Terpenoid Diversity in the Leaf Essential Oils of Himalayan Lauraceae Species

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The leaf terpenoid compositions of nine Lauraceae species, *viz*., *Neolitsea pallens*, *Lindera pulcherrima*, *Dodecadenia grandiflora*, *Persea duthiei*, *Persea odoratissima*, *Persea gamblei*, *Phoebe lanceolata*, *Cinnamomum tamala*, and *Cinnamomum camphora*, collected from the Himalayan region (India) were examined by GC, GC/MS, and NMR analyses in order to determine the similarities and differences among their volatile constituents. Furano-sesquiterpenoids were the principal constituents of *N. pallens*, *L. pulcherrima*, and *D. grandiflora*. (*E*)-Nerolidol, limonene, β-pinene, and α-pinene were the major constituents of *P. duthiei*; α-pinene, sabinene, and β-caryophyllene were predominant in *P. odoratissima*, while the oils of *P. gamblei* and *P. lanceolata* possessed β-caryophyllene as common major constituent. *C. camphora* and *C. tamala* were marked by the presence of camphor and cinnamaldehyde, respectively. Cluster analysis of the oil composition was carried out in order to discern the differences and similarities within nine species of six genera of Lauraceae.

Introduction. – The Lauraceae or Laurel family comprises a group of flowering plants included in the order Laurels. The family contains *ca.* 55 genera and over 2000 species worldwide, mostly in warm, tropical, humid subtropical, and mild temperate regions of northern and southern hemispheres [1]. These plants are less common in the Himalayan region with almost 15 species belonging to six genera, *viz*. *Neolitsea*, *Lindera*, *Persea*, *Dodecadenia*, *Phoebe*, and *Cinnamomum* [2–4]. Some of them are known as a source of spice, edible fruits, seed fat, and essential oils. Distribution of sesquiterpene furans and chemosystematics of some Lauraceae species have already been reported [5–7].

The chemical compositions of essential oils of various *Litsea*/*Neolitsea* species have been previously investigated [8–14]. A wide range of furanosesquiterpenoids have been isolated from *Lindera* species [15–19].

The GC and GC/MS analysis of leaf oils of various *Persea* and *Phoebe* species revealed β-caryophyllene, germacrene D, (*E*)-nerolidol, caryophyllene oxide, valencene, camphor, 1,8-cineole, (*E*)-avocadienofuran, methyl chavicol, 2-dodecanal, decanal, 11-dodecenal, dodecenoic acid, linalool oxides, δ-3-carene, and limonene as the major constituents. One or two of these compounds are generally dominant to the exclusion of others in each species [7][20–26].

The leaves and bark of *Cinnamomum tamala* are very commonly used as spice in Indian food. Several chemotypes were reported within *C. tamala* [27–30]. *C. camphora*, native of Japan, has been cultivated in the Himalayan region up to

1500 m, for the production of camphor which is the major constituent of the oil [31][32].

Dodecadenia grandiflora, an evergreen tree distributed at an altitude of 2400–2700 m in Himalayan forests, is the only species of this genus found in this region [4].

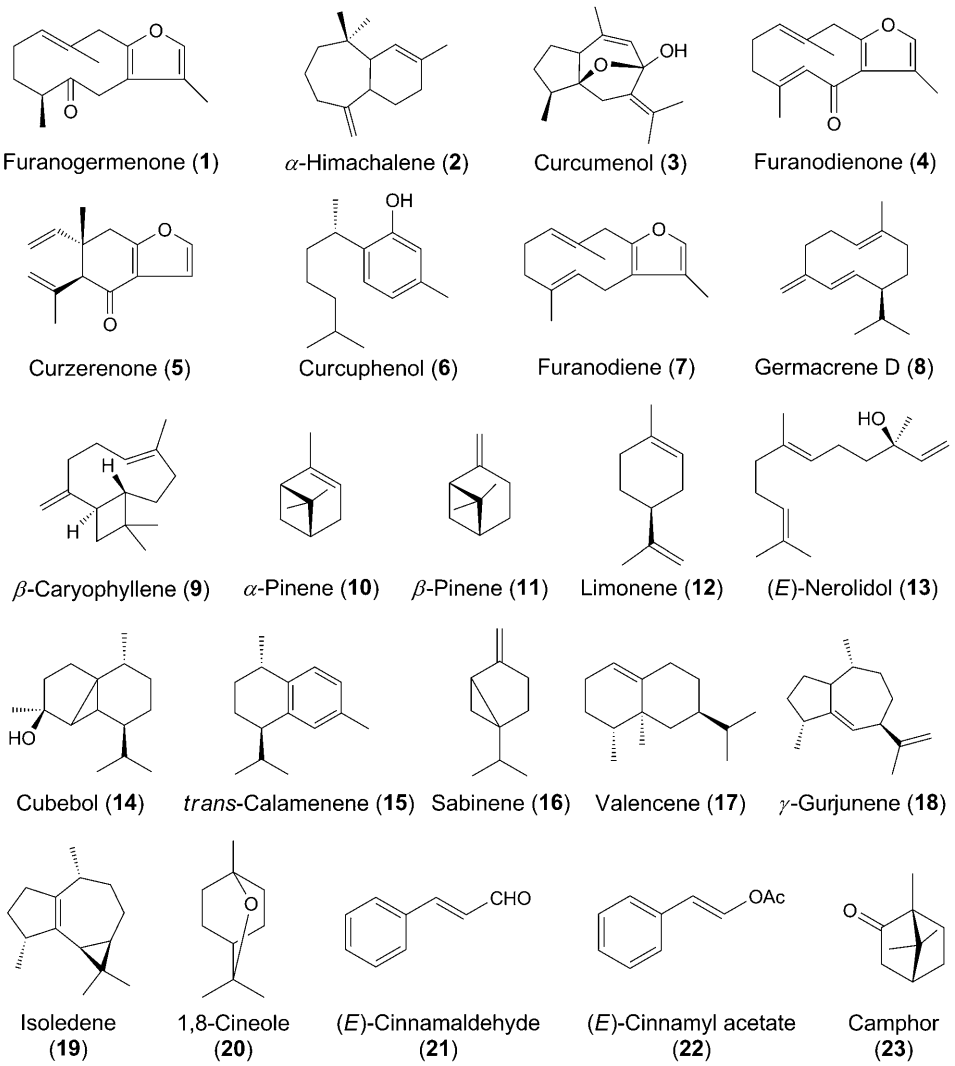
As a part of biochemical investigations on aromatic and medicinal plants of the Himalayan region, the present study deals with the chemical compositions of the leaf essential oils of nine Lauraceae species, *viz*., *Neolitsea pallens*, *Lindera pulcherrima*, *Dodecadenia grandiflora*, *Persea duthiei*, *P. odoratissima*, *P. gamblei*, *Phoebe lanceolata*, *Cinnamomum tamala*, and *C. camphora*, collected at different locations of the Himalayan region Uttarakhand (*Table 1*) with the aim to determine the terpenoid diversity among Himalayan Lauraceae. To the best of our knowledge, there is no previous report on the leaf essential-oil composition of *Persea duthiei*, *P. odoratissima*, *P. gamblei*, *Phoebe lanceolata*, and *Dodecadenia grandiflora*.

Table 1. *Collection and Steam Distillation of Some Lauraceae Species Collected from the Himalayan Region*

Plant	Abbreviation	Voucher number	Collection site[a])	Oil yield [%, *v*/*w*]
Neolitsea pallens	Np	Chem DST# 1–7/06	Barabe (Pithoragarh), 2000 m	1.10
Lindera pulcherrima	Lp	Chem DST# 1–9/06	Thalkedar (Pithoragarh), 2300 m	1.12
Persea duthiei	Pd	Chem DST# 1–4/07	Nainital, 1800 m	0.95
Persea odoratissima	Po	Chem DST# 2–4/07	Mandal (Gopeshwer), 1600 m	0.45
Persea gamblei	Pg	Chem DST# 3–4/07	Bhimtal, 1750 m	0.42
Phoebe lanceolata	Pl	Chem DST# 1–9/07	Gopeshwer, 1850 m	0.53
Dodecadenia grandiflora	Dg	Chem DST# 1–7/07	Cheena-peak (Nainital), 1800 m	0.90
Cinnamomum tamala	Ct	Chem DST# 1/2/08	Jeolikot, 900 m	1.20
Cinnamomum camphora	Cc	Chem DST# 3–5/07	Naukuchiatal, 1300 m	1.25

[a]) Different locations of Uttarakhand (Himalayan region, India)

Results and Discussion. – The constituents of the oils are listed in *Table 2*, in the order of their elution from an *Rtx-5* column. A total of 106 compounds were identified accounting for 92.5 to 97.9% of the total compositions of the leaf essential oils. Furanosesquiterpenoids were the principal constituents of *Neolitsea pallens* (59.5%), *Lindera pulcherrima* (79.3%), and *Dodecadenia grandiflora* (36.9%). Furanogermenone (**1**; 59.5%) was found to be the major compound in the leaf oil of *Neolitsea pallens* along with β-caryophyllene (**9**; 6.6%), sabinene (**16**; 4.8%), germacrene D (**8**; 4.6%), and curcumenol (**3**; 2.3%). The leaf oil of *Lindera pulcherrima* was characterized by a high content of sesquiterpenoids (96.8%), dominated mainly by furanosesquiterpenoids (79.3%), *viz*., furanodienone (**4**; 46.6%), curzerenone (**5**; 17.6%), furanodiene (**7**, 1.8%), and curzerene (1.2%). Other constituents in significant amounts were spathulenol (4.5%), β-selinene (2.0%), germacrene B (1.9%), curcuphenol (**6**; 1.9%), 10-*epi*-γ-eudesmol (1.8%), and β-eudesmol (1.3%). The linderene furanosesquiterpenoids reported in other *Lindera* species were not detected in the leaf oil of *L. pulcherrima*. Furthermore, our analysis also revealed a very small concentration of



monoterpenoids in the leaf oil of *L. pulcherrima*, as compared to earlier reports in which monoterpenoids constituted the major part of the oils of several other *Lindera* species [16][33][34].

The oil of *Dodecadenia grandiflora* showed similarity to that of *Neolitsea pallens* and *Lindera pulcherrima* in having furanosesquiterpenoids (36.9%) as major constituents. Other significant constituents were germacrene D (**8**, 26.0%), β-caryophyllene (**9**; 5.4%), and β-eudesmol (4.1%).

Apparently, the leaf essential oils obtained from *Persea* species represented yields ranging from 0.42 to 0.95 (*Table 1*). Monoterpene hydrocarbons (36.4%) and oxygenated sesquiterpenoids (35.7%) were abundant in *Persea duthiei* represented

Table 2. *Terpenoid Diversity in Leaf Essential Oil Constituents of Himalayan Lauraceae Species*

Compound[a])	RI[b])	RI[c])	Percent composition (FID [%])								
			Np[d])[e])	Lp[d])[f])	Dg[d])	Pd[d])	Po[d])	Pg[d])	Pl[d])	Ct[d])	Cc[d])
α-Thujene	932	931	0.2	–	–	t[g])	t	4.4	–	–	–
α-Pinene (**10**)	941	939	t	–	–	10.0	16.6	0.1	0.2	–	1.4
Camphene	954	953	–	t	–	0.5	1.5	–	4.1	–	1.1
Benzaldehyde	964	961	–	–	t	–	–	–	–	0.3	–
Sabinene (**16**)	978	976	4.8	–	–	–	13.1	0.6	0.1	–	0.8
β-Pinene (**11**)	982	980	0.3	t	–	10.0	2.7	0.2	5.8	1.3	t
Myrcene	994	991	t	0.1	t	1.7	2.9	–	–	t	1.0
α-Phellandrene	1009	1005	t	0.1	–	–	t	4.4	–	–	0.2
α-Terpinene	1019	1018	0.1	–	–	–	0.5	–	–	–	0.2
p-Cymene	1029	1026	–	0.2	–	3.5	0.1	0.1	1.2	0.6	2.3
Limonene (**12**)	1034	1031	–	–	t	10.1	0.5	0.2	8.1	0.8	–
β-Phellandrene	1037	1031	0.2	0.1	0.9	–	–	–	–	–	t
1,8-Cineole (**20**)	1038	1033	1.2	–	–	1.8	2.7	1.3	18.2	t	2.6
(*Z*)-β-Ocimene	1042	1040	0.1	–	–	–	–	–	t	–	0.2
(*E*)-β-Ocimene	1054	1050	0.2	–	–	–	t	0.3	6.9	–	0.2
γ-Terpinene	1065	1062	0.1	–	–	–	0.6	0.3	0.2	0.5	t
cis-Sabinene hydrate	1069	1068	t	–	–	–	–	–	–	–	–
Terpinolene	1089	1088	–	–	–	0.6	1.0	0.5	–	–	t
Linalool	1101	1098	0.5	t	–	0.4	0.3	0.4	0.4	5.4	t
cis-*p*-Menth-2-en-1-ol	1123	1121	–	–	–	t	–	–	–	–	–
trans-*p*-Menth-2-en-1-ol	1145	1140	–	–	–	0.1	–	–	–	–	–
Camphor (**23**)	1147	1143	–	–	–	–	–	–	–	–	81.5
Borneol	1167	1165	–	–	–	–	–	–	–	0.3	0.8
Terpinen-4-ol	1180	1177	0.5	–	0.6	–	1.2	0.9	0.3	0.1	0.6
α-Terpineol	1192	1189	–	0.1	0.3	0.2	t	0.4	1.2	–	0.9
Myrtenol	1195	1194	–	–	–	–	t	–	–	–	–
Methyl chavicol	1198	1195	–	–	t	–	–	–	–	–	–
trans-Piperitol	1209	1205	–	–	–	–	t	–	–	–	–
(*Z*)-Cinnamaldehyde	1216	1214	–	–	–	–	–	–	–	0.6	–
Piperitone	1254	1252	–	–	–	–	t	–	–	–	–
(*E*)-Cinnamaldehyde (**21**)	1268	1266	–	–	–	–	–	–	–	79.4	–
Bornyl acetate	1285	1285	0.5	0.1	–	2.9	2.6	2.3	1.5	–	–
δ-Elemene	1340	1339	0.2	0.2	0.9	–	–	0.3	–	–	t
α-Cubebene	1355	1351	–	–	t		–	–	–	–	–
Citronellyl acetate	1359	1354	t	–	–	–	–	–	–	–	–
Eugenol	1360	1356	–	–	–	–	t	–	–	–	–
α-Ylangene	1376	1372	t	–	–	–	–	–	–	–	–
Isoledene (**19**)	1378	1373	–	–	–	–	–	1.2	–	–	–
α-Copaene	1379	1376	–	0.3	1.2	0.1	–	1.0	1.5	1.0	t
(*E*)-Methyl cinnamate	1381	1379	–	–	–	–	–	–	–	t	–
β-Patchoulene	1383	1380	–	–	0.7	–	–	0.5	–	–	–
β-Bourbonene	1386	1384	–	t	–	–	–	0.2	–	–	–
β-Cubebene	1390	1390	1.2	0.2	0.4	0.1	–	7.2	–	0.5	–
β-Elemene	1394	1391	–	–	t	–	–	0.8	–	–	–
β-Longipinene	1402	1398	–	0.6	–	–	–	–	–	–	t
α-Gurjunene	1410	1409	–	–	0.5	–	–	0.4	–	–	0.1
β-Caryophyllene (**9**)	1418	1418	6.6	0.8	5.4	5.8	10.4	22.1	27.4	0.9	0.8
β-Gurjunene	1436	1432	–	–	–	0.3	–	t	–	–	–

Table 2 (cont.)

Compound[a])	RI[b])	RI[c])	Percent composition (FID [%])								
			Np[d])[e])	Lp[d])[f])	Dg[d])	Pd[d])	Po[d])	Pg[d])	Pl[d])	Ct[d])	Cc[d])
α-trans-Bergamotene	1439	1436	–	–	–	–	–	–	0.7	–	–
α-Guaiene	1443	1439	–	–	–	–	–	0.2	t	–	–
(*E*)-Cinnamyl acetate (**22**)	1445	1443	–	–	–	–	–	–	–	3.7	–
α-Himachalene (**2**)	1451	1447	1.1	–	–	–	–	–	–	–	–
α-Humulene	1457	1454	t	–	2.6	2.1	2.5	2.4	2.1	–	1.3
(*E*)-*β*-Farnesene	1459	1458	–	–	–	0.1	–	0.6	–	–	–
cis-Muurola-4,14-diene	1465	1460	–	–	–	–	t	–	–	–	–
γ-Gurjunene (**18**)	1475	1473	–	–	–	–	–	16.8	–	–	–
γ-Muurolene	1479	1477	–	t	–	4.0	t	–	0.6	–	0.4
Germacrene D (**8**)	1481	1480	4.6	0.5	26.0	–	0.7	3.9	7.3	–	0.3
ar-Curcumene	1485	1483	–	–	–	–	–	1.3	–	–	0.3
β-Selinene	1489	1485	–	2.0	0.8	1.9	–	–	–	–	–
cis-β-Guaine	1490	1490	–	–	t	–	–	t	–	–	–
Valencene (**17**)	1492	1491	–	–	–	–	6.9	–	–	–	–
Epicubebol	1494	1493	0.4	–	0.6	5.8	t	3.8	3.2	–	–
α-Selinene	1496	1494	0.9	–	0.7	–	–	–	–	–	–
Bicyclogermacrene	1497	1495	–	–	–	–	t	–	–	–	–
Curzurene	1500	1496	–	1.2	–	–	0.5	–	–	–	–
α-Muurolene	1503	1499	–	t	–	–	1.5	1.1	1.1	–	–
trans-β-Guaine	1504	1500	–	–	1.0	–	t		–	–	–
α-Bulnesene	1507	1505	t	–	0.5	0.1	1.7	1.7	–	–	–
γ-Cadinene	1515	1513	1.0	0.1	0.4	–	3.3	–	t	–	–
Cubebol (**14**)	1517	1514	–	–	–	2.9	–	–	–	–	–
δ-Cadinene	1529	1524	t	–	2.6	–	6.5	0.6	0.7	–	–
trans-Calamenene (**15**)	1534	1532	–	–	–	1.1	–	–	–	–	–
(*Z*)-Nerolidol	1535	1534	–	–	0.5	0.5	–	–	–	–	–
Germacrene B	1558	1556	–	1.9	–	–	0.2	0.5	–	–	0.2
(*E*)-Nerolidol (**13**)	1564	1564	–	–	0.6	13.2	–	–	–	–	–
Germacren D-4-ol	1578	1574	1.2	–	0.7	–	–	–	–	–	0.1
Spathulenol	1579	1576	–	4.5	–	0.7	–	1.8	0.1	0.2	–
Caryophyllene oxide	1584	1581	1.6	t	2.4	0.4	1.9	0.9	1.2	0.5	0.2
Globulol	1588	1583	0.1	–	–	t	–	–	–	–	–
Guaiol	1597	1595	–	–	0.9	2.4	0.4	0.2	–	–	–
Curzerenone (**5**)	1603	1601	–	17.6	–	–	–	–	–	–	–
Humulene epoxide-II	1606	1606	0.3	–	1.2	–	–	0.1	0.6	–	–
β-Oplopenone	1608	1606	–	–	0.3	–	–	–	–	–	–
10-*epi*-*γ*-Eudesmol	1622	1619	0.1	1.8	–	2.5	–	2.2	–	–	0.1
1-Epicubenol	1630	1627	0.5	–	–	0.7	0.3	–	–	–	–
α-Acorenol	1631	1630	–	–	–	–	0.4	–	–	–	–
γ-Eudesmol	1632	1630	–	–	0.2	–	–	0.1	–	–	–
epi-*α*-Cadinol	1643	1640	–	0.4	0.6	1.0	4.9	1.7	t	–	–
Cubenol	1645	1642	–	–	–	–	0.2	–	–	–	–
β-Eudesmol	1652	1649	2.0	1.3	4.1	4.0	–	0.1	–	–	–
α-Eudesmol	1657	1652	–	–	–	–	t	–	–	–	–
Selin-11-en-4-*α*-ol	1658	1652	–	–	–	1.3	–	2.5	–	–	–
α-Cadinol	1655	1653	–	–	0.5	–	3.9	0.3	t	–	0.3
Furanodiene (**7**)	1680	–	–	1.8	13.7	–	–	–	–	–	–
α-Bisabolol	1685	1683	–	–	–	0.3	–	–	–	–	–

Table 2 (cont.)

Compound[a])	RI[b])	RI[c])	Percent composition (FID [%])								
			Np[d])[e])	Lp[d])[f])	Dg[d])	Pd[d])	Po[d])	Pg[d])	Pl[d])	Ct[d])	Cc[d])
Germacrone	1697	1693	0.6	0.5	–	–	–	–	–	–	–
Curcuphenol (**6**)	1718	1715	–	1.9	–	–	–	–	–	–	–
Furanosesquiterpenoid (M^+ 250)	1722	–	–	–	13.7	–	–	–	–	–	–
Curcumenol (**3**)	1730	1726	2.3	–	–	–	–	–	–	–	–
Furanosesquiterpenoid (M^+ 250)	1732	–	–	–	9.5	–	–	–	–	–	–
Oplopanone	1737	1733	–	0.5	–	–	–	–	–	–	–
Furanosesquiterpenoid (M^+ 230)	1740	–	–	3.4	–	–	–	–	–	–	–
Furanosesquiterpenoid (M^+ 230)	1748	–	–	8.7	–	–	–	–	–	–	–
Furanodienone (**4**)	1750	–	–	46.6	–	–	–	–	–	–	–
Furanogermenone (**1**)	1786	–	59.5	–	–	–	–	–	–	–	–
Total			**92.9**	**97.5**	**95.0**	**93.1**	**92.5**	**92.9**	**94.7**	**96.1**	**97.9**
Monoterpene hydrocarbons			6.0	0.5	0.9	36.4	39.5	11.1	26.6	3.5	7.4
Oxygenated monoterpenoids			2.7	0.2	0.9	5.4	6.8	5.3	21.6	89.5	86.4
Sesquiterpene hydrocarbons			15.6	7.7	44.2	15.6	34.2	62.8	41.4	2.4	3.4
Oxygenated sesquiterpenoids			68.6	89.1	49.0	35.7	12.0	13.7	5.1	0.7	0.7
Unidentified			7.1	2.5	5.0	6.9	7.5	7.1	5.3	3.9	2.1

[a]) Mode of identification: retention index (RI), MS (GC/MS), IR, and NMR (^{1}H- and ^{13}C-NMR) of major isolates. [b]) RI determined in the present work (based on homologous series of *n*-alkanes (C_8–C_{24})). [c]) Literature RI values [35]. [d]) For plant abbreviations, see *Table 1*. [e]) Part of our previous results on the oil composition of *Neolitsea pallens* [13]. [f]) Part of our previous results on the oil composition of *Lindera pulcherrima* [19]. [g]) Trace ($< 0.1\%$)

by (*E*)-nerolidol (**13**; 13.2%), limonene (**12**; 10.1%), α-pinene (**10**; 10.0%), β-pinene (**11**; 10.0%), epicubebol (5.8%), β-caryophyllene (**9**; 5.8%), and β-eudesmol (4.0%). The leaf oil of *P. odoratissima* was marked by dominant presence of hydrocarbons (73.7%), mainly comprising α-pinene (**10**; 16.6%), sabinene (**16**; 13.1%), β-caryophyllene (**9**; 10.4%), valencene (**17**; 6.9%), and δ-cadinene (6.5%). The leaf oil of *P. gamblei* was also marked by hydrocarbons (73.9%) which were mainly sesquiterpene hydrocarbons (62.8%) represented by β-caryophyllene (**9**; 22.1%), γ-gurjunene (**18**; 16.8%), and β-cubebene (7.2%). Other constituents in significant quantity were α-thujene (4.4%), α-phellandrene (4.4%), germacrene D (**8**; 3.9%), and epicubebol (3.8%). Some of the essential-oil constituents previously reported in the *Persea* species, *viz.*, (*E*)-avocadienofuran, methyl chavicol, 2-dodecanal, decanal, 11-dodecenal, dodecenoic acid, linalool oxides, and δ-3-carene [20–23] were not detected even as trace constituents in the oils from any of the *Persea* species of the present investigation.

The leaf essential oil of *Phoebe lanceolata* was composed of monoterpene hydrocarbons (26.6%), oxygenated monoterpenoids (21.6%), and sesquiterpene hydrocarbons (41.4%). Major constituents were β-caryophyllene (**9**; 27.4%) and 1,8-cineole (**20**; 18.2%), along with limonene (**12**; 8.1%), germacrene D (**8**; 7.3%), and

(*E*)-β-ocimene (6.9%). Based on cluster analysis, the leaf essential oil of *P. lanceolata* was shown to have the maximum similarity to the essential oil of *P. gamblei*.

It can be noted that *Persea duthiei*, *P. odoratissima*, and *P. gamblei*, though having uniform qualitative essential-oil compositions, differ greatly in quantitative content. This has very little to do with morphological similarities. *Persea duthiei* and *P. odoratissima* are morphologically very similar but significantly different in their oil compositions. Also, *P. gamblei* is morphologically very similar to the northeast Indian cultivar *P. bombycina*, but quite different in its composition as compared to the latter [21].

The leaves of *Cinnamomum tamala* are known for eugenol-rich essential oil, but the material from this region contained (*E*)-cinnamaldehyde (**21**; 79.4%) along with linalool (5.4%) and (*E*)-cinnamyl acetate (**22**; 3.7%). Eugenol was not detected in natural samples of *C. tamala* collected from this region. The leaf oil of *C. camphora* (cultivated) contained camphor (**23**; 81.5%) as the single major constituent along with 1,8-cineole (2.6%), *p*-cymene (2.3%), α-pinene (1.4%), α-humulene (1.3%), and camphene (1.1%). The essential oils of *C. tamala* and *C. camphora* were shown to be most dissimilar in terms of their chemical composition compared with other genera of the family Lauraceae.

Furanosesquiterpenoids have been isolated from Zingerberaceae and Lauraceae species and are considered as one of the important chemosystematic features of these families [6][7]. In our investigations on the essential-oil composition of six genera of Lauraceae, *viz*., *Neolitsea*, *Lindera*, *Persea*, *Dodecadenia*, *Phoebe*, and *Cinnamomum*, only three, namely *Neolitsea*, *Lindera*, and *Dodecadenia*, were shown to contain furanosesquiterpenoids, while the oil composition of the remaining three genera, *viz*., *Persea*, *Phoebe*, and *Cinnamomum*, were dominated by mono- and sesquiterpenoids, furanosesquiterpenoids being completely absent.

The results of the cluster analysis (*Fig.*) provide useful chemotaxonomic correlations. Himalayan Lauraceae species may thus be grouped into two categories, *viz*., furan-containing genera (*Neolitsea*, *Lindera*, and *Dodecadenia*), mono- and sesquiterpenoid-rich genera (*Persea* and *Phoebe*), and oxygenated monoterpenoids-dominating genus (*Cinnamomum*). Biochemical markers/major constituents of leaf essential oil of Himalayan Lauraceae species are given in *Table 3*.

Furanogermenone (**1**), a constituent (59.9%) of the essential oil of *Neolitsea pallens* is also a constituent of Chinese and Japanese traditional medicinal plants and has been established as an allergy inhibitor and antiulcer agent [36–38]. Furanodienone (**4**) and curzerenone (**5**), which are major constituents of *Lindera pulcherrima*, are known to possess insecticidal activity [39] and have also been shown to exhibit significant anti-inflammatory, antimicrobial, and analgesic activities [40][41].

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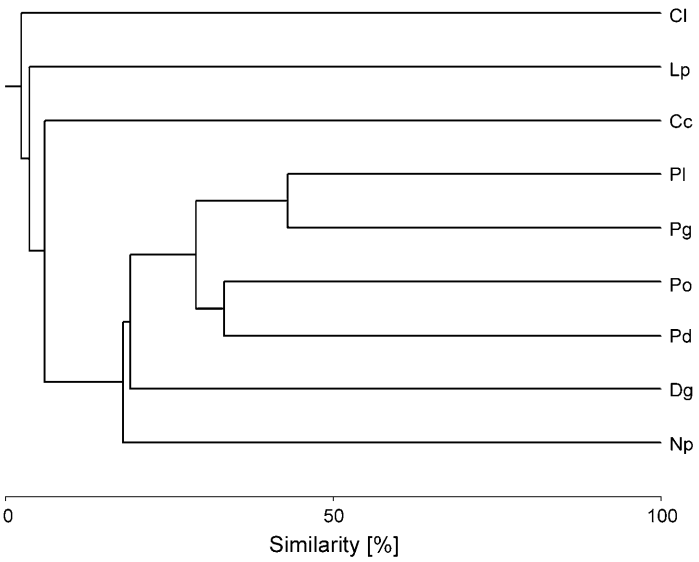

Figure. *Dendrogram obtained by* Bray–Curtis *cluster analysis* (simple average link) *of essential oils of Himalayan Lauraceae species.* Np: *Neolitsea pallens*; Lp: *Lindera pulcherrima*; Pd: *Persea duthiei*; Po: *Persea odoratissima*; Pg: *Persea gamblei*; Pl: *Phoebe lanceolata*; Dg: *Dodecadenia grandiflora*; Ct: *Cinnamomum tamala*; Cc: *Cinnamomum camphora.*

Table 3. *Biochemical Markers of Himalayan Lauraceae Species*

Species	Biochemical Markers
Neolitsea pallens	Furanogermenone (**1**), α-himachalene (**2**), curcumenol (**3**)
Lindera pulcherrima	Furanodienone (**4**), curzerenone (**5**), curcuphenol (**6**)
Dodecadenia grandiflora	Furanodiene (**7**), germacrene D (**8**), β-caryophyllene (**9**)
Persea duthiei	α-Pinene (**10**), β-pinene (**11**), limonene (**12**), (*E*)-nerolidol (**13**), cobebol (**14**), *trans*-calamenene (**15**)
Persea odoratissima	β-Caryophyllene (**9**), α-pinene (**10**), sabinene (**16**), valencene (**17**)
Persea gamblei	β-Caryophyllene (**9**), γ-gurjunene (**18**), isoledene (**19**)
Phoebe lanceolata	β-Caryophyllene (**9**), 1,8-cineole (**20**), limonene (**12**)
Cinnamomum tamala	(*E*)-Cinnamaldehyde (**21**), (*E*)-cinnamyl acetate (**22**)
Cinnamomum camphora	Camphor (**23**)

Experimental Part

1. *General.* The essential oils were fractionated by column chromatography (CC) on silica gel (SiO_2; 230–400 mesh, *Merck*, 600 × 25 cm column) packed and eluted with hexane, followed by gradient elution with Et_2O/hexane (5–20%). The isolated compounds were further purified by HPLC (*Waters*) using a μ-*Porosil* column (250 × 7.8 mm), 2.0 ml/min flow rate, RI detector (attenuation of 32X at 3000 psi), using 5–15% Et_2O in hexane. ^{1}H- and ^{13}C-NMR spectra: *Bruker Avance DRX 300* instrument (at 300 and 75 MHz, resp., in $CDCl_3$ at 25°; δ in ppm rel. to Me_4Si). The identification was achieved on the basis of retention indices (RI; determined with reference to homologous series of *n*-alkanes (C_8–C_{24}) under

identical experimental conditions), by MS Library search (*NIST* and *WILEY*), by comparing with the MS literature data [35], and by ^{1}H- and ^{13}C-NMR data of major isolates.

2. *GC and GC/MS Analysis.* The GC analysis was performed on a *Nucon 5765* gas chromatograph (*Rtx-5* column, 30 m × 0.32 mm i.d., FID, split ratio 1:48, N_2 flow of 4 kg/cm^2) and on a *ThermoQuest Trace GC 2000* interfaced with a *Finnigan MAT PolarisQ* ion-trap mass spectrometer fitted with an *Rtx-5* fused SiO_2 cap. column (*Restek Corp.*; 30 m × 0.25 mm; 0.25 μm film coating). The column temp. was programmed from 60 to 210° at 3°/min using He as carrier gas at 1.0 ml/min. The injector temp. was 210°, injection size 0.1 μl prepared in hexane, split ratio 1:40. MS were recorded at 70 eV with a mass scan range of 40–450 amu.

3. *Plant Material.* The fresh leaves of *Neolitsea pallens*, *Lindera pulcherrima*, *Dodecadenia grandiflora*, *Persea duthiei*, *P. odoratissima*, *P. gamblei*, *Phoebe lanceolata*, *Cinnamomum tamala*, and *C. camphora* were collected from different locations of the Himalayan region Uttarakhand (*cf. Table 1*). Plant herbaria were identified by the *Botanical Survey of India*, Dehradun, and voucher specimens have been deposited with the Phytochemistry Laboratory, Chemistry Department, Kumaun University, Nainital.

4. *Extraction of Oils.* The fresh leaves (2 kg of each plant) were chopped and steam-distilled (2 h) using copper still fitted with spiral glass condensers. The distillates (5 l) were saturated with NaCl, and the oils were extracted with hexane and CH_2Cl_2. The oils were dried (Na_2SO_4), and the percentage content was calculated on the basis of dry weight of plant materials. The oil yields are listed in *Table 1*.

5. *Cluster Analysis.* The percentage compositions of the essential oils were used to determine the chemical relationship between the six genera of Lauraceae by cluster analysis with BD-Pro software. The *Bray–Curtius* percentage was selected as the measure of similarity, and a simple-average method was used as the basis of cluster analysis [42].

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