Review

Chemistry of the Genus *Plectranthus*

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Abstract

This review presents the phytochemical constituents of the genus *Plectranthus* up to 1999. Only a tetrameric derivative of caffeic acid was isolated from *P. japonicus*, but a group of long-chain alkylphenols, of possible taxonomic significance in the genus, was isolated. As a genus of the subfamily Nepetoideae, *Plectranthus* is free from iridoid glycosides and rich in essential oil (i.e. > 0.5% volatile oil on a dry weight basis).

Diterpenoids are the more common secondary metabolites in *Plectranthus*. The majority of them are highly modified abietanoids. It seems to be similar to the pattern of diterpenoids of *Salvia*, but no clerodane diterpenoids were found in *Plectranthus*.

*Keywords: Plectranthus, Coleus, Labiatae, phytochemical constituents, abietane diterpenoids.*
Introduction

Labiatae is a large family occurs worldwide and has species that are adapted to almost all habitats and altitudes. The genus *Plectranthus* L' He'r. belongs to subfamily Nepetoideae of tribe Ocimeae [1]. It comprizes about eighty species worldwide, as indicated in this review. *Coleus* Lour. is taxonomically the closest to *Plectranthus* [2]. *Coleus* species are now generally accepted as belonging to either *Plectranthus* or to *Solenostemon* Thonn. (eds.) [3]. Many combinations are made between *Plectranthus* and *Coleus* species [4,5].

In *Plectranthus*, the upper lip of the flower is unusually four-lobed and the large shoe-shaped lower lip is formed from a single lobe, while in Labiatae the upper lip often consisting of two lobes and the lower consisting of three [6].

Many *Plectranthus* species are economic and medicinal plants. Several species may be grown as ornamentals; like *P. tenuiflorus* in Saudi Arabia. The tubers of an unidentified *Plectranthus* species are eaten in Swaziland [7]. Livingstone potato tubers, *P. esculentus* is cultivated in tropical Africa for its edible tubers [8,9]. *P. floribundus* is cultivated in Nigeria for its edible tubers; that are also relished in Natal [10,11]. In Polynesia, the seed-oil of *P. amboinicus* is applied to the ear for acute edematous otitis acuta [12]. The leaf extract of *P. tenuiflorus* is used in Saudi Arabia to treat ear infections [13]. The leaves of *P. asirensis* are used as an antiseptic dressing for wounds in Saudi Arabia [13]. The leaves of *P. caninus* are chewed in Africa to relieve toothache [14]. In East Africa the leaves of *P. elegans* are used as a vermicide [14]. *P. vettiveroides* is prescribed in Indian ayurvedic medicine against vomiting and nausea [15]. The East African medicinal plant *P. barbatus* is used as a remedy for stomach-ache and as a purgative, and is also resistant to insect attack, from which an aphid antifeedant diterpene was isolated [16].

The chemistry of *Plectranthus* is still not well known. This is the first review of chemical constituents of *Plectranthus* species.

The main phytochemical constituents of the genus *Plectranthus* are diterpenoids, essential oils and phenolics.
**Diterpenoids**

About 140 diterpenoids were identified from the colored leaf-glands of *Plectranthus* species. The majority of them are highly modified abietanoids, in addition to some phyllocladanes (structures D140-D146), *ent*-kaurenes (structures D147-D154) and a seco-kaurene (structure D155). Abietanoids could be classified, according to structure variation, into royleanones (structures D1-D37), spirocoleons (structures D38-D66), vinylogous quinones (also named extended quinones) (structures D67-D76), quinone methides (structures D77-D93), acylhydroquinones (structures D94-D117), (4→3) abeo-acylhydroquinones (structures D118, D119), phenolic abietanoids (structures D120-D122), 1,4-phenanthraquinones (structures D123-D127), dimeric abietanoids (structures D128-D136) and seco-abietanoids (structures D137-D139). Names of these diterpenoids are listed in Table 2. Distribution of diterpenoids and other constituents in species of *Plectranthus* is shown by Table 1.

**Essential oils**

*Plectranthus* is one of the oil-rich genera belonging to the subfamily Nepetoideae [17]. Table 1 shows *Plectranthus* species that have been investigated for essential oils. The main constituents of essential oils of *Plectranthus* are mono- and sesquiterpenes. As instances, constituents of essential oil of *P. rugosus* [18], as eluted from fused silica capillary column, are α-pinene, camphene, β-pinene, sabinene, 3-carene, myrcene, α-phellandrene, α-terpinene, limonene, β-phellandrene, cis-β-ocimene, γ-terpinene, trans-β-ocimene, *p*-cymene, terpinolene, thujone, 1-nonen-3-ol, α-copane, β-bourbonene, β-cubebene, linalool, caryophyllene, terpinen-4-ol, humulene, γ-muurolene, germacrene D, piperitone epoxide, α-muurolene, bicyclogermacrene, δ-cadinene, γ-cadinene, α-curcumene, caryophyllene oxide, T-cadinol, torreyol and α-cadinol. On the same GC column (fused silica capillary), essential oil of *P. amboinicus* [19] was separated into α-pinene, camphene, 1-octen-3-ol, β-pinene, myrcene, α-phellandrene, Δ-3-carene, α-
terpinene, *p*-cymene, limonene, (Z)-β-ocimene, (E)-β-ocimene, α-phelandrène, γ-terpinene, α-terpinolene, linalool, camphor, 1-terpinen-4-ol, α-terpineol, thymol, carvacrol, α-cubebene, β-cubebene, β-elemene, β-caryophyllene, α-bergamotene, (Z)-β-farnesene, α-humulene, β-guaiene, (-)α-selinene, β-bisabolene, δ-cadinene, caryophyllene oxide, δ-cadinol, α-cadinol, farnesol, calamenol and (-)-4β-7β-aromadendrandiol. Also on fused silica capillary column, essential oil of *P. fruticosus* [20] gave α-thuyene, sabinene, γ-terpinene, β-bourbonene, linalool, terpinen-4-ol, sabinyl acetate, α-humulene, aromadendrene, α-cubebene, β-bisabolene, γ-cadinene, α-elemene, *trans*-farnesol and *trans*-copaene.

**Long-chain alkylphenols**

A group of long-chain alkylphenols, of possible taxonomic significance in the genus, was isolated [28,29]. From *P. albidus* long-chain alkylphenols **L1-L8, L10-L12** were isolated and showed a significant in vitro antioxidant activity [28]. Antioxidant activity guided fractionation of extracts of *P. sylvestris* [29] and HPLC separation yielded the oxygenated long-chain alkylcatechols **L9, L13-L18**.

**Miscellaneous constituents**

Only one aristolane sesquiterpene, 1(10)-aristolen-13-al **M1**, was isolated from *P. hereroensis* [30].

Five triterpenoids, named plectranthoic acid, **M2**, acetylplectranthoic acid, **M3**, plectranthadiol, **M4**, plectranthoic acid A, **M5** and plectranthoic acid B, **M6**, in addition to β-sitosterol were isolated from *P. rugosus* [31, 32]. From the same species Misra *et al.* [85] isolated the triterpenoids oleanolic acid **M7**, ursolic acid **M8** and betulin **M9**, in addition to β-sitosterol and hexacosanol.

Flavonoids seem to be rare in *Plectranthus*. Only two flavonoids were identified, 4′,7-dimethoxy-5,6-dihydroxyflavone, **M10** from *P. ambiguus* [33] and chrysosplenetin, **M11** from *P. marruboides* [34].
From *P. mollis* (= *P. incanus*), Mahmoud *et al.* reported the isolation of vernolic and cyclopropenoid fatty acids [35].

From *P. japonicus* (= *Rabdosia japonica*), a tetrameric derivative of caffeic acid was isolated [36].

**Conclusion**

Although the genus *Plectranthus* comprises many medicinal and economic plants [80], its chemistry remains poorly known. Caffeic acid and its derivatives are of widespread occurrence in the Labiatae family and of particular attention as chemotaxonomic markers. Chlorogenic acid appears to be of almost universal occurrence within this family, whereas rosmarinic acid is restricted to the subfamily Nepetoideae [81]. Only a tetrameric derivative of caffeic acid was isolated from *P. japonicus* [36]. But a group of long-chain alkylphenols, of possible taxonomic significance in the genus, was isolated [28,29]. Generally, the subfamily Lamioideae is rich in iridoid glycosides, whereas they are absent from the Nepetoideae [82]. No iridoid glycosides were isolated from *Plectranthus*.

Generally, *Plectranthus* species are essential-oil-rich (i.e. > 0.5% volatile oil on a dry weight basis), in agreement with the general situation that the Nepetoideae are oil-rich, whilst the Lamioideae are oil-poor [83].

Diterpenoids are the more common secondary metabolites in *Plectranthus*. The majority of them are highly modified abietanoids, in addition to some phyllocladanes and *ent*-kaurenes. It seems to be similar to the pattern of diterpenoids of *Salvia* [84], but no clerodane diterpenoids were found in *Plectranthus*. 
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Table 1: Alphabetical list of *Plectranthus* species and isolated compounds from them.

| *Plectranthus* species | Isolated chemical constituents | References |
|------------------------|-------------------------------|------------|
| Abyssinian *P.* sp.    | D1, D5, D9, D10, D12-D14, D21, D30 | 37         |
| *P. albidus*           | L1-L8, L10-L12                 | 28         |
| *P. aliciae*           | —                              | 62         |
| *P. alloplectus*       | —                              | 63         |
| *P. ambiguus*          | D141-D146, flavonoid M10       | 33         |
| *P. amboinicus*        | Essential oil                  | 19         |
| *P. argentatus*        | D4, D5, D8, D21, D25, D101, D102, D112 | 38         |
| *P. asirensis*         | —                              | 13         |
| *P. australis*         | —                              | 64         |
| *P. barbatus*          | D29, D65, D75, D76, D115, D117 | 39         |
|                        | D65                            | 16         |
| *P. burorum*           | —                              | 65         |
| *P. caninus*           | D108, D109                     | 40         |
|                        | D59-D64                        | 86         |
| *P. ciliatus*          | —                              | 61         |
| *P. coeha*             | D148                           | 41         |
|                        | D147                           | 42         |
| *P. coesia*            | —                              | 66         |
| *P. coetsoides*        | D147, D149-D154                | 43         |
| *P. coleoides*         | Essential oil                  | 25         |
| *P. cypriculoides*     | —                              | 67         |
| *P. defoliatus*        | Essential oil                  | 26         |
| *P. ekclosii*          | D86, M12-M15                   | 68         |
| *P. edulis*            | D17, D18, D21, D22, D23, D24, D38-D48, D50, D55, D56, D66, D67, D69, D70, D94-D100, D106, D107, D118, D119, D137, D138 | 44         |
|                        | D118                           | 45         |
| *P. elegans*           | D93, D120                      | 46         |
| *P. esculentus*        | —                              | 69         |
| *P. fasciculatos*      | —                              | 70         |
| *P. floribundus*       | —                              | 11         |
| *P. fruticosus*        | Essential oil                  | 20         |
| *P. gandicalyx*        | —                              | 65         |
| *P. garckeanus*        | —                              | 65         |
| *P. geradianus*        | —                              | 71         |
| *P. glandulosus*       | Essential oil                  | 23         |
| *P. glaucocalyx*       | An antimicrobial diterpenoid    | 47         |
| *P. grandidentatus*    | D68, D101, D102, D128-D134     | 48         |
|                        | D5, D11                        | 49         |
| *P. gratus*            | —                              | 63         |
| *P. hadiensis*         | —                              | 67         |
| *P. hereroensis*       | D9, D35, D36                   | 50         |
|                        | D37                            | 51         |
|                        | D9, D16                        | 52         |
|                        | Sesquiterpene M1               | 30         |
| *P. hilliardiae*       | —                              | 61         |
| *P. incanu (= P. mollis)* | Essential oil               | 27, 79     |
|                        | Fatty acids                    | 35         |
| *P. inflexus*          | —                              | 72         |
| Species                        | Code | Additional Information                        |
|-------------------------------|------|-----------------------------------------------|
| *P. japonicus*                | D155 | Caffeic acid derivative                       |
| *P. japonicus* var. glaucoalyx|      |                                               |
| *P. kapatensis*               |      |                                               |
| *P. lanuginosus*              |      |                                               |
| *P. lucidus*                  |      |                                               |
| *P. madagascariensis*         |      | Essential oil                                 |
| *P. malvinus*                 |      |                                               |
| *P. marrubioides*             |      | Flavonoid M11                                 |
| *P. melissoides*              |      |                                               |
| *P. mollis (= P. incanus)*    |      |                                               |
| *P. myrianthus*               | D128 |                                               |
| *P. neochilus*                |      |                                               |
| *P. nilgherricus*             | D82, D83, D139, D140 |                               |
| *P. oribiensis*               |      |                                               |
| *P. ornatus*                  |      |                                               |
| *P. parviflorus*              | D77, D82-D86 |                                      |
| *P. pentheri*                 |      |                                               |
| *P. porpeodon*                |      |                                               |
| *P. pseudobarbatus*           |      |                                               |
| *P. puberulentus*             |      |                                               |
| *P. purpuratus*               | D72, D73, D77, D79, D91, D92, D121, D122, D140 | 56 |
| *P. purpuratus* subsp. montanus |      |                                               |
| *P. purpuratus* subsp. tongaensis |      |                                               |
| *P. reflexus*                 |      |                                               |
| *P. rugosus*                  |      | Essential oil                                 |
| Triterpenoids M2-M6 & β-sitosterol | 51, 32 |                             |
| *P. saccatus* subsp. pongdoensis |      |                                               |
| *P. saccatus* var. longitubus |      |                                               |
| *P. sanguineus*               | D3, D4-D7, D9, D15, D21, D25, D26, D68, D99, D102, D128-D131, D139 | 57 |
| *P. schimperi*                |      |                                               |
| *P. sp. from the borders of Lake Kiwu, Rwanda* | D19-D21, D27-D29, D49, D51, D75, D76, D104, D105, D113-D116, D123-D127 | 58 |
| *P. spectabilis*              |      |                                               |
| *P. stenophyllus*             |      |                                               |
| *P. stocksii*                 |      |                                               |
| *P. strigosus*                | D77, D78, D82-D87 |                                     |
| *P. sylvestris*               | L9, L13-L18 |                                  |
| *P. tenuiflorus*              |      | Essential oil                                 |
| *P. vestitus*                 |      | Essential oil                                 |
| *P. vettiveroides*            |      |                                               |
| Species            |  |
|--------------------|---|
| *P. zatarhendi*     | 67|
| *P. zatarhendi* var.| 67|
| *tomentosus*       | 67|
| *P. zuluensis*      | 61|
Table 2: Names of diterpenoids encountered in *Plectranthus* species.

| diterp. | Name of diterpenoid | Diterp. | Name of diterpenoid |
|---------|---------------------|---------|---------------------|
| D1      | Royleanone          | D79     | (11-Hydroxy-19-isovaleroyloxy-5,7,9(11),13-abietatetraen-12-one) |
| D2      | 6β, 7α-Dihydroxy-royleanone | D80 | Fuerstione          |
| D3      | 7-O-Formylhorninone  | D81     | 3β-Acetoxyfuerstione |
| D4      | 6β-Hydroxy-7α-formyloxyroyleanone | D82 | Parviflorone C     |
| D5      | 6β-Hydroxy-7α-acetoxyroyleanone | D83 | Parviflorone E     |
| D6      | 6β-Hydroxyroyleanone  | D84     | Parviflorone B      |
| D7      | 5,6-Dihydrocoleone U | D85     | Parviflorone D      |
| D8      | 6β-Formyloxy-7α-hydroxyroyleanone | D86 | Parviflorone F     |
| D9      | Horminone           | D87     | Parviflorone G      |
| D10     | 7α-Acetoxyroyleanone | D88 | Lanugone M         |
| D11     | 6β-Hydroxy-7α-acytoxyroyleanone | D89 | Lanugone L         |
| D12     | Taxoquinone (= 7β-Hydroxyroyleanone) | D90 | Lanugone N         |
| D13     | 7-Oxoroyleanone     | D91     | 6α,11-Dihydroxy-19-isovaleroyloxy-7,9(11),13-abietatrien-12-one |
| D14     | 8α,9α-Epoxo-7-Oxoroyleanone | D92 | 6α,11-Dihydroxy-19-senecioyloxy-7,9(11),13-abietatrien-12-one |
| D15     | 6β,7α-Dihydroxy(allyl)royleanone | D93 | 11-Hydroxy-12-oxo-7,9(11),13-abietatriene |
| D16     | 7α,12-Dihydroxy-17(15→16)-abeo-abieta-8,12,16-trien-11,14-dione | D94 | (2',1S,3aR,10R)-8-(2'-Acetoxy-1'-methylethyl)-3,3a-dihydro-7,9,10-trihydroxy-3a,10b-dimethyl-1H-phenanthro[10,1-bc]furan-4(2H),6(10bH)-dione |
| D17     | Lanugone A           | D95     | 16-O-Acetylcoleon C |
| D18     | (4bS,7R,8aR)-7-Formyloxy-4b,5,6,7,8,8a-hexahydro-3-hydroxy-4b,8,8-trimethyl-2-(2-propenyl)phenanthren-1,4-dione | D96 | Coleon U         |
| D19     | Plectranthone F      | D97     | Coleon C           |
| D20     | Plectranthone G      | D98     |                     |
| D21     | 6β,7α-Dihydroxyroyleanone | D99 | 16-O-Acetylcoleon D |
| D22     | (4bS,7R,8aR,9S,10S)-7-Formyloxy- | D100 | (15S)-Coleon D     |
| D23  | 4b,5,6,7,8,8a,9,10-octahydro-3,9,10-trihydroxy-4b,8,8-trimethyl-2-(2-propenyl)phenanthren-1,4-dione | D101 | Coleon V |
|------|-----------------------------------------------------------------------------------------------|------|----------|
| D24  | (4bS,7R,8aS,9S,10S)-4b,5,6,7,8,8a,9,10-Octahydro-3,9,10-trihydroxy-4b,7-dimethyl-8-methyliden-2-(2-propenyl)phenanthren-1,4-dione | D102 | Coleon U |
| D25  | Coleon-U-quinone                                                                               | D103 | (15S)-Coleon C |
| D26  | 8α,9α-Epoxy-8,9-dihydrocoleon-U-quinone                                                         | D104 | (15S)-2α-Acetoxycoleon C |
| D27  | Plectranthone H                                                                                | D105 | (15S)-Coleon H |
| D28  | Plectranthone I                                                                                | D106 | (2′ξ,4aS,10aS)-1,2,3,4,4a,10a-Hexahydro-5,6,8-trihydroxy-7-(2′-hydroxypropyl)-1,1,4a-trimethylphenanthren-9,10-dione |
| D29  | Plectranthone J                                                                                | D107 | (2′ξ,4aR)-2,3,4,4a-Tetrahydro-5,6,8,10-tetrahydroxy-7-(2′-hydroxypropyl)-1,1,4a-trimethylphenanthren-9(1H)-one |
| D30  | 6,7-Didehydroroleanone                                                                          | D108 | Coleon T |
| D31  | Lanugone B                                                                                     | D109 | Coleon S |
| D32  | Lanugone C                                                                                     | D110 | Lanugone R |
| D33  | Lanugone D                                                                                     | D111 | Lanugone S |
| D34  | Lanugone E                                                                                     | D112 | 5,6-Dihydrocoleon U |
| D35  | 3β-Acetoxy-6β,7α,12-trihydroxy-17-((15→16);18(4→3)-bisabeo-abieta-4(19),8,12,16-tetraen-11,14-dione | D113 | (15S)-2α-Acetoxycoleon D |
| D36  | 16-Acetoxyhorminone                                                                            | D114 | (15S)-Coleon I |
| D37  | 16-Acetoxy-7α,12-dihydroxy-8,12-abietadien-11,14-dione                                          | D115 | Plectrinone B |
| D38  | (2R,2′S,3′R,4bS,7R,8′aS,9′S,10′S)-3′,10′-                                                | D116 | (16S)-Plectrinone A |
| Code | Formula | Description |
|------|---------|-------------|
| D39  | 16 | Diacetoxy-4,5,6,7,8,8a,9,10'-octahydro-9'-hydroxy-2,4,7'-trimethyl-8'-methylidenspiro[cyclopropan-1,2'(1'H)-phenanthren]-1',4'(3'H)-dione |
| D39  | 16 | (2R,2'S,3'R,4'bS,7'R,8'aS,9'S,10'S)-3'-Acetoxy,10'-formyloxy-4,5,6,7,8,8a,9,10'-octahydro-9'-hydroxy-2,4,7'-trimethyl-8'-methylidenspiro[cyclopropan-1,2'(1'H)-phenanthren]-1',4'(3'H)-dione |
| D40  | 16 | (2R,2'S,3'R,4'bS,7'R,8'aS,9'S,10'S)-10'-Acetoxy-4,5,6,7,8,8a,9,10'-octahydro-3',9'-dihydroxy-2,4,7'-trimethyl-8'-methylidenspiro[cyclopropan-1,2'(1'H)-phenanthren]-1',4'(3'H)-dione |
| D41  | 16 | (2R,2'S,3'R,4'bS,7'R,8'aS,9'S,10'S)-3'-Acetoxy-4,5,6,7,8,8a,9,10'-octahydro-9',10'-dihydroxy-2,4,7'-trimethyl-8'-methylidenspiro[cyclopropan-1,2'(1'H)-phenanthren]-1',4'(3'H)-dione |
| D42  | 16 | (2R,2'S,3'R,4'bS,7'R,8'aS,9'S,10'S)-10'-Formyloxy-4,5,6,7,8,8a,9,10'-octahydro-3',9'-dihydroxy-2,4,7'-trimethyl-8'-methylidenspiro[cyclopropan-1,2'(1'H)-phenanthren]-1',4'(3'H)-dione |
| D43  | 16 | (2R,2'S,3'R,4'bS,7'R,8'aS,9'S,10'S)-4,5,6,7,8,8a,9,10'-Octahydro-3',9',10'-trihydroxy-2,4,7'-trimethyl-8'-methylidenspiro[cyclopropan-1,2'(1'H)-phenanthren]-1',4'(3'H)-dione |
| D44  | 16 | (2R,2'S,3'R,4'bS,7'R,8'aR,9'S,10'S)-9'-Acetoxy-7'-formyloxy-4,5,6,7,8,8a,9,10'-octahydro-3',10'-dihydroxy-2,4,8,8'-tetramethylspiro[cyclopropan-1,2'(1'H)-phenanthren]-1',4'(3'H)-dione |
| D45  | 16 | Lanugon G |

**Notes:**
- **D39** is (16R)-Plectrinone A.
- **D40** is Edulone A.
- **D41** is (1'S,10bS)-7,9,10-Trihydroxy-8-(2'-hydroxy-1'-methylthyl)-3,10b-dimethyl-1H-benzo[g]cyclopenta[de][1]benzopyran-4(2H),6(10bH)-dione.
- **D42** is 7,11-Dihydroxy-12-methoxy-8,11,13-abietatriene.
- **D43** is 11,12-Dihydroxy-19-isovaleroyloxy-8,11,13-abietatrien-7-one.
- **D44** is 11,12-Dihydroxy-19-senecioyloxy-8,11,13-abietatrien-7-one.
- **D45** is Plectranthone B.
| Code | Compounds                                                                 | Reference |
|------|---------------------------------------------------------------------------|-----------|
| D46  | (2R,2'S,3'R,4'bS,7'R,8'aR,9'S)-7'-Formyloxy-4'b,5',6',7',8',8'a,9',10'-octahydro-3',9'-dihydroxy-2,4'b,8',8'-tetramethylspiro[cyclopropan-1,2'(1'H)-phenanthren]-1',4'(3'H)-dione | D124 Plectranthone A |
| D47  | Lanugone F                                                                | D125 Plectranthone C |
| D48  | (2R,2'S,3'R,4'bS,7'R,8'aR,9'S,10'S)-7',10'-Bisformyloxy-4'b,5',6',7',8',8'a,9',10'-octahydro-3',9'-dihydroxy-2,4'b,8',8'-tetramethylspiro[cyclopropan-1,2'(1'H)-phenanthren]-1',4'(3'H)-dione | D126 Plectranthone D |
| D49  | Plectranthone K                                                           | D127 Plectranthone E |
| D50  | (2R,2'S,3'R,4'bS,7'ξ,8'aR,9'S,10'S)-7',10'-Diacetoxy-4'b,5',6',7',8',8'a,9',10'-octahydro-3',9'-dihydroxy-2,4'b,7'-trimethyl-8'-methylidenspiro[cyclopropan-1,2'(1'H)-phenanthren]-1',4'(3'H)-dione | D128 Grandidone A |
| D51  | Plectranthone L                                                           | D129 7-Epigrandidone A |
| D52  | Lanugone H                                                                | D130 Grandidone B |
| D53  | Lanugone I                                                                | D131 7-Epigrandidone B |
| D54  | Lanugone J                                                                | D132 Grandidone D |
| D55  | (2S,2'S,3'R,4'bS,7'R,8'aR,9'S,10'S)-7'-Formyloxy-4'b,5',6',7',8',8'a,9',10'-octahydro-3',9'-diacetoxy-10'-hydroxy-2,4'b,8',8'-tetramethylspiro[cyclopropan-1,2'(1'H)-phenanthren]-1',4'(3'H)-dione | D133 7-Epigrandidone D |
| D56  | (2S,2'S,3'R,4'bS,7'R,8'aR,9'S,10'S)-7',10'-Bisformyloxy-4'b,5',6',7',8',8'a,9',10'-octahydro-3',9'-dihydroxy-2,4'b,8',8'-tetramethylspiro[cyclopropan-1,2'(1'H)-phenanthren]-1',4'(3'H)-dione | D134 Grandidone C |
| D57  | Lanugone K                                                                | D135 Nilgherron A |
| D58  | Lanugone K'                                                               | D136 Nilgherron B |
| D59  | Coleon R                                                                  | D137 (3R)-6,9-Dihydroxy-3,4-dimethyl-7-(1-methylethyl)-3-(2-propenyl)naphtho[2,3-b]furan-2-(3H),5,8-trione |
| D60 | Coleon M | D138 | (2''\(\xi\),3R)-7-(2''-Acetoxy-1''-methylethyl)-6,9-dihydroxy-3,4-dimethyl-3-(2''-propenyl)naphtho[2,3-b]furan-2-(3H),5,8-trione |
| D61 | 7,12-Diacetylcoelon J | D139 | Sanguinon A |
| D62 | Coleon N | D140 | (16R)-17,19-Diacetoxy-16-hydroxy-13\(\beta\)-kauran-3-one |
| D63 | Coleon Q | D141 | (16R)-2\(\alpha\)-Senecioyloxy-3\(\alpha\)-acetoxyphyllocladan-16,17-dirol |
| D64 | Coleon P | D142 | (16R)-2\(\alpha\)-Senecioyloxy-3\(\alpha\),17-diacetoxy-16-hydroxyphyllocladane |
| D65 | Plectrin | D143 | (16R)-2\(\alpha\)-Isovaleroyloxy-3\(\alpha\)-acetoxyphyllocladan-16,17-dirol |
| D66 | Coleon Z | D144 | (16R)-2\(\alpha\)-Isovaleroyloxy-3\(\alpha\),17-diacetoxy-16-hydroxyphyllocladane |
| D67 | (15S)-Lanugone O | D145 | (16R)-3\(\alpha\)-Acetoxyphyllocladan-16,17-dirol |
| D68 | 14-Hydroxytaxodione | D146 | (16R)-2\(\alpha\)-Senecioyloxy-16,17-dihydroxyphyllocladan-3-one |
| D69 | (4bS,8aS)-2-(2-Acetoxypropyl)-4b,5,6,7,8,8a-hexahydro-1,4-dihydroxy-4b,8,8-trimethylphenanthren-3,9-dione | D147 | Plecostonol (N coetsidin A) |
| D70 | (2''\(\xi\),4bS,8aS)-4b,5,6,7,8,8a-Hexahydro-1,4-dihydroxy-2-(2''-hydroxypropyl)-4b,8,8-trimethylphenanthren-3,9-dione | D148 | Coestinol |
| D71 | Lanugone P | D149 | Coetsidin B |
| D72 | 19-Isovaleroyloxytaxodione | D150 | Coetsidin C |
| D73 | 19-Senecioyloxytaxodione | D151 | Coetsidin D |
| D74 | Lanugone Q | D152 | Coetsidin E |
| D75 | Coleon F | D153 | Coetsidin F |
| D76 | (16S)-Coleon E | D154 | Coetsidin G |
| D77 | Parviflorone A (= 11-hydroxy-19-senecioyloxy-5,7,9(11),13-abietatetraen-12-one) | D155 | Rabdosin B |
| D78 | Parviflorone H | | |
Diterpenoids isolated from *Plectranthus* Royleanones

D1: \( R^1 = R^2 = H \)
D2: \( R^1 = R^2 = OH \)
D3: \( R^1 = H, R^2 = OCHO \)
D4: \( R^1 = OH, R^2 = OCHO \)
D5: \( R^1 = OH, R^2 = OAc \)
D6: \( R^1 = OH, R^2 = H \)
D7: \( R^1 = OH, R^2 = =O \)
D8: \( R^1 = OCHO, R^2 = OH \)
D9: \( R^1 = H, R^2 = OH \)
D10: \( R^1 = H, R^2 = OAc \)
D11: \( R^1 = OH, R^2 = \text{fatty acid carboxylate} \)

D12: \( R = OH \)
D13: \( R = =O \)
D14: \( R = =O, 8\alpha, 9\alpha\)-epoxide

D15: \( R = OH \)
D16: \( R = H \)

D17: \( R^1 = H, R^2 = CH_2CH=CH_2 \)
D18: \( R^1 = \alphaOCHO, R^2 = CH_2CH=CH_2 \)
D19: \( R^1 = \betaOH, R^2 = CH_2CH=CH_2 \)
D20: \( R^1 = \betaOH, R^2 = CH_2CH(OAc)CH_3 \)

D21: \( R^1 = H, R^2 = CH(CH_3)_2 \)
D22: \( R^1 = OCHO, R^2 = \text{allyl} \)
D23; R = allyl
D24; R = CH$_2$-CH(OH)CH$_3$

D25
D26; 8α, 9α-epoxide

D27; R = H
D28; R = OH

D29

D30

D31; R = H
D32; R = CHO
Spirocoleons

D33: $R^1 = \text{CHO, } R^2 = \text{H}$
D34: $R^1 = \text{H, } R^2 = \text{C}_2\text{H}_5$

D35

D36: $R = \text{Ac}$
D37: $R = \text{CH}_3$

D38: $R^1 = R^2 = \text{Ac}$
D39: $R^1 = \text{CHO, } R^2 = \text{Ac}$
D40: $R^1 = \text{Ac, } R^2 = \text{H}$
D41: $R^1 = \text{H, } R^2 = \text{Ac}$
D42: $R^1 = \text{CHO, } R^2 = \text{H}$
D43: $R^1 = R^2 = \text{H}$

D44: $R^1 = \text{OCHO, } R^2 = \text{OAc, } R^3 = \text{OH}$
D45: $R^1 = \text{H, } R^2 = \text{OH, } R^3 = \text{OCHO}$
D46: $R^1 = \text{OCHO, } R^2 = \text{OH, } R^3 = \text{H}$
D47: $R^1 = \text{H, } R^2 = R^3 = \text{OH}$
D48: $R^1 = R^2 = \text{OCHO, } R^3 = \text{OH}$
D49: $R^1 = \text{H, } R^2 = \text{OH, } R^3 = \text{OAc}$
D50

D51

D52; $R^1 = H$, $R^2 = \text{CHO}$
D53; $R^1 = \text{CHO}$, $R^2 = H$
D54; $R^1 = R^2 = \text{CHO}$
D55; $R^1 = \text{OCHO}$, $R^2 = \text{OAc}$, $R^3 = \text{OH}$
D56; $R^1 = R^3 = \text{OCOH}$, $R^2 = \text{OH}$
D57; $R^1 = H$, $R^2 = \text{OH}$, $R^3 = \text{OAc}$
D58; $R^1 = H$, $R^2 = \text{OH}$, $R^3 = \text{OCHO}$
D59; $R^1 = R^2 = R^3 = \text{OAc}$

D60

D61; $\alpha \text{CH}_3$
D62; $\beta \text{CH}_3$
Vinylogous quinones

D63

D64

D65

D66

D67; R = OH
D68; R = H

D69; R^1 = H, R^2 = Ac
D70; R^1 = R^2 = H
D71; R^1 = OCHO, R^2 = H
Quinone methides

D72; R = COCH₂CH(CH₃)₂
D73; R = COCH=CH(CH₃)₂

D74

D75; R = CH₂CH=CH₂
D76; R = (S)-CH₂CH(OH)CH₃

D77; R¹ = H, R² = COCH=CH(CH₃)₂
D78; R¹ = OH, R² = COCH=CH(CH₃)₂
D79; R¹ = H, R² = COCH₂CH(CH₃)₂

D80; R = H
D81; R = OAc
D82; R = H  
D83; R = OH  
D84; R = OCH₃  
D85; R = H  
D86; R = OH  
D87; R = OCH₃  

D88; R = CH₂CH=CH₂  
D89; R = (S)-CH₂CH(OH)CH₃  

D90  

D91; R = COCH₂CH(CH₃)₂  
D92; R = COCH=CH(CH₃)₂  

D93
Acylhydroquinones

D94; R<sub>1</sub>= OAc, R<sub>2</sub>= H
D95; R<sub>1</sub>= OAc, R<sub>2</sub>= H
D96; R<sub>1</sub>= H, R<sub>2</sub>= H
D97; R<sub>1</sub>= OH, R<sub>2</sub>= H
D98; R<sub>1</sub>= OH, R<sub>2</sub>= OAc

D99; R= OAc
D100; R= OH
D101; R= H
D102; R<sub>1</sub>= R<sub>2</sub>= R<sub>3</sub>= H
D103; R<sub>1</sub>= R<sub>2</sub>= H, R<sub>3</sub>= OH
D104; R<sub>1</sub>= OAc, R<sub>2</sub>= H R<sub>3</sub>= OH
D105; R<sub>1</sub>= H, R<sub>2</sub>= OAc, R<sub>3</sub>= OH

D106
D107
D108; R = CH\_2=CH\_2
D109

D110; R = CH\_2CH=CH\_2
D111; R = CH\_2CH(OH)CH\_3

D112

D113; R\_1 = OAc, R\_2 = H
D114; R\_1 = H, R\_2 = OAc

D115; R = CH\_2CH=CH\_2
D116; R = (S)-CH\_2CH(OH)CH\_3
D117; R = (R)-CH\_2CH(OH)CH\_3
(4→3)abeo-Acylhydroquinones

\[ \text{D118; } R = \text{Ac} \]
\[ \text{D119; } R = \text{H} \]

Miscellaneous Phenolics

\[ \text{D120} \]
\[ \text{D121; } R = \text{COCH}_2\text{CH}(_3)_2 \]
\[ \text{D122; } \text{COCH}=\text{C}(_3)_2 \]

1,4-Phenanthraquinones

\[ \text{D123} \]
\[ \text{D124; } R^1 = \text{CH}_3, R^2 = R^3 = \text{H} \]
\[ \text{D125; } R^1 = R^2 = R^3 = \text{H} \]
\[ \text{D126; } R^1 = R^2 = \text{H}, R^3 = \text{CH}_3 \]
\[ \text{D127; } R^1 = R^3 = \text{H}, R^2 = \text{OH} \]
Dimeric abietanoids

\[ \text{D128; } \beta-C(7)-O-C(11') } \]
\[ \text{D129; } \beta-C(7)-O-C(12') } \]
\[ \text{D130; } \beta-C(7)-O-C(11') } \]
\[ \text{D131; } \beta-C(7)-O-C(12') } \]
\[ \text{D132; } \alpha-C(7)-O-C(14) } \]
\[ \text{D133; } \beta-C(7)-O-C(14) } \]
\[ \text{D134; } \text{D135; } R= H } \]
\[ \text{D136; } R= OAc } \]
Seco-abietanoids

1,10-Seco-abietanoids

\[ \text{D137: } R = H \]
\[ \text{D138: } R = \text{OAc} \]

6,7- Seco-abietanoids

Phyllocladanes

\[ \text{D141: } R^1 = \text{OCOCH}=\text{C(CH}_3\text{)}_2, R^2 = H \]
\[ \text{D142: } R^1 = \text{OCOCH}=\text{C(CH}_3\text{)}_2, R^2 = \text{Ac} \]
\[ \text{D143: } R^1 = \text{OCOCH}_2\text{CH}(\text{CH}_3)_2, R^2 = H \]
\[ \text{D144: } R^1 = \text{OCOCH}_2\text{CH}(\text{CH}_3)_2, R^2 = \text{Ac} \]
\[ \text{D145: } R^1 = R^2 = H \]
Ent-kaurenes

D147

D148; $R^1 = \beta$ OH, $R^2 = \alpha$ OH
D149; $R^1 = \alpha$ OH, $R^2 = \beta$ OH

D150; $R^1 = H$, $R^2 = \text{OCH}_3$, $R^3 = H$
D151; $R^1 = \text{OH}$, $R^2 = \text{OCH}_3$, $R^3 = H$
D152; $R^1 = H$, $R^2 = \text{OC}_2\text{H}_5$, $R^3 = H$
D153; $R^1 = R^3 = H$, $R^2 = \text{OH}$
D154; $R^1 = R^2 = H$, $R^3 = \text{OH}$

Seco-kaurenes

D155
Long-chain alkylphenols

L1; \( n = 1 \)
L2; \( n = 3 \)
L3; \( n = 5 \)
L4; \( n = 1 \)
L5; \( n = 3 \)
L6; \( n = 5 \)
L7; \( n = 7 \)
L8; \( n = 9 \)
L9; \( n = 11 \)

L10; \( R = H \)
L11; \( R = \text{OH} \)

L12

L13; \( R = \text{Ac} \)
L14; \( R = H \)

L15; \( R^1 = H, R^2 = \text{Ac} \)
L16; \( R^1 = \text{Ac}, R^2 = H \)
L17; R = OH
L18; R = H

Miscellaneous constituents

M1

M2; R\textsuperscript{1} = H, R\textsuperscript{2} = COOH
M3; R\textsuperscript{1} = Ac, R\textsuperscript{2} = COOH
M4; R\textsuperscript{1} = H, R\textsuperscript{2} = CH\textsubscript{2}OH
M5; R\textsuperscript{1} = CH\textsubscript{3}, R\textsuperscript{2} = \(\beta\) COOH
M6; R\textsuperscript{1} = COOH, R\textsuperscript{2} = \(\alpha\) CH\textsubscript{3}
M7; oleanolic acid

M8; ursolic acid

M9; betulin

M10

M11
M12; ecklonoquinone A

M13; ecklonoquinone B