. w^{-1}); *M. virgata*; (leaf and stem bark), calculated on a dry weight basis. All samples were light yellow. Oil samples were stored under refrigeration prior to analysis.

Gas Chromatography Analysis

Gas chromatography (GC) analysis was performed on an Agilent Technologies HP 6890 Plus Gas chromatograph equipped with an FID and fitted with HP-Wax and HP-5MS columns (both 30 m × 0.25 mm, film thickness, 0.25μm, Agilent Technology). The analytical conditions were carrier gas H_2 (1mL.min^{-1}), injector temperature (PTV) 250°C, detector temperature 260°C, column temperature programmed from 40дC (2 min hold) to 220°C (10 min hold) at 4°C. min^{-1}. The volume of injection was 1.0 μL, split ratio 10:1. Inlet pressure was 6.1 kPa.

Gas Chromatographic—Mass Spectral Analysis

Agilent Technologies HP 6890N Plus Chromatograph fitted with a fused silica capillary HP-5 MS column (30 m × 0.25 mm, film thickness 0.25 μm) and interfaced with a mass spectrometer HP 5973 MSD was used under the same conditions as those used for GC analysis, with He (1mL.min^{-1}) as carrier gas. The MS conditions were ionization voltage 70eV; emission current 40mA; acquisitions scan mass range of 35 to 350 amu at a sampling rate of 1.0scan. s^{-1}.

Identification of the Constituents

The identification of constituents was by retention indices determined by co-injection with reference to a homologous series of *n*-alkanes, under identical experimental conditions. Further identification was performed by comparison of their mass spectra with those from NIST 08 Libraries (on ChemStation HP) and Wiley Ninth Version and the home-made MS library built up from pure substances and components of known essential oils as well as by comparison of their retention indices with literature values (1,13). The relative amounts of individual components were calculated based on the GC peak area (FID response) without using correction factors.

RESULTS

One hundred and thirty-four compounds were identified in the studied oil samples. This accounted for 91.6% to 99.5% of the total composition of the oils (Table 1).

Friesodielsia filipes

Monoterpene hydrocarbons (43.0%), sesquiterpene hydrocarbons (25.0%), and oxygenated sesquiterpenes (16.5%) were the major fractions present

TABLE 1 Chemical Composition of the Essential Oils from *Friesodielsia filipes, Meiogyne virgata, Orophea hirsute, Polyalthia sessiliflora*, and *Pseuduvaria indochinensis (Annonaceae)*

			Percentage composition									
(%) Compounds[a]	RI[b]	RI[c]	*F.fl*	*F.fs*	*M.vl*	*M.vs*	*P.sl*	*P.ss*	*P.il*	*P.is*	*P.ib*	*O.hl*
α-Thujene	930	924	—	—	—	—	0.2	0.2	—	8.8	0.4	—
α-Pinene	939	932	19.1	30.6	Tr	0.1	1.4	0.5	7.6	7.6	2.3	—
Camphene	953	946	0.5	—	—	8.7	—	—	0.6	1.8	0.2	—
Verbenene	962	961	—	—	—	—	—	—	0.5	—	—	—
Sabinene	976	969	0.3	—	—	0.4	1.8	0.3	0.4	1.9	2.9	—
β-Pinene	980	974	8.3	7.9	—	—	—	0.4	0.9	—	—	—
6-methyl-5-Hepten-2-one	981	981	—	—	—	—	—	—	—	2.3	—	—
trans-Isolimonene	983	980	0.2	—	—	—	—	—	—	—	—	—
1(7),4,8-*o*-Menthatriene	989	—	0.2	—	—	—	—	—	—	—	—	—
β-Myrcene	990	988	2.6	1.4	Tr	0.6	1.0	2.4	0.3	—	1.1	—
α-Phellandrene	1,006	1,002	—	—	Tr	2.8	7.4	17.2	1.6	13.0	7.4	0.1
δ-3-Carene	1,011	1,008	0.2	6.0	—	—	—	—	—	—	—	—
α-Terpinene	1,017	1,014	Tr	—	—	0.2	0.4	0.4	0.1	3.9	0.7	—
p-Cymene	1,026	1,020	—	—	—	1.8	—	—	1.3	—	—	—
o-Cymene	1,028	1,022	0.5	—	—	—	3.7	—	—	—	4.6	—
Limonene	1,032	1,024	4.4	—	Tr	7.1	17.0	24.1	4.4	15.4	19.2	0.2
1,8-Cineole	1,034	1,026	—	—	—	—	—	—	5.7	—	—	—
(*Z*)-β-Ocimene	1,043	1,032	—	—	—	—	—	—	—	1.2	—	—
(*E*)-β-Ocimene	1,042	1,044	5.1	2.7	Tr	2.1	3.1	0.3	0.7	—	3.5	—
γ-Terpinene	1,061	1,054	0.2	—	Tr	0.2	0.5	—	0.2	2.8	1.2	—
cis-*p*-Mentha-2, 4(8)-diene	1,088	1,085	—	—	—	—	—	—	—	—	—	21.6
Terpinolene	1,090	1,086	0.2	—	—	0.2	0.3	Tr	0.2	0.7	0.6	—
Linalool	1,100	1,095	0.5	—	—	0.3	0.4	0.2	1.7	0.2	4.9	—
p-Ethyl Anisole	1,122	—	0.8	—	0.3	—	—	0.1	—	—	—	—
α-Campholenal	1,125	1,122	—	—	—	—	—	—	0.3	—	—	—
allo-Ocimene	1,128	1,128	—	—	—	—	—	—	—	0.1	—	—
trans-*p*-Menth-2-en-1-ol	1,139	1,136	—	—	—	—	—	—	0.2	Tr	—	—
neoallo-Ocimene	1,140	1,140	1.2	—	—	—	—	0.2	—	—	—	—

trans-Verbenol	1,145	1,140	—	—	—	—	—	—	1.0	—	—	—
Camphor	1,145	1,141	—	—	—	0.2	—	—	—	—	—	—
Pinocarvone	1,160	1,160	0.2	—	—	—	—	—	1.1	—	—	—
Borneol	1,167	1,165	—	—	—	—	—	—	1.4	—	—	—
Terpinen-4-ol	1,177	1,174	0.1	—	—	0.2	0.4	0.4	0.4	0.3	4.2	—
p-Cymen-8-ol	1,180	1,179	—	—	—	—	—	—	0.2	—	—	—
Thuj-3en-10-al	1,190	1,181	—	—	—	—	—	—	1.3	—	—	—
α-Terpineol	1,191	1,186	0.2	—	—	—	—	0.8	1.2	—	1.1	—
Myrtenol	1,198	1,194	0.1	—	—	—	—	—	—	—	—	—
n-Dodecane	1,200	1,200	—	—	0.1	—	—	—	—	—	—	—
Verbenone	1,205	1,204	0.1	—	—	—	—	—	0.5	—	—	—
trans-Carveol	1,217	1,215	—	—	—	—	—	—	0.2	—	—	—
endo-Fenchyl acetate	1,220	1,218	0.1	—	—	—	—	—	—	—	—	—
Cuminaldehyde	1,241	1,238	—	—	—	0.3	—	—	—	—	—	—
Chavicol	1,249	1,247	—	—	—	—	—	0.3	—	—	—	—
(*E*)-Citral	1,271	1,271	0.2	—	—	0.3	1.1	—	0.5	—	0.4	—
Bornyl acetate	1,285	1,287	0.4	—	—	—	—	—	0.3	0.7	—	—
Thymol	1,292	1,289	—	—	—	—	—	Tr	—	—	—	—
trans-Sabinyl acetate	1,294	1,289	—	—	—	—	—	—	—	0.2	—	—
trans-Pinocarvyl acetate	1,295	1,298	0.6	—	—	—	—	—	—	—	—	—
Carvacrol	1,298	1,298	—	—	—	—	—	0.2	—	—	—	—
n-Tridecane	1,300	1,300	—	—	—	—	0.1	—	—	—	—	—
Methyl geranate	1,321	1,322	—	—	—	—	—	—	—	0.2	—	—
Myrtenyl acetate	1,326	1,324	0.2	—	—	—	—	—	—	—	—	—
Bicycloelemene	1,337	1,338	0.5	—	13.9	1.0	1.7	0.3	—	0.2	0.4	1.2
α-Cubebene	1,351	1,345	—	—	Tr	—	0.4	—	—	0.1	—	—
Eugenol	1,356	1,356	0.3	—	Tr	1.0	3.0	42.9	1.3	Tr	0.4	—
Deacanoic acid	1,365	1,364	—	—	—	—	0.3	—	—	—	—	—
Cyclosativene	1,371	1,369	0.1	—	Tr	—	—	—	—	0.1	—	—
α-Ylangene	1,373	1,373	—	—	—	—	—	—	—	Tr	—	0.3
Isoledene	1,376	1,374	—	—	—	0.2	—	—	0.6	—	—	—
α-Copaene	1,378	1,374	0.6	0.7	0.3	1.3	1.1	0.1	26.5	0.5	0.8	—
β-Bourbonene	1,385	1,387	—	—	—	—	0.3	—	—	—	—	—
β-Cubebene	1,388	1,387	—	—	—	—	8.4	0.4	—	—	—	—
β-Elemene	1,397	1,398	0.2	—	0.6	0.6	—	0.1	—	0.3	1.5	2.6

(*Continued*)

TABLE 1 (Continued)

			Percentage composition									
(%) Compounds[a]	RI[b]	RI[c]	*F.fl*	*F.fs*	*M.vl*	*M.vs*	*P.sl*	*P.ss*	*P.il*	*P.is*	*P.ib*	*O.bl*
n-Decyl acetate	1,407	1,407	0.8	—	—	—	2.9	—	—	—	—	—
Methyl eugenol	1,407	1,410	—	—	—	—	—	—	0.2	0.1	20.0	0.1
β-Caryophyllene	1,419	1,417	16.8	5.6	14.5	6.2	10.2	0.1	—	1.7	—	5.3
β-Gurjunene	1,431	1,431	—	—	—	1.1	—	—	0.3	—	—	—
trans-α-Bergamotene	1,432	1,432	—	—	—	2.0	—	—	0.4	—	—	—
γ-Elemene	1,437	1,434	—	—	—	—	—	0.2	—	—	—	—
α-Guaiene	1,440	1,437	—	—	—	—	—	—	0.4	—	—	—
Aromadendrene	1,441	1,439	0.2	—	5.6	2.2	—	0.1	—	0.1	—	1.3
Seychellene	1,450	1,444	—	—	—	—	—	0.1	—	—	—	—
α-Humulene	1,454	1,452	3.9	—	20.4	13.3	4.7	0.1	—	6.0	0.9	—
trans-β-Farnesene	1,454	1,454	—	—	—	0.2	—	—	—	—	—	—
Ishwarane	1,465	1,465	—	—	—	—	—	—	—	—	—	1.1
γ-Gurjunene	1,477	1,475	—	—	—	0.9	—	—	0.5	—	—	—
Germacrene D	1,480	1,484	0.4	—	—	—	3.8	—	—	1.9	0.5	27.8
α-Amorphene	1,485	1,483	—	—	—	—	—	—	2.7	0.3	—	—
β-Selinene	1,490	1,489	0.8	0.9	0.7	0.5	5.3	—	—	0.4	1.1	0.4
α-Zingiberene	1,494	1,493	—	—	—	0.8	—	—	—	—	—	—
Cadina-1,4-diene	1,496	1,495	—	—	—	—	0.2	—	—	—	—	—
Viridiflorene	1,496	1,496	0.2	—	0.7	—	—	0.4	—	—	—	—
Valencene	1,498	1,496	—	—	—	—	—	—	—	—	—	0.4
α-Selinene	1,498	1,498	—	—	—	—	6.0	—	—	—	1.8	—
Bicyclogermacrene	1,500	1,500	0.6	—	15.4	9.2	0.4	0.4	—	2.9	0.3	15.3
α-Muurolene	1,500	1,500	—	—	—	—	—	—	1.8	—	—	—
Epizonarene	1,501	1,501	—	—	2.7	—	0.4	—	—	—	—	—
Cyclododecanone	1,502	1,502	0.1	—	—	—	0.8	—	—	—	—	—
β-Bisabolene	1,506	1,505	—	—	0.4	—	—	—	—	—	—	—
(*E, E*)-α-Farnesene1,506	1,505	0.3	—	—	—	—	—	—	—	—	—	
γ-Cadinene	1,514	1,513	—	—	—	0.5	—	0.1	0.2	0.3	—	0.4
cis-(*Z*)-α-Bisabolene epoxide	1,515	1,515	0.1	—	—	0.6	0.3	—	—	—	—	—

1-Phenyl heptan-3-one[d]	1,524	—	—	—	—	—	—	1.1	—	—	—	—
β-Sesquiphellandrene	1,525	1521	—	—	0.4	—	—	—	—	—	—	—
δ-Cadinene	1,525	1,522	0.4	—	—	1.0	2.3	—	1.6	1.0	0.7	6.2
cis-Calamenene	1,530	1,528	—	—	—	—	—	—	3.6	—	—	—
α-Calacorene	1,546	1,544	—	—	—	—	—	—	0.6	0.1	—	—
Elemol	1,550	1,548	—	—	—	—	—	—	—	0.2	—	0.5
Germacrene B	1,560	1,559	—	—	1.2	1.1	—	—	—	—	—	0.6
(*E*)-Nerolidol	1,563	1,561	—	—	1.8	0.8	—	0.1	—	0.2	—	—
1,5-Epoxysalvial-4(14)-ene	1,564	1,564	—	—	—	—	—	—	—	—	—	0.5
Palustrol	1,565	1,567	—	—	—	0.7	—	2.3	—	—	—	—
α-Caryophyllene alcohol	1,570	1,570	0.7	—	—	—	—	—	—	—	—	—
Spathulenol	1,578	1,577	—	—	3.4	4.3	0.3	—	0.7	0.6	0.5	4.1
Caryophyllene oxide	1,583	1,582	9.6	1.8	—	—	—	—	0.8	2.2	0.7	—
Globulol	1,585	1,590	—	—	2.7	—	—	—	—	—	—	—
Viridiflorol	1,593	1,592	—	—	3.4	7.5	0.4	—	—	1.1	—	0.4
Rosifoliol	1,603	1,600	—	—	—	—	—	0.2	—	—	—	—
Tetradecanal	1,611	1,611	—	—	—	—	—	—	—	—	0.3	—
cis-Asarone	1,619	1,616	—	—	—	—	—	—	—	—	0.5	—
Isospathulenol	1,625	1,631	—	—	0.9	1.0	—	—	—	—	—	0.8
Aromadendrene epoxide	1,638	1,639	—	—	—	—	—	—	0.3	—	—	—
5-*epi*-Neointermedeol	1,639	1,639	—	—	—	—	—	—	—	—	1.1	—
Caryophylla-4(12),8(13)-diene-5 α-ol	1,640	1,639	5.8	—	—	—	—	—	3.2	0.2	—	—
τ-Muurolol	1,642	1,640	—	—	—	—	1.5	—	—	0.6	—	—
Torreyol[d]	1,645	—	0.2	—	—	—	—	—	—	—	—	—
β-Eudesmol	1,650	1,649	—	—	—	—	—	0.1	—	—	—	—
Aristol-9-en-ol	1,651	—	—	—	—	—	—	—	—	—	—	0.3
α-Cadinol	1,651	1,652	—	—	0.2	0.7	1.4	0.2	3.2	0.1	—	1.0
Amorphan-3-en-9-ol	1,652	—	—	—	—	—	—	—	—	0.7	—	1.9
α-Bisabolol	1,688	1,685	—	—	1.7	1.8	—	—	—	0.1	—	—
Germacrene D-1,10-epoxide[d]	1,700	—	—	—	—	—	—	—	4.1	—	—	0.4
Mint sulfite	1,741	1,741	—	—	—	—	—	—	—	—	—	0.2
trans-Farnesol[e]	1,741	1,742	0.1	—	—	—	—	—	—	0.3	—	—
Benzyl benzoate	1,760	1,760	—	34.6	—	10.3	—	—	—	Tr	—	—
Tetradecanoic acid	1,770	1,770	0.1	—	—	—	—	—	—	—	—	—

(*Continued*)

TABLE 1 (Continued)

(%) Compounds[a]	RI[b]	RI[c]	*F.fl*	*F.fs*	*M.vl*	*M.vs*	*P.sl*	*P.ss*	*P.il*	*P.is*	*P.ib*	*O.bl*
			Percentage composition									
6,10,14-trimethyl-2-Pentadecanone (= Hexahydrofarnesylacetone)	1,844	1,844	—	—	0.1	—	—	—	—	—	—	—
1,2-Benzenedicarboxylic acid	1,917	1,917	4.8	4.6	—	1.0	0.9	0.2	0.2	0.4	5.0	0.4
n-Hexadecanoic acid	1,970	1,959	0.2	—	0.1	0.2	0.2	—	—	0.3	—	—
n-Eicosane	2,000	2,000	0.1	—	—	—	—	—	—	Tr	—	—
n-Octadecanol	2,062	2,062	2.0	3.1	—	—	—	2.1	—	—	—	—
Phytol	2,125	1,970	Tr	—	—	—	—	—	—	—	—	—
Octadecanoic acid	2,188	2,188	0.1	—	0.1	1.0	—	—	—	0.1	—	—
(*Z*)-9-Octadecenamide[d]	2,398	2,398	—	—	0.1	—	—	—	2.6	0.7	3.1	2.8
Total			95.4	97.9	91.6	96.5	99.5	99.0	90.4	97.1	98.9	98.2
Monoterpene hydrocarbons			43.0	46.4	—	24.2	36.8	46.0	18.8	57.2	43.9	21.9
Oxygenated monoterpenes			2.9	—	—	2.3	4.9	44.3	17.5	1.7	31.0	0.2
Sesquiterpene hydrocarbon			25.0	7.2	76.8	40.1	45.8	2.3	36.7	26.4	12.8	63.6
Oxygenated sesquiterpenes			16.5	1.8	14.0	17.4	3.9	2.9	14.6	8.0	2.8	9.4
Aromatic esters			—	34.6	—	10.3	—	—	—	—	—	—
Non-terpenes			9.0	7.7	0.8	2.2	8.1	3.5	2.8	3.8	8.4	3.2

F.fl, Friesodielsia filipes (leaf); *F.fs, Friesodielsia filipes* (stem); *M.vl, Meiogyne virgata* (leaf); *M.vs, Meiogyne virgata* (stem); *P.sl, Polyalthia sessiliflora* (leaf); *P ss, Polyalthia sessiliflora* (stem); *P.il, Pseuduvaria indochinensis* (leaf); *P.is, Pseuduvaria indochinensis* (stem); *P.ib, Pseuduvaria indochinensis* (bark); *O.bl, Orophea hirsuta*.

[a]Elution order on HP-5MS capillary column.

[b]Retention indices on HP-5MS capillary column.

[c]Literature retention indices (see Experimental); Tr, trace amounts < 0.1%; not identified and not present in literature; tentative assignment.

[d]Correct isomer not identified.

in the leaf oil (see Table 1). The main constituents were identified as α-pinene (19.7%), β-caryophyllene (16.8%), caryophyllene oxide (9.6%), β-pinene (8.3%), caryophylla-4(12),8(13)-diene-5α-ol (5.8%), and (*E*)-β-ocimene (5.1%). However, monoterpene hydrocarbons (46.6%) and aromatic esters (34.6%) were the main oil fraction in the stem oil. The main constituents were benzyl benzoate (34.6%) and α-pinene (30.6%), along with β-pinene (7.9%) and δ-3-carene (5.6%).

Meiogyne virgata

All six monoterpene compounds identified in the leaf oil of *M. virgata* were present in trace amounts (see Table 1). The sesquiterpene fractions (90.8%) were represented mainly by α-humulene (20.4%), bicyclogermacrene (15.4%), β-caryophyllene (14.5%), bicycloelemene (13.9%), and aromadendrene (5.6%). On the other hand, monoterpene hydrocarbons (24.2%), sesquiterpene hydrocarbons (40.1%), and oxygenated sesquiterpene (17.4%) were the major fractions identified in the stem. The compounds of quantitative significance were camphene (8.7%) and limonene (7.1%) among the monoterpenes; and α-humulene (13.3%), bicyclogermacrene (9.2%), viridiflorol (7.5%), and β-caryophyllene (6.2%) among the sesquiterpene. Benzyl benzoate (10.3%) represents the non-terpenes present in higher amount. The main sesquiterpene compounds common to both oils were bicycloelemene (13.9 and 1.0%), β-caryophyllene (14.6 and 6.2%), α-humulene (20.4 and 13.3%), and bicyclogermacrene (15.4 and 9.2%), respectively.

Polyalthia sessiliflora

While the leaf oil of *P. sessiliflora* consisted mainly of monoterpene hydrocarbons (36.8%) and sesquiterpene hydrocarbons (45.8%) fraction (see Table 1), the stem oil had abundance of monoterpene hydrocarbons (46.0%) and oxygenated counterpart (44.3%). Limonene (17.0%), β-caryophyllene (10.2%), β-cubebene (8.4%), α-phellandrene (7.4%), α-selinene (6.0%), and β-selinene (5.3%) were the main compounds of the leaf oil. Eugenol (42.9%), limonene (24.1%), and α-phellandrene (17.2%) represented the major constituents of the stem oil.

Pseuduvaria indochinensis

Large amounts of monoterpene compounds were present in the stem (58.9%) and bark (74.9%) oils of *P. indochinensis* (see Table 1). In the leaf oil, monoterpenes (32.5%) and sesquiterpenes (51.3%) were the major fractions. The major constituents of the leaf were α-copaene (26.5%) along with α-pinene (7.6%) and 1, 8-cineole (5.7%), while the stem consists mainly of limonene (15.4%), α-phellandrene (13.0%), β-caryophyllene (12.6%), α-thujene (8.8%), α-pinene (7.6%), and α-humulene (6.0%). In the bark oil were present methyl eugenol (20.1%), limonene (19.2%), α-phellandrene (7.4%), and 1, 2-benzedicarboxylic acid (5.0%). The main compounds common to the oil samples were α-pinene (2.3-7.6%), α-phellandrene (1.6-3.0%), limonene (4.4-19.2%), α-copaene (0.5-26.5%), and β-caryophyllene (0.2-12.6%)

Orophea hirsuta

Sesquiterpenes (73.0%) represent the major fraction of the leaf oil of *O. virgata*. A monoterpene, cis-ρ-mentha-2,4(8)-diene (21.6%) as well as the sesquiterpene compounds germacrene D (27.8%), bicyclogermacrene (15.3%), δ-cadinene (6.2%), and γ-elemene (5.3%) were the major oil constituents (see Table 1).

DISCUSSION

Monoterpenes (26.5-90.3%) and sesquiterpenes (9.0-90.8%) are the major classes of compounds identified in the samples. Aromatic esters are also prominent in the stem oil of *F. filipes* (34.6%) and *M. virgata* (10.3%). Two different reports previously identified β-caryophyllene (30.0%), α-zingiberene (21.7%), aromadendrene (15.2%), and β-selinene (9.1%) on one hand (5); and δ-cadinene (24.5%), zingiberene, and aromadendrene (19.1%) on the other (18) as the main constituents of *Polyalthia longifolia var. pendula* from Vietnam. Eugenol was not previously described as a major constituent of any *Polyalthia* oils. Essential oils of *Polyalthia* sp. have been classified into four different chemical classes (5). These are oils with an abundance of sesquiterpene hydrocarbons, such as found in *P. longifolia* var. *pendula, P. longifolia, P. suaveolens*, and *P. nitidissima*; oils with relative large amounts of hydrocarbon and oxygenated sesquiterpenes, exemplified by *P. australis* and *Polyalthia* sp.; oils dominated by oxygenated sesquiterpenes, as seen in *P. michaelii*; and oils consisting mainly of monoterpene hydrocarbons, as found in the fruit of *P. suaveolens* and *P. nitidissima*. The leaf oil of *P. sessiliflora* belongs to first class above, while the stem oil could be classified into the fourth class based on its high contents of limonene and α-phellandrene.

Previous analysis on the volatile oils of some *Pseuduvaria* species (3) revealed the predominance of sesquiterpene hyrdrocarbon compounds such as α-copaene, β-caryophyllene, α-himachalene, and α-humulene in *Pseuduvaria villosa* and *Pseuduvaria hylandii*; elemicin in *Pseuduvaria mulgraveana var. mulgraveana*; and oxygenated sesquiterpene compounds caryophyllene oxide, dihydroagarofuran isomer (froggatt ether), and spathulenol in *P. froggattii*. However, the phenylpropanoid, methyl eugenol was the most abundant constituent of *P. mulgraveana var. glabrescens*. When compared with the previous study, the main monoterpene compounds such as limonene, α-phellandrene, α-thujene, and α-pinene were not earlier reported to be in significant quantities in *Pseuduvaria* oils. However, β-caryophyllene, α-humulene, caryophyllene oxide, and spathulenol were present in lower amounts in these studied *P. indochinensis* oils. Moreover, α-himachalene, elemicin, and dihydroagarofuran isomer were conspicuously absent in the oil samples under investigation. To be noted is the presence of α-copaene and methyl eugenol in higher quantity.

The results showed that the studied oil samples fall into two groups in which one contains aromatic and terpenoid components while the second group contains only terpenoid constituents. The first group has its members as *F. filipes* (stem: benzyl benzoate, α-pinene); *M. virgata* (stem; α-humulene, benzyl benzoate, bicyclogermacrene); and *P. sessiliflora* (stem: eugenol, limonene, α-phellandrene). The second group producing terpenoid oils includes *F. filipes* (leaf: α-pinene, β-caryophyllene, and caryophyllene oxide); *M. virgata* (leaf: α-humulene, bicyclogermacrene, β-caryophyllene, and bicycloelemene); *P. sessiliflora* (leaf: limonene, β-caryophyllene, and β-cubebene); *P. indochinensis* (leaf: α-copaene and α-pinene; stem: limonene, α-phellandrene, and β-caryophyllene); and *O. hirsuta* (leaf: cis-ρ-mentha-2,4(8)-diene, germacrene D, and bicyclogermacrene).

The compounds identified in the oils from these plant species may contribute to their ethnomedicinal uses. 1,8-Cineole has been reported to exhibit insecticidal, antimicrobial, and antioxidant activity (24) and may synergistically enhance the biological activities of other essential oil components (10). Limonene is an abundant constituent of many essential oils and has exhibited cancer chemopreventive activity, possibly due to induction of glutathione-S-transferase and glutathione peroxidase (8). In addition, limonene has been shown to have muscle relaxant and sedative activities (7).

The presence of germacrene D, α-humulene, and β-caryophyllene as major components is consistent with the ethnopharmacological uses of some of the plants to treat skin problems. For example, some commercially marketed herbal treatments for skin problems include goldenrod (*Solidago canadensis*) oil, rich in germacrene D; salves from purple coneflower (*Echinacea purpurea*) root extract, rich in germacrene D and β-caryophyllene; and lotions from extracts of hops (*Humulus lupulus*) "flowers," rich in α-humulene and β-caryophyllene (24). Furthermore, β-caryophyllene showed anti-inflammatory and anesthetic effects in addition to anticarcinogenic and antineoplastic (17) activities. Caryophyllene oxide exhibited anti-dermatophytic activity (32) and smooth-muscle-relaxant activity (31). Some of the oil samples examined in this study were sufficiently rich in β-caryophyllene, α-humulene, germacrene D, and caryophyllene oxide.

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