The Hydroquinone Terpenoids of *Cordia elaeagnoides*

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Five new geranyl-hydroquinone derived compounds [(2), (6), (11), (12), (15)] have been isolated from the ether extract of *Cordia elaeagnoides* (Boraginacae) heartwood and characterized. The structural character of the compounds adds information to expand the earlier proposed biogenetic pathway for the geranyl-hydroquinone and geranyl-benzoquinones in *Cordia*.

Cordia elaeagnoides D.C. (Boraginacae) is a gerascanthus *Cordia* species indigenous to the southwestern coast of Mexico. The physical properties and appearance of the wood of this tree are comparable to those of the marine borer-resistant Central American wood *Cordia alliodora*.[1] The natural resistance of *C. elaeagnoides* to attack by marine or terrestial organisms has not been evaluated. This present study constitutes the first chemical investigation of the heartwood extractives of *Cordia elaeagnoides*, and reports the characterization of nine geranyl-hydroquinone constituents, four of which [geranyl hydroquinone (1), alliodorin (4), alliodorol (5), cordallinol (8)], were previously obtained from *C. alliodora*.[2] The remaining five compounds are new geranyl-hydroquinones, three of which were characterized as their acetyl derivatives.

The ether extract of the heartwood of *C. elaeagnoides* was subjected to preparative and semi-preparative silica gel h.p.l.c. to yield fractions or acetylated sub-fractions from which the nine geranylhydroquinone constituents or their acetate derivatives were obtained. The compounds were isolated from three distinct chromatographic groupings and are reported in the order of their h.p.l.c. elution (hexane–ethyl acetate, 5 : 1). Group one (R_f 1.5—3.0) included compounds (1), (10), (11), and (12), group two (R_f 4.8—5.3) contained compounds (4) and (5), while compounds (6), (8), and (15) appeared in group three (R_f 6.5—7.6).

The least polar constituent of group one was geranyl hydroquinone (1), identified by a direct comparison with an authentic sample. The second compound, elaeagin (11), was obtained as an optically active oil ($C_{16}H_{18}O_3$) which slowly reduced silver nitrate and formed a monoacetate (oil). The compound exhibits an intense u.v. absorption at 227 nm and a strong i.r. carbonyl band at 1 675 cm^{-1}. ^1H N.m.r. signals for (11) included a chromen methyl [δ 1.36(s)], a vinyl methyl [δ 1.68(s)], two vicinal vinyl (chromen) protons [δ 5.53(d), 6.29(d)], three aromatic protons [δ 6.40—6.64(m)], and a single aldehyde proton [δ 9.33(s)]. Elaeagin was successfully synthesized from cordiachromen A (10)[2] by selenium dioxide oxidation.

Dehydroelaeagin (12) was next obtained as an optically active oil ($C_{16}H_{16}O_3$) which slowly reduced silver nitrate and formed a monoacetate (14) (oil). The ^1H n.m.r. spectrum of (12) shows two methyl groups (δ 1.58(s), 1.59(s)], four vicinally coupled vinyl protons [δ 5.56(d), 6.41(d), 6.21(d), and 6.81(d)], a doubly vicinally coupled vinyl proton [δ 6.70(dd)], three aromatic protons [δ 6.51—6.78(m)] and an aldehyde proton [δ 9.41(s)]. With the exception of a typical chromen methyl resonance (δ 1.20) and the additional vinyl proton resonances, the spectrum of (12) is nearly identical with that of (11). The shift of the methyl resonance in dehydroelaeagin may be explained either by functionalization of the 9′-methyl or by deshielding of this methyl by the 4′–5′ vinyl group. Two structures (12) and (13) are consistent with these data. Proton double-resonance experiments, i.r. and u.v. spectral measurements, and a comparison of the ^{13}C n.m.r. spectra of (4), (10), (11), and (14) provide the evidence to establish structure (12) for dehydroelaeagin.

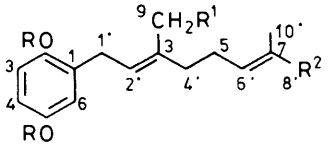
Dehydroelaeagin exhibits i.r. spectral absorptions for carbonyl (1 680 cm^{-1}) and conjugated diene (1 605, 1 630 cm^{-1}) which are consistent with the occurrence of an αβ, γδ-unsaturated aldehyde grouping. The compound displays an intense u.v. absorption at 274 nm which represents a 47 nm bathochromic shift from the u.v. maximum observed for (11). This shift reflects the extension of conjugation of a terminal α,β unsaturated aldehyde through a γ,δ conjugated double bond. Aldehyde substitution at 9′ in (13) includes no conjugated unsaturation to the carbonyl, therefore these data effectively eliminate structure (13) as representative of dehydroelaeagin.

The structural designation (12) for dehydroelaeagin is substantiated by ^1H n.m.r. data. The observed chemical shift of the 6′ vinyl proton of 8′-aldehyde (12) (δ 6.81) is in agreement with the observed chemical shift of similar protons in the *trans* vinyl 8′-aldehydes elaeagin (11) and alliodorin (4). Aldehyde substitution at 9′ in (12) would result in a 6′ vinyl proton chemical shift near δ 5.5 as observed for geranyl hydroquinone (1) and cordiachromen A (10).[2] The observed paramagnetic shift of the 9′-methyl of (4) must therefore be the result of a deshielding effect exerted by the 4′–5′ double bond in the compound.

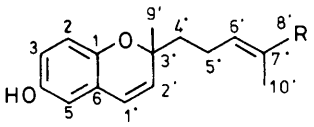
A comparison of the ^{13}C chemical shifts of the 9′- and 10′-methyl resonances of dehydroelaeagin acetate (14) with those of *E*, *E*-alliodorin (4), elaeagin (11) and cordiachromen A (10) confirm an *E*-configuration of the terminal vinyl aldehyde grouping in (12). The ^{13}C resonances for the 10′-vinyl methyls of (11) and (4) appear at 9.1 p.p.m. while the 9′-methyls of (11) and (4) resonate at 26.2 and 15.9 p.p.m. respectively. The 26.2 p.p.m. resonance of the 9′-chromen methyl corresponds to that observed for the same methyl in cordiachromen A (10) while the 8′- and 10′-methyls of (10) occur at 25.6 and 17.6 p.p.m. respectively. Therefore, observed resonances of 27.1 and 9.6 p.p.m. in (14) can be assigned to the 9′- and 10′-methyls and an *E*-configuration of the terminal vinyl aldehyde is defined in the compound.

Final confirmation of the butadiene system of (12) was obtained from proton double resonance experiments on the vinyl proton resonances of (12). These experiments place the 4′-, 5′- and 6′-vinyl resonances at δ 6.21, 6.70, and 6.81 respectively. The coupling constants observed for these resonances [J (4′,5′) 15.0 Hz; J (5′,6′) 11.0 Hz] are consistent with values recorded for *E*,*E*-butadiene systems[3] and designate the conformation of dehydroelaeagin as *E*,*E*. The absolute configuration at 3′ remains unresolved.

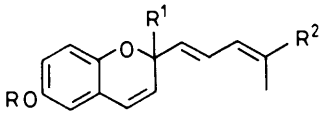
Methyl alliodorate (2), the fourth compound isolated from this group, was obtained as an optically inactive oil ($C_{17}H_{22}O_4$). The compound readily reduced silver nitrate and formed a



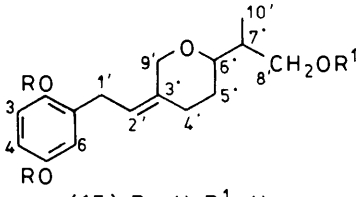
(1) R, R^1 = H, R^2 = Me
(2) R, R^1 = H, R^2 = CO_2Me
(3) R = Ac, R^1 = H, R^2 = CO_2Me
(4) R, R^1 = H, R^2 = CHO
(5) R, R^1 = H, R^2 = CH_2OH
(6) R = H, R^1 = OH, R^2 = CHO
(7) R = Ac, R^1 = OAc, R^2 = CHO
(8) R = H, R^1 = OH, R^2 = CH_2OH
(9) R = Ac, R^1 = OAc, R^2 = CH_2OAc



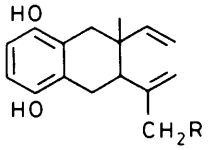
(10) R = Me
(11) R = CHO



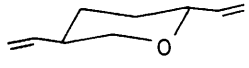
(12) R = H, R^1 = Me, R^2 = CHO
(13) R = H, R^1 = CHO, R^2 = Me
(14) R = Ac, R^1 = Me, R^2 = CHO



(15) R = H, R^1 = H
(16) R = Ac, R^1 = Ac



(17) R = H
(18) R = OH



(19)

diacetate (3) (oil). The ^1H n.m.r. spectrum of the compound was similar to that of alliodorin with resonances for two vinylic methyl groups [δ 1.67 and 1.80(s)], a benzylic methylene [δ 3.23(d)], vinyl protons at [δ 5.24(t)], and [δ 6.72(t)], and three aromatic protons [δ 6.8—7.1(m)]. A three-proton singlet at δ 3.68 and the appearance of a distinctive ester methyl resonance at 51.6 p.p.m. in the ^{13}C n.m.r. spectrum of the diacetate (3) provides strong evidence for (2) to be a methyl ester of the geranyl hydroquinone 8′-acid. Structure (2) was substantiated by reductive hydrolysis of the compound with lithium aluminium hydride to give (5) which was identical with an authentic specimen.

Alliodorin (4) and alliodorol (5) chromatographically co-occur in a second group of compounds obtained in the preparative h.p.l.c. of *C. elaeagnoides* constituents (R_f 4.8—5.3). Alliodorin (22.3 g) was obtained through the fractional crystallization of the gross preparative fraction. Alliodorol (2.9 g) was obtained through chromatography of the alliodorin filtrates. Both compounds were identical with authentic specimens previously obtained from *C. alliodora*.[2]

The third chromatographic group (R_f 6.5—7.6) was re-chromatographed to obtain cordallinol (8), identified by spectral and chromatographic comparison with an authentic specimen. Two less polar constituents (15) and (6) were inseparable in the h.p.l.c. solvent systems utilized in the study. The purified fraction containing these compounds was subsequently acetylated and the acetyl derivatives (16) and (7) were successfully separated by h.p.l.c.

Cyclocordallinol triacetate (16) was obtained as an oil ($C_{22}H_{28}O_7$) from the acetylated fraction. Initial spectral data of (16) showed signals from two alkyl methyl groups [δ 0.94 and 0.97(d)] and other paired multiplets suggestive of the occurrence of (16) as a mixture of diastereoisomers. Repeated chromatography of the suspected mixture yielded a pure sample of one of the diastereoisomers. A 200 MHz n.m.r. spectrum of pure (16) showed signals for an alkyl methyl group [δ 0.97(d)], five alkyl protons [δ 1.50, 1.65, 1.87 2.25—2.36(2H); (m)], an alkyl acetate [δ 2.07(s)], two aromatic acetates [δ 2.28, 2.31(s)], two unusually coupled benzylic methylene protons [δ 3.17, 3.33(dd)], an alkoxy methine proton [δ 3.44(m)], two distinct, geminally coupled acetoxy methylene protons [δ 3.97, 4.11(dd)], two geminally coupled alkoxy methylene protons [δ 3.78, 4.66[(d)], a vinyl proton [δ 5.25(t)], and three aromatic protons [δ 6.90—7.16(m)]. These data suggest that (16) is a cyclized derivative of cordallinol (8) (*vide infra*), with cyclization involving the 9′-hydroxymethyl group. Support for this structural designation and determination of the relative stereochemistry of (16) was obtained from n.m.r. resonance experiments and a comparison of spectral data to model systems.

A comparison of the spectral character of the 9′-methylene protons of (16) with the 9′ protons of cordallinol (8) [2] and the 6 methylene protons of (19),[4] provides evidence for the existence of a 2,5 disubstituted tetrahydropyran moiety in (16). The mean chemical shift value of the 9′ geminal proton doublet resonances in (16) (δ 4.22) corresponds exactly with the observed chemical shift for the 9′-methylene protons of (8). The appearance of the distinct 9′ geminal proton doublets

in (16) is in accord with similar signals observed for the geminally coupled 6*a*- and 6*e*- protons of (19). The difference in chemical shift and the coupling constants of the 6*a*- and 6*e*-coupled protons of (19) [Δδ 0.81 p.p.m., *J* 11.0 Hz] is in agreement with those observed for the 9′-methylene protons of (16) [Δδ 0.88 p.p.m., *J* 15 Hz]. These data therefore offer strong support for the existence of the 2,5 disubstituted tetrahydropyran moiety in (16).

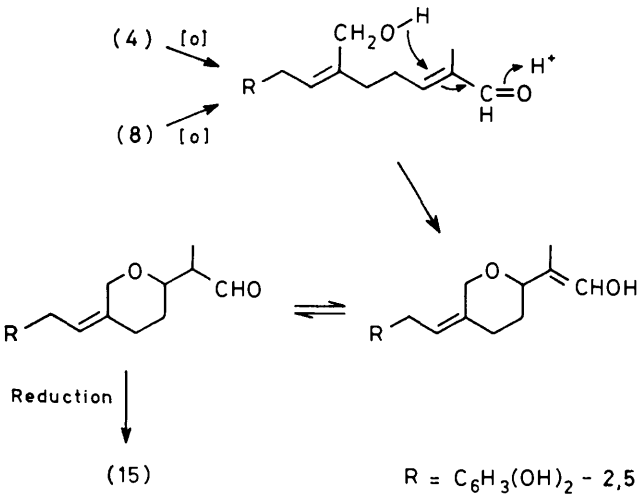
Double-resonance experiments further substantiate (16) as the structure for cyclocordallinol triacetate. The presence of a 2-substituted propan-1-ol moiety in (16) can be ascertained through irradiation of the single proton multiple resonance at δ 1.87. This irradiation alters four separate signals [δ 0.97, 3.44, 3.97, 4.11]. The δ 0.97 alkyl methyl doublet signal collapses to a singlet while the 6′ alkoxy methine multiple resonance (δ 3.44) changes to a broadened doublet. The δ 3.97 and 4.11 double doublet resonances collapse to doublets and can be assigned to the 8′-methylene acetoxy protons. Irradiation at δ 1.87 and 2.34 also allows specific assignment of the 5′–6′ coupling constants [*J* (5′*a*,6′*a*) 11.0 Hz, *J* (5′*e*,6′*a*) 2.5 Hz]. Irradiation of the 5′-methylene resonance at δ 1.50 reduces the 6′-proton multiplet to a broadened doublet and establishes the 6′–7′ coupling constant (*J* 3.8 Hz). These coupling constants define a 6′*e* substitution of the terminal 2-substituted propan-1-ol group in (16).

The specific conformation of the 2-substituted propan-1-ol group in (16) has not been established; however, the appearance of the 8′-acetoxy methylene protons as distinct double doublets suggest restricted rotation about the 7′–8′ bond. This lack of rotation may be associated with the necessary orientation of the terminal acetate group away from the tetrahydropyran system in order for free rotation to occur at the 6′–7′ bond. Such an orientation would be consistent with the observed 8′-coupling constants and would result in an eclipsed relationship of the 8′-oxygen and 7′-methine proton. This conformation could explain the observed downfield shift of the 7′-proton (δ 1.87) compared with the typical alkyl protons at 5′ (δ 1.50, 1.65).

Establishment of the configuration about the 2′–3′ vinyl group of (16) was accomplished through an n.O.e. experiment. Irradiation of the 4′-methylene multiple resonance at δ 2.3 results in an increase in the intensity and sharpening of the 2′-vinyl proton resonance at δ 3.45 indicating a *Z* configuration exists at the 2′–3′ double bond. Consideration of these data clearly establishes the structure of cyclocordalliol triacetate to be as depicted in (16) and consequently cyclocordallinol is (15).

Cordallinal triacetate (7) was obtained from the acetylated fraction as an optically inactive oil ($C_{22}H_{26}O_7$). The ^{1}H n.m.r. of the compound showed resonances for a vinyl methyl group [δ 1.71(s)], an alkyl acetate [δ 2.04(s)], two aromatic acetates [δ 2.24(s)], four alkyl protons [δ 2.2—2.6(m)], a benzylic methylene [δ 3.33(d)], a vinyl hydroxy methylene [δ 4.67(s)], two vinyl protons [δ 5.52, 6.44(t)], three aromatic protons [δ 6.8—7.1], and an aldehyde proton [δ 9.49(s)]. These data compare with those observed for cordallinol (8) with the exception of a lower field resonance for the vinyl methyl, one hydroxymethylene resonance, an aldehyde proton resonance and a large downfield shift for one vinyl proton. The spectral data are consistent with a geranyl-hydroquinone containing both an allyl alcohol and aldehyde functionality. Sodium borohydride reduction of (7) followed by acetylation gave cordallinol tetra-acetate (9), identical with an authentic specimen, thus confirming (7) and establishing cordallinal as (6).

The compounds isolated from *C. elaeagnoides* in this study serve to extend the proposed biogenesis of geranyl-benzoquinones [5] and geranyl-hydroquinones [2] in *Cordia*. These



Scheme

proposals were based on the premise that the *Cordia* constituents could be derived from a geranyl-phenol precursor capable of undergoing oxidations, intramolecular cyclizations and rearrangements to produce the varied geranyl-hydroquinone, and geranyl-benzoquinone derivatives obtained from the *Cordia* woods.

The characterization of elaeagin (11) and dehydroelaeagin (12) from *C. elaeagnoides* demonstrates a logical two-step extension of the oxidative cyclization sequence proposed as the source of cordiachromen A in *C. alliodora*. The presence of cordallinal (6) and cyclocordallinol (15) in *C. elaeagnoides* provides further examples of the ability of *Cordia* species to elaborate compounds from alliodorin (4) or cordallinol (8) (see Scheme). Cordallinol was previously suggested as the probable precursor to form the allioquinols (17),(18) in *C. alliodora* by intramolecular cyclization.

While the compounds isolated from *C. elaeagnoides* effectively enlarge the proposed biogenesis of the geranyl-hydroquinones and geranyl-benzoquinones in *Cordia*, the relationship of the occurrence of these compounds to the natural durability of the woods has not yet been established. Initial screening results for the effect of alliodorin against marine boring organisms [6] and wood destroying fungi [7] have shown low rates of effectiveness. Evaluation of alliodorin and other geranyl-hydroquinone analogues is continuing.

Experimental

^{1}H N.m.r. spectra were run in solutions of $CDCl_3$ or $(CD_3)_2CO$ on a Varian EM-390 (90 MHz) or Nicolet NMC-200 (200 MHz) spectrometer. ^{13}C Spectra were run on a Jeol Model PS-100 spectrometer. Optical rotations were run on a Perkin-Elmer Model 241 polarimeter. Mass spectra were obtained on a VG-Micromass 70/70. Preparative h.p.l.c. was performed on a Waters Prep 500. Analytical and semi-preparative h.p.l.c. was performed on a Waters h.p.l.c. system utilizing u.v. and r.i. (refractive index) detection. All chromatography utilized silicic acid as the stationary phase.

Extraction of Cordia elaeagnoides.—Hammermilled *C. elaeagnoides* heartwood (4.26 kg) was successively extracted with hot light petroleum (b.p. 30—60 °C), ether, acetone, and methanol. Only the ether extract (186 g) was examined in this investigation.

Ether Extract

A portion of the ether extract (140 g) was dissolved in EtOAc (120 ml) and preparatively chromatographed (as 10-ml fractions) on a Waters Prep 500 h.p.l.c. (hexane–EtOAc, 1 : 1). Four fractions (A, 7.3 g; B, 4.5 g; C, 67.2 g; D, 56.0 g) were collected.

T.l.c. (silica gel) of the fractions (hexane–EtOAc, 4 : 1) and spray detection with $AgNO_3$ and $FeCl_3$–$K_3Fe(CN)_6$ showed hydroquinone and phenolic constituents to occur primarily in fractions B, C, and D.

Fraction B.—This fraction was preparatively rechromatographed (hexane–EtOAc, 3 : 1) on the Waters Prep 500. Four sub-fractions were collected based upon r.i. changes (B1, 0.6 g; B2, 2.3 g; B3, 1.2 g; B4, 0.9 g). Each of the sub-fractions was surveyed by analytical h.p.l.c. (hexane–EtOAc, 4 : 1). Four major components were present in enriched amounts among the sub-fractions. Semi-preparative h.p.l.c. of these sub-fractions (hexane–EtOAc, 4 : 1) resulted in the preliminary isolation of the four compounds. The compounds are described in the order of their elution from the h.l.p.c. column.

Geranyl hydroquinone [8-(2,5-*dihydroxyphenyl*)-2,6-*dimethylocta*-2,6-*diene*] (1). Semi-preparative h.p.l.c. (hexane–EtOAc, (4 : 1) (R_f 1.5) of B1 yielded a dark oil (1) (0.36 g) (Found: C, 78.1; H, 8.9. $C_{16}H_{22}O_2$ requires C, 78.0; H, 9.0). Chromatographic and spectral data were identical with those previously recorded for (1).[2]

Elaeagin [2-*methyl*-2-(4-*formyl*-4-*methylpent*-3-*enyl*)-2H-*chromen*-6-*ol*] (11). Semi-preparative h.p.l.c. separation hexane–EtOAc, 4 : 1) of B2 yielded a dark yellow oil (R_f 1.8): (3) (0.69 g) (Found: C, 74.4; H, 7.1. $C_{16}H_{18}O_3$ requires C, 74.4; H, 7.0), $[\alpha]_D^{25}$ −3.13° (*c* 1.0, $CHCl_3$); $\lambda_{max.}$ (EtOH) 227 nm ($\varepsilon_{max.}$ 20 500); $\nu_{max.}$ (neat) 2 990s, 2 940s, 2 720w, 1 670s, 1 640s, 1 580m, 1 490s, 1 460s, 1 280s, and 920s cm^{-1}; δ_H ($CDCl_3$, 90 MHz) 1.36 (3 H, s), 1.68 (3 H, s), 1.6—1.9 (2 H, m), 5.53 (1 H, d, *J* 10 Hz), 6.29 (1 H, d, *J* 10 Hz), 6.3—6.6 (4 H, m), and 9.33 (1 H, s); δ_C (C no.) 9.1(10′), 24.2(5′), 26.2(9′), 39.2(4′), 77.8(3′), 113.1(6), 115.8(3), 116.5(4), 121.4(7′), 123.5(2′), 129.7(1′), 139.1(1), 146.1(5), 150.0(2), 156.0(6′), and 196.1 p.p.m. (8′); M^+ 258.1255; *m*/*z*(%) 258(21), 243(13), 161(100), and 28(83).

Synthetic elaeagin (11). The chromen (10)[2] (50.7 mg) was dissolved in 95% EtOH, freshly prepared SeO_2[8] (44 mg) was added, and the mixture was refluxed for 6 h. The alcohol was removed, water (30 ml) and ether 30 ml) were added and the mixture was extracted (×2). The ether extract was dried ($MgSO_4$), concentrated to dryness, and preparatively chromatographed (hexane–EtOAc, 4 : 1) to yield (11) as a yellow oil (23.4 mg). Spectral and chromatographic properties for the synthetic sample were identical with the natural product.

Dehydroelaeagin [2-*methyl*-2-(4-*formyl*-4-*methylpent*-1,3-*dienyl*)-2H-*chromen*-6-*ol*] (12). Semi-preparative h.p.l.c. of B3 (hexane–EtOAc, 4 : 1), yielded a fraction (R_f 2.3) containing two compounds. Extensive rechromatography of the fraction resulted in the isolation of (12) as a yellow-brown oil (18 mg) (Found: M^+, 256.1106. $C_{16}H_{16}O_3$ requires *M*, 256.1099), $[\alpha]_D^{25}$ −5.625° (*c* 0.169), $\lambda_{max.}$ (EtOH) 274 ($\varepsilon_{max.}$ 39 300) and 217 nm ($\varepsilon_{max.}$ 39 500); $\nu_{max.}$ ($CHCl_3$) 3 130s, 2 720w, 1 680s, 1 630m, and 1 605m cm^{-1}; δ_H ($CHCl_3$, 200 MHz) 1.58 (3 H, s), 1.59 (3 H, s), 5.66 (1 H, d, *J* 10 Hz), 6.21 (1 H, d, *J* 15 Hz), 6.52 (1 H, d, *J* 3 Hz), 6.63 (1 H, dd, *J* 9.5 Hz), 6.70 (1 H, dd, *J* 15.0, 11.0 Hz), 6.81br (1 H, d, *J* 15 Hz), and 9.41 (1 H, s); *m*/*z*(%), 256(44), 241(58), 174(27), 161(100), 140(60), 123(92), and 109(27).

Dehydroelaeagin acetate (14). Acetylation of (12) (12 mg) (Ac_2O, pyr) yielded (14) as an oil (12 mg) (Found: M^+ 298.1223. $C_{18}H_{18}O_4$ requires *M*, 298.1205), δ_H ($CDCl_3$, 200 MHz) 1.60 (3 H, s), 1.81 (3 H, s), 2.28 (3 H, s), 5.67 (1 H, d, *J* 8 Hz), 6.23 (1 H, d, *J* 14 Hz), 6.41 (1 H, d, *J* 8 Hz), 6.68 (1 H, d, *J* 11 Hz), 6.72—6.93 (4 H, m), and 9.42 (1 H, s); δ_C ($CDCl_3$) (C no.) 9.6 (10′), 21.0 (Ac,Me), 27.1(9′), 77.6(3′), 116.6(6), 119.4(6′), 121.3(7′), 122.1(3), 123.3(4), 123.9(2′), 127.6(1′), 138.6(1), 144.3(5′), 144.4(5), 147.4(4′), 150.0(2), 169.7(Ac,CO), and 194.8 p.p.m. (8′); *m*/*z*(%) 298(38), 283(55), 256(51), 241(94), 238(11), 227(15), 213(21), 203(22), 174(49), 161(63), 97(29), 71(58), and 57(100).

Methyl alliodorate [*methyl* 8-(2,5-*dihydroxyphenyl*-2,6-*dimethylocta*-2,6-*dienoic acid*)] (2). A fourth compound (R_f 3.0) was isolated from the purified ether fraction B4 as a yellow oil (2) (0.24 g), $[\alpha]_D^{25}$ −0.15° (*c* 1.1, $CHCl_3$) (Found: C, 70.4; H, 7.6. $C_{17}H_{22}O_4$ requires C, 70.3; H, 7.6), δ_H ($CDCl_3$, 90 MHz) 1.61 (3 H, s), 1.80 (3 H, s), 2.2—2.5 (4 H, m), 3.26 (2 H, d, *J* 7.5 Hz), 3.71 (3 H, s), 5.20br (1 H, s), 5.30 (1 H, t, *J* 7.5 Hz), 6.3—6.7 (4 H, m), and 6.9br (1 H, s); M^+ 290.1518; *m*/*z*(%) 290(61), 258(12), 256(21), 241(30), 202(50), 177(16), 174(19), 161(100), 135(35), 123(82), 114(18), 107(34), and 95(19).

Methyl alliodorate diacetate (3). Acetylation of (2) 34 (mg) (Ac_2O, pyr) yielded (3) as a pale yellow oil (35 mg) (Found: M^+, 374.1733. $C_{21}H_{26}O_6$ requires M^+ 374.1729), δ_H ($CDCl_3$, 90 MHz) 1.67 (3 H, s), 1.80 (3 H, s), 2.24 (6 H, s), 2.1—2.4 (4 H, m), 3.23 (2 H, d), 3.68 (3 H, s), 5.24 (1 H, t, *J* 7 Hz), 6.72 (1 H, t, *J* 6.5 Hz), and 6.85—7.1 (3 H, m); δ_C ($CDCl_3$) (C no.). 12.4(10′), 16.2(9′), 20.8(Ac,Me), 21.0(Ac,Me) 27.1(5′), 28.6(1′), 38.2(4′), 51.6(OCH_3), 119.9(6), 121.6(2′), 122 6(3), 122 9(4), 127.7(3′), 134.5(1), 136.4(7′), 141.8(6′), 146.2(5), 148.3(2), 168.5(Ac,CO), 169.1(Ac,CO), 169.2(Ac,CO); *m*/*z*(%) 374(2), 342(27), 300(33), 290(55), 261(12), 258(46), 219(20), 177(41), 163(33), 161(31), 149(18), 136(20), 135(25), 123(32), 114(50), and 43 p.p.m. (100).

Hydrolysis of (2). Methyl alliodorate (30 mg) was dissolved in Et_2O (10 ml), $LiAlH_4$ (10 mg) was added, and the mixture was refluxed (1 h). Excess of $LiAlH_4$ was destroyed, 10% NH_4Cl was added, and the mixture filtered. The residue was washed with Et_2O (10 ml), water (10 ml) was added, and the mixture extracted. The ether layer was dried ($MgSO_4$) and concentrated to a dark oil (16 mg). Chromatographic and spectral comparison of the product with (15) showed complete agreement.

Fraction C.—Alliodorin [8-(2,5-*dihydroxyphenyl*)-2,6-*dimethylocta*-2,6-*dienal*] (4) and *alliodorol* [2-(8-*hydroxy*-3,7-*dimethylocta*-2,6-*dienyl*)*hydroquinone*] (5). Fraction C crystallized upon standing. Recrystallization of the fraction (Et_2O–CCl_4) yielded alliodorin (4) (19.4 g), m.p. 89—90 °C, identical with an authentic specimen. δ_c ($CDCl_3$) (C no.) 9.1(10′), 15.9(9′), 27.5(5′), 28.9(1′), 38.6(4′), 113.6(6), 116.2(3), 117.0(4), 124.6(2′), 129.2(3′), 134.9(1), 139.8(7′), 148.4(5), 151.0(2), 154.6(6′), and 195.2 p.p.m. (8′). The filtrate of fraction C was concentrated (40 ml) and applied (10 ml fractions in EtOAc) to a preparative column (Prep 500). The column was eluted ($CHCl_3$–EtOH, 15 : 1) and twenty fractions, based upon r.i. changes, were collected. Upon concentration, fractions 5 and 6 crystallized. Recrystallization (Et_2O–$CHCl_3$) yielded additional alliodorin (2.1 g). The filtrates of fractions 5 and 6 were combined with fraction 7. Preparative chromatography (hexane–EtOAc, 3 : 2) of the combined fractions yielded impure alliodorol (5). Semi-preparative chromatography of the impure sample yielded alliodorin (0.8 g) and (5), oil (2.9 g). The chromatographic and spectral properties of (5) were identical with an authentic specimen.

Fraction 9 was concentrated and subjected to further preparative chromatography (hexane–EtOAc, 3 : 2). The

resulting preparative fractions were surveyed by analytical h.p.l.c. and occurrence of two major peaks were noted in fraction 6. The two components were separated by semi-preparative chromatography and the n.m.r. of the first peak showed the presence of two compounds. Extensive efforts to separate pure specimens of these compounds were unsuccessful. The purified fraction was subsequently acetylated (Ac_2O, pyr) and chromatographed (hexane–EtOAc, 5 : 1) to obtain (16) and (7).

Cyclocordallinol triacetate (16). Chromatography of the acetylated mixture from fraction 9 yielded (16) (mixed diastereoisomers) as a pale yellow oil (93 mg). Semi-preparative re-chromatography (hexane–EtOAc, 6 : 1) of the mixture yielded the pure diastereoisomer (16) as a pale yellow oil (41 mg), $[\alpha]_{436}^{25}$ 1.28° (*c* 0.47, $CHCl_3$) (Found: C, 65.1; H, 7.0. $C_{22}H_{28}O_7$ requires C, 65.3; H, 7.0%), δ_H ($CDCl_3$, 200 MHz) 0.97 (3 H, s, *J* 7.0 Hz), 1.50 (1 H, ddd, *J* 6.0, 10.5, 11.0 Hz), 1.65 (1 H, dddd, *J* 10.5, 2.5, 5.5, 5.5 Hz), 1.87 (1 H, dddd, *J* 7.0, 7.0, 7.0, 3.8 Hz), 2.07 (3 H, s), 2.28 (3 H, s), 2.31 (3 H, s), 2.25—2.36 (2 H, m), 3.17 (1 H, dd, *J* 15.5, 7.5 Hz), 3.33 (1 H, dd, *J* 15.5, 7.5 Hz), 3.44 (1 H, ddd, *J* 11.0, 2.5, 3.8 Hz), 3.78 (1 H, d, *J* 13.0 Hz), 3.97 (1 H, dd, *J* 6.5, 11.0 Hz), 4.11 (1 H, dd, *J* 6.5, 11.0 Hz), 4.66 (1 H, d, *J* 13.0 Hz), 5.25 (1 H, t, *J* 7.5 Hz), and 6.90—7.16 (3 H, m); δ_C (C no.) 12.0(10′), 20.8(Ac,Me), 20.9(Ac,Me) 21.0(Ac,Me), 27.9(1′), 30.4(4′), 33.1(5′), 37.5(7′), 66.7(9′), 78.2(6′), 120.2(6), 120.5(2′), 122.8(3), 123.0(4), 134.0(3′), 135.6(1), 146.2(5), 148.2(2), 169.2(Ac,CO), 169.3(Ac,CO), and 171.1 p.p.m. (Ac,CO); M^+ 404.1837; *m*/*z*(%) 404(6), 361(13), 260(6), 201(9), 197(53), 174(17), 161(21), 137(41), 123(21), 119(15), 109(14), 95(10), 93(12), 55(12), and 43(100).

Cordallinal triacetate [8-(2,5-*diacetoxyphenyl*)-6-*acetoxymethyl*-2-*methylocta*-2,6-*dienal*] (7). The second compound (7) obtained from chromatography of the acetylated mixture was a yellow oil (0.21 g), $[\alpha]_D^{25}$ 0.17° (*c* 0.57, $CHCl_3$) (Found: C, 65.4; H, 6.4. $C_{22}H_{26}O_7$ requires C, 65.7, H, 6.5), δ_H ($CDCl_3$, 90 MHz) 1.71 (3 H, s), 2.04 (3 H, s), 2.24 (3 H, s), 2.26 (3 H, s), 2.2—2.6 (4 H, m), 3.33 (2 H, d, *J* 7.5 Hz). 4.67 (2 H, s), 5.52 (1 H, d, *J* 7.5 Hz), 6.44 (1 H, t, *J* 6 Hz), 6.8—7.1 (3 H, m), and 9.49 (1 H, s); δ_C ($CDCl_3$) (C no.) 9.1(10′), 20.6(Ac,Me), 20.7(Ac,Me), 20.8(Ac,Me) 27.2(5′), 28.3(1′), 33.7(4′), 61.4(9′), 120.4(6), 122.7(3), 123.2(4), 128.3(2′), 133.5(3′), 134.5(1), 139.6(7′), 146.2(5), 148.3(2), 153.3(6′), 169.0(Ac,CO), 169.1(Ac,CO), and 194.8 p.p.m. (8′); *m*/*z*(%) 402(0.31), 360(2.6), 342(6), 300(7), 174(17), 161(14), 136(13), 123(15), and 43(100).

Synthesis of Cordallinol Tetra-acetate (9).—Cordallinal triacetate (7) (30 mg) was dissolved in methanol (5 ml), $NaBH_4$ (30 mg) was added, and the mixture was stirred for 1 h. The mixture was diluted with water (25 ml), acidified, and extracted with Et_2O (2 × 20 ml). The ether layer was dried ($MgSO_4$) and concentrated to a yellow oil (21 mg). The reduced product was acetylated (Ac_2O, pyr) to yield a pale yellow oil (23 mg). Comparison of the product with an authentic specimen of (9) showed complete spectral and chromatographic agreement.

Cordallinol [2-(8-*hydroxy*-3-*hydroxymethyl*-7-*methylocta*-2,6-*dienyl*)*hydroquinone*] (8). Preparative and semi-preparative chromatography of sub-fraction 10 of fraction C ($CHCl_3$–EtOH, 10 : 1) yielded (8) as an oil (0.18 g). Chromatographic and spectral data comparison of (8) with an authentic specimen showed complete agreement.

Cordiachromen A (10). This compound was previously isolated from *C. alliodora*.[2] The ^{13}C spectrum was not previously described: δ_C ($CDCl_3$) (C no.) 17.6(10′), 22.7(5′), 25.6(8′), 26.0(9′), 40.9(4′), 78.1(3′), 110.0(7′), 112 9(6), 115.4(3), 116.6(4), 122.6(2′), 124.1(6′), 130.9(1′), 131.6(1), 146.9(5), and 149.3 p.p.m. (2).

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