

Stemonolone, a New Sesquiterpenoid from *Pogostemon plectranthoides* (Desf) †

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The structure of a new sesquiterpene isolated from *Pogostemon plectranthoides* (Desf) has been assigned from its spectral properties and confirmed by X-ray crystallographic evidence. The compound has been identified as 5 α -hydroxy-10 β -selina-1,4(15),7-trien-6-one (1).

Pogostemon plectranthoides (Desf) (Labiatae), a shrub which grows up to 2 m high, with pinkish white flowers and a strong odour, is found throughout most of India. Bruised leaves are reported to be applied as a cataplasm to wounds, and the juice is given for colic and fever.¹ During our work on pest control agents from plant materials we collected *P. plectranthoides* from the Western Ghats of Maharashtra (India). The essential oil of this plant has been reported to contain sesquiterpene hydrocarbons, caryophyllene, aromadendrene, and Se-guaiazulene,² and a mixture of oxygenated compounds which have not been characterized;³ phytol has been isolated from a light petroleum extract of the plant.⁴ Here we report the isolation, from an acetone extract of the whole plant, and the characterization of a new eudesmane-type ketol, stemonolone (1).

The whole shade-dried plant (roots, stem, leaves, and flowers) was powdered and extracted with acetone. The dark viscous extract on careful chromatography over silica gel yielded a white crystalline solid, stemonolone (1) (0.078%), C₁₅H₂₀O₂ (*M*⁺, 232), m.p. 112–114 °C. The spectra indicated the presence of a hydroxy group [ν_{\max} (Nujol) 3 250 cm⁻¹, ν_{\max} (CCl₄) 3 590 cm⁻¹ (OH, bonded)]; this was shown to be tertiary and hindered by the fact that the compound showed strong resistance to acetylation when treated with acetic anhydride and pyridine at room temperature or under reflux. The i.r. and u.v. spectra [ν_{\max} 1 660 cm⁻¹ and λ_{\max} 245 nm (ϵ 6 022)] also revealed the presence of an α,β -unsaturated carbonyl group in the molecule. Attempts to reduce compound (1) with sodium borohydride and lithium aluminium hydride were not successful. The ¹H n.m.r. spectrum showed the presence of three double bonds, CH=CH [δ 5.33 (1 H, m), 5.68 (1 H, m)], C=CH₂ [δ 5.17 (1 H, m), 5.56 (1 H, m)], and CH₂CH=C(CHMe₂)CO [δ 6.46 (1 H, ddd, *J* 6, 2.5, and 1 Hz)], as well as a quaternary methyl group (δ 1.06, s) and an isopropyl group [δ 1.07 (6 H, d, *J* 6.5 Hz)]. As there is no signal corresponding to a methyl on a double bond, the isopropyl group must be attached to the quaternary carbon of the trisubstituted double bond giving rise to the multiplicity as indicated. The assignments of these groups are also supported by the ¹³C n.m.r. data (Table 1). Catalytic hydrogenation of stemonolone (1) with platinum oxide and with palladium-carbon produced two different products, both mixtures of isomers of (2), C₁₅H₂₄O₂ (*M*⁺, 436); the former hydrogenation yielded a product with m.p. 128 °C ($[\alpha]_D^{25} + 69.7^\circ$) and the latter a product with m.p. 145–148 °C ($[\alpha]_D^{25} - 41.2^\circ$). The ¹H n.m.r. spectrum of the hydrogenated products showed an additional methyl signal and an unchanged olefinic proton signal at δ 6.46 (ddd, *J* 6, 2.5, and 1 Hz); the u.v. spectra of both the products were unchanged.

Stemonolone (1) exhibited two non-equivalent CH₂ protons as two double doublets (1 H, δ 2.03, *J* 18 and 6.5 Hz and 1 H, δ 2.62, *J* 18 and 3.5 Hz). Decoupling revealed that the olefinic proton at δ 6.46 is adjacent to this methylene group and shows

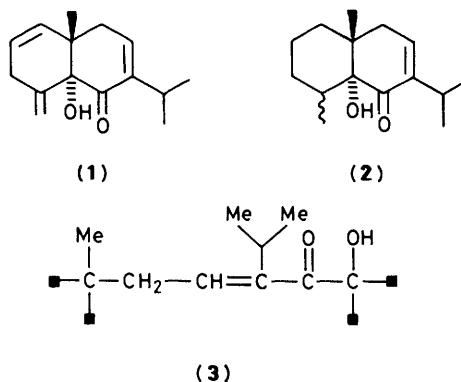


Table 1. ¹³C N.m.r. spectrum of stemonolone (1)^a

| Carbon atom | δ_c /p.p.m. | Multiplicity |
|-------------|---------------------|--------------|
| 1 | 124.84 ^b | d |
| 2 | 133.2 ^b | d |
| 3 | 35.02 ^c | t |
| 4 | 143.75 ^d | s |
| 5 | 76.94 | s |
| 6 | 194.77 | s |
| 7 | 140.37 ^d | s |
| 8 | 137.84 | d |
| 9 | 34.59 ^c | t |
| 10 | 43.15 | s |
| 11 | 26.90 | d |
| 12 | 21.57 ^e | q |
| 13 | 22.35 ^e | q |
| 14 | 24.17 | q |
| 15 | 114.57 | t |

^aThe ¹³C n.m.r. spectrum was obtained for a CDCl₃ solution with a Bruker WH-90 spectrometer. Chemical shifts are expressed in p.p.m. relative to internal Me₄Si. ^{b-c} Assignments with the same sign may be interchanged.

an AMX splitting pattern which in turn is attached to a fully saturated carbon atom. Irradiation at δ 6.46 collapses the dd's at δ 2.03 and 2.62 into a pair of sharp doublets (1 H, *J* 18 Hz, geminal coupling constant).

The above data suggest that stemonolone (1) contains the partial structure (3) in a bicyclic system. Taking into account the presence of two non conjugated double bonds (one is exocyclic) and the biogenetic considerations, stemonolone was proposed to be 5 α -hydroxyselina-1,4(15),7-trien-6-one (1). Fortunately, as (1) crystallized in a form suitable for X-ray analysis, we were able to confirm the structure (1) unambiguously by single-crystal X-ray diffraction analysis, which also established the stereochemistry at the ring-junction as *trans*.

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Experimental

Optical rotations were taken for solutions in chloroform. U.v. spectra were reported for solutions in ethanol, i.r. spectra as Nujol mulls, and ^1H and ^{13}C n.m.r. spectra for solutions in deuteriochloroform with SiMe_4 as internal standard. Mass spectra were determined at 70 eV using a direct inlet system.

Isolation of Stemonolone (1).—The whole plant of *P. plectranthoides* (roots, stem, leaves, and flowers), collected in November, was dried in the shade and powdered. The powdered material (2 kg) was extracted with acetone (3×10 l) at room temperature. The acetone was removed at $40^\circ\text{C}/25$ mmHg in a rotavapour and the dark extract (98 g) was chromatographed on silica gel. The column was eluted successively with benzene [to give fraction A (10 g)], benzene–acetone (90:10) [to give fraction B (42.4 g)], acetone [to give fraction C (40 g)], and methanol [to give fraction D (7 g)]. Fraction B was rechromatographed on silica gel. Benzene eluted a yellow semisolid (24.84 g) which on repeated chromatography yielded stemonolone (1) (1.56 g), m.p. $112\text{--}114^\circ\text{C}$ (from light petroleum); $[\alpha]_{\text{D}}^{26} +155.5^\circ$ (c , 0.64 in CHCl_3) (Found: C, 77.9; H, 8.8. $\text{C}_{15}\text{H}_{20}\text{O}_2$ requires C, 77.55; H, 8.68%); ν_{max} (Nujol) 3 240, 2 800, 1 660, 1 460, 1 220, 1 100, 950, and 840 cm^{-1} ; λ_{max} (EtOH) 245 nm (ϵ 6 022); δ_{H} (80 MHz; CDCl_3) 1.07 (6 H, d, J 6.5 Hz), 1.06 (3 H, s), 2.03 (1 H, dd, J 18 and 6.5 Hz), 2.62 (1 H, dd, J 18 and 3.5 Hz), 2.65–3.40 (4 H, m), 5.17, 5.56 (2 H), 5.33 (1 H, m), 5.68 (1 H, m), and 6.46 (1 H, ddd, J 6, 2.5, and 1 Hz); m/z (%) 232 (M^+ , 10), 215 (47), 204 (11), 189 (5), 122 (100), 107 (72), 94 (70), 91 (88), 79 (88), and 67 (79).

Hydrogenation of Stemonolone (1).—(a) *With PtO₂ as catalyst.* Compound (1) (30 mg) was hydrogenated in ethanol (5 ml) in the presence of platinum oxide (10 mg). When no more hydrogen was being absorbed, the reaction mixture was filtered, the solvent evaporated, and the residue crystallized from light petroleum to give 5 α -hydroxy-10 β -selin-7-en-6-one (2) as a mixture of isomers (20 mg), m.p. 128°C ; $[\alpha]_{\text{D}}^{26} +69.7^\circ$ (c , 0.88 in CHCl_3); ν_{max} (Nujol) 3 250, 2 800, 1 660, 1 380, 1 300, 1 050, 980, 900, and 840 cm^{-1} ; λ_{max} (EtOH) 245 nm (ϵ 6 050); δ_{H} (60 MHz; CDCl_3) 1.01–1.18 (12 H), 1.53 (1 H, s, exchanges with D_2O), 1.9–2.5 (9 H, m), 2.8 (1 H, m), and 6.57 (1 H, ddd, J 6, 2.5, and 1 Hz); m/z (%) 236 (M^+ , 74), 218 (17), 208 (74), 203 (22), 193 (41), 175 (11), 126 (100), 111 (86), 95 (65), and 67 (58).

(b) *With Pd–C as catalyst.* Compound (1) (100 mg) in ethanol (10 ml) was hydrogenated over 10% Pd–C (25 mg). When the consumption of hydrogen was complete the reaction mixture was filtered, the solvent evaporated, and the residue crystallized from light petroleum to give compound (2) as a mixture of isomers (90 mg), m.p. $145\text{--}148^\circ\text{C}$; $[\alpha]_{\text{D}}^{26} -41.2^\circ$ (c , 0.77 in CHCl_3); ν_{max} (Nujol) 3 250, 2 800, 1 660, 1 380, 1 050, 980, 900, and 850 cm^{-1} ; λ_{max} (EtOH) 245 nm (ϵ 6 075); δ_{H} (60 MHz; CDCl_3) 1.05–1.18 (12 H), 1.58 (1 H, exchanges with D_2O), 1.9–2.5 (9 H, m), 2.8 (1 H, m), and 6.57 (1 H, ddd, J 6, 2.5, and 1 Hz); m/z (%) 236 (M^+ , 33), 218 (10), 208 (56), 203 (10), 193 (20), 175 (3), 126 (100), 111 (66), 95 (66), and 67 (27).

Crystallographic Structure Determination of Stemonolone (1).—*Crystal data.* $\text{C}_{15}\text{H}_{20}\text{O}_2$, $M = 232.0$, Monoclinic, space group $P2_1$ (C_2^2 , No. 4), $a = 11.762(2)$, $b = 5.961(2)$, $c = 19.363(3)$ Å, $\beta = 103.89(1)^\circ$, $U = 1\ 317.82$ Å³, $D_c = 1.169$ g cm^{-3} , $Z = 4$, $F(000) = 506.0$. Monochromatic Mo- K_α radiation, $\lambda = 0.7107$ Å, $\mu = 0.7\text{ cm}^{-1}$; the crystal used was a needle, $0.25 \times 0.20 \times 0.50$ mm.

Structure determination. A unique data set was measured within the limit $2\theta_{\text{max}} = 48^\circ$ using a CAD4F-11M four-circle diffractometer in the conventional ω - 2θ scan. 2 285 Independent reflections were obtained, 1 312 of which with $I > 3\sigma(I)$ were considered 'observed' and were used in the least-

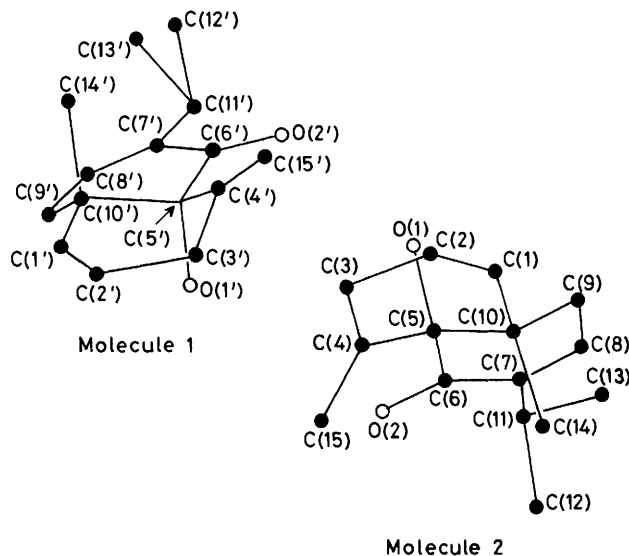


Figure. A view of the two molecules in the asymmetric unit showing the crystallographic numbering scheme

Table 2. Non-hydrogen atomic co-ordinates for stemonolone (1) with e.s.d.s in parentheses

| Atom | x | y | z |
|------------|-------------|--------------|-------------|
| Molecule 1 | | | |
| O(1) | 0.648 0(6) | 0.327 9(14) | 0.476 3(3) |
| O(2) | 0.597 2(6) | -0.125 6(16) | 0.536 9(4) |
| C(1) | 0.755 4(9) | 0.263 4(16) | 0.359 2(5) |
| C(2) | 0.652 2(10) | 0.311 8(22) | 0.319 5(5) |
| C(3) | 0.541 1(10) | 0.222 1(22) | 0.334 1(5) |
| C(4) | 0.562 6(8) | 0.045 2(18) | 0.390 9(5) |
| C(5) | 0.662 9(8) | 0.105 9(20) | 0.451 5(6) |
| C(6) | 0.679 4(8) | -0.034 7(18) | 0.519 9(5) |
| C(7) | 0.797 6(8) | 0.029 2(19) | 0.570 8(5) |
| C(8) | 0.884 6(8) | 0.075 5(18) | 0.552 8(5) |
| C(9) | 0.875 5(9) | 0.195 8(24) | 0.483 8(6) |
| C(10) | 0.776 7(8) | 0.104 9(20) | 0.424 2(5) |
| C(11) | 0.803 2(8) | -0.143 4(21) | 0.642 7(5) |
| C(12) | 0.814 2(12) | -0.393 7(29) | 0.634 4(7) |
| C(13) | 0.910 5(12) | -0.567 9(26) | 0.699 8(6) |
| C(14) | 0.804 4(9) | -0.138 2(22) | 0.402 7(5) |
| C(15) | 0.504 2(9) | -0.151 0(24) | 0.382 1(5) |
| Molecule 2 | | | |
| O(1') | 0.317 8(6) | 0.216 1(15) | 0.967 2(4) |
| O(2') | 0.442 6(6) | 0.646 0(17) | 1.027 5(4) |
| C(1') | 0.122 5(9) | 0.326 0(25) | 0.853 0(6) |
| C(2') | 0.187 5(13) | 0.249 9(26) | 0.809 8(7) |
| C(3') | 0.318 4(10) | 0.307 3(27) | 0.825 5(6) |
| C(4') | 0.350 3(8) | 0.486 3(19) | 0.881 0(5) |
| C(5') | 0.295 0(8) | 0.446 7(18) | 0.942 5(5) |
| C(6') | 0.341 0(9) | 0.582 7(19) | 1.010 6(5) |
| C(7') | 0.265 7(8) | 0.604 0(21) | 1.060 6(5) |
| C(8') | 0.156 8(10) | 0.515 0(26) | 1.042 4(6) |
| C(9') | 0.107 2(10) | 0.394 0(23) | 0.974 3(7) |
| C(10') | 0.160 5(7) | 0.467 8(17) | 0.914 8(5) |
| C(11') | 0.319 3(11) | 0.724 3(23) | 1.129 8(6) |
| C(12') | 0.287 3(24) | 0.936 9(43) | 1.127 1(15) |
| C(13') | 0.238 4(25) | 0.903 0(45) | 1.158 0(17) |
| C(14') | 0.132 6(9) | 0.715 6(23) | 0.894 8(6) |
| C(15') | 0.415 6(10) | 0.631 3(22) | 0.873 3(6) |

squares refinement without absorption correction. The structure was solved by direct methods using MULTAN-78.⁵ A full matrix least squares refinement⁶ was used with anisotropic

Table 3. Bond lengths (Å) and bond angles (°) for stemonolone (1) with e.s.d.s in parentheses

| | Molecule A | Molecule B |
|-------------------------|------------|------------|
| <i>(a) Bond lengths</i> | | |
| O(1)–C(5) | 1.43(1) | 1.46(1) |
| O(2)–C(6) | 1.22(1) | 1.22(1) |
| C(1)–C(2) | 1.30(2) | 1.34(2) |
| C(2)–C(3) | 1.50(2) | 1.54(2) |
| C(3)–C(4) | 1.50(1) | 1.50(2) |
| C(4)–C(5) | 1.49(1) | 1.50(1) |
| C(4)–C(15) | 1.35(2) | 1.34(2) |
| C(5)–C(6) | 1.54(1) | 1.53(1) |
| C(5)–C(10) | 1.55(1) | 1.55(1) |
| C(6)–C(7) | 1.50(1) | 1.46(1) |
| C(7)–C(8) | 1.31(1) | 1.35(2) |
| C(8)–C(9) | 1.50(1) | 1.49(2) |
| C(9)–C(10) | 1.53(1) | 1.50(1) |
| C(10)–C(14) | 1.56(2) | 1.54(2) |
| C(1)–C(10) | 1.55(2) | 1.45(2) |
| C(7)–C(11) | 1.54(1) | 1.52(2) |
| C(11)–C(13) | 1.55(2) | 1.61(3) |
| C(11)–C(12) | 1.51(2) | 1.52(3) |
| <i>(b) Bond angles</i> | | |
| C(2)–C(1)–C(10) | 124.1(9) | 127.3(9) |
| C(1)–C(2)–C(3) | 122.7(9) | 119.7(9) |
| C(2)–C(3)–C(4) | 112.7(9) | 111.5(9) |
| C(5)–C(4)–C(15) | 126.3(9) | 125.7(9) |
| C(5)–C(4)–C(3) | 111.6(9) | 112.0(9) |
| C(3)–C(4)–C(15) | 121.8(9) | 122.2(9) |
| O(1)–C(5)–C(4) | 110.5(8) | 109.1(8) |
| O(1)–C(5)–C(6) | 102.4(8) | 102.5(8) |
| O(1)–C(5)–C(10) | 107.7(8) | 106.4(8) |
| C(4)–C(5)–C(6) | 117.2(9) | 117.9(8) |
| C(4)–C(5)–C(10) | 108.3(9) | 108.2(8) |
| C(6)–C(5)–C(10) | 110.4(8) | 112.0(8) |
| O(2)–C(6)–C(5) | 122.0(9) | 121.0(9) |
| O(2)–C(6)–C(7) | 120.1(9) | 120.3(9) |
| C(5)–C(6)–C(7) | 117.4(8) | 118.0(9) |
| C(6)–C(7)–C(11) | 114.7(8) | 115.8(9) |
| C(6)–C(7)–C(8) | 119.6(9) | 118.6(9) |
| C(8)–C(7)–C(11) | 125.7(9) | 125.6(9) |
| C(7)–C(8)–C(9) | 126.9(9) | 124.4(9) |
| C(8)–C(9)–C(10) | 112.5(9) | 112.8(9) |
| C(5)–C(10)–C(9) | 107.7(9) | 106.9(8) |
| C(5)–C(10)–C(1) | 106.9(8) | 109.0(9) |
| C(5)–C(10)–C(14) | 110.3(8) | 107.6(8) |
| C(9)–C(10)–C(5) | 110.1(9) | 106.9(8) |
| C(9)–C(10)–C(14) | 111.1(9) | 111.7(9) |
| C(1)–C(10)–C(14) | 110.6(9) | 110.3(9) |
| C(7)–C(11)–C(12) | 109.2(9) | 111.3(9) |
| C(7)–C(11)–C(13) | 110.4(9) | 117.3(9) |
| C(12)–C(11)–C(13) | 109.2(9) | 109.5(9) |

temperature factors for the non-hydrogen atoms. The hydrogen atoms were located on the basis of stereochemical considerations

* For details of the Supplementary Publications Scheme see Instructions for Authors (1984) in *J. Chem. Soc., Perkin Trans. 1*, 1984, Issue 1.

and were included in the refinement with temperature factors constrained at idealized estimates. The final *R* value at convergence was 0.077. A Cruickshank type⁷ weighting scheme was employed with *a* = 3.5, *b* = 1.0, and *c* = 0.025. Tables of structure factor amplitudes, thermal parameters, and hydrogen parameters are available as a Supplementary Publication (SUP No. 23868, 19 pp.).* The atomic scattering factors were taken from the International Tables for *X*-Ray Crystallography.⁸

Discussion

The atomic co-ordinates for non-hydrogen atoms are given in Table 2. A view of the two molecules in the asymmetric unit is shown in the Figure. The bond lengths and angles (Table 3) in both molecules are normal. The methyl and hydroxy substituents at the ring junction are *trans* (methyl as β) with respect to each other with an average dihedral angle [O(1)–C(5)–C(10)–C(14) and O(1')–C(5')–C(10')–C(14')] of 174.8°. Both six-membered rings adopt the half-chair conformation close to those predicted by Bucort and Hainaut⁹ as the most energetically stable conformation for both unsubstituted and substituted cyclohexenes. The angle between the least-squares planes passing through these two rings is 11.8° indicating a slightly folded overall conformation. The crystal structure is stabilized by intermolecular hydrogen bonds between similar molecules, *viz.* the molecules are joined either *via* O(1)–H...O(2) type interactions or *via* O(1')–H...O(2') type interactions. The average O...O distance is 3.01(1) Å.

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