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TWO NOVEL CASSANE DITERPENOIDS FROM *ACACIA JACQUEMONTII*

K. C. Joshi, R. K. Bansal and T. Sharma
Department of Chemistry, University of Rajasthan, Jaipur, India 302004

and

R. D. H. Murray,* I. T. Forbes, A. F. Cameron and A. Maltz
Department of Chemistry, University of Glasgow, Glasgow G12 8QQ, Scotland

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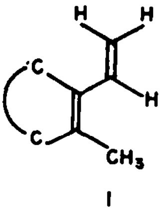
Abstract—The structure of two new diterpenoids (1 and 3), both of which contain the unique feature of a 7-membered hemiacetal ring B, have been established from chemical and spectroscopic (especially NMR) evidence. Single crystal X-ray crystallographic analysis of 1 has confirmed the structure and allowed the relative stereochemistry to be determined.

Acacia jacquemontii, a bushy, thorny shrub with sweet scented yellow flowers, is distributed over various parts of India.[1] Since no phytochemical investigation of the plant has yet been reported, the present examination of the constituents of the roots was undertaken.

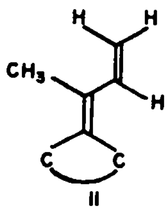
Chromatography of an extract of air-dried roots on alumina and light petroleum elution gave n-triacontanol[2] and a new diterpenoid (A), $C_{20}H_{32}O_2$. Further elution with mixtures of light petroleum and benzene afforded successively a second new diterpenoid (B), $C_{20}H_{30}O_3$, n-triacontanoic acid,[2] tectol,[3] β-amyrin[2] and β-sitosterol.[2]

The major diterpenoid (A) was readily seen to contain a conjugated diene system and an OH group from its UV (λ_{max}^{EtOH} 239 nm, ε 19,000) and IR ($\nu_{max}^{CCl_4}$ 3610 cm^{-1}, ε 117) spectra respectively. From the absence of CO absorption in the IR spectrum and end absorption in the UV spectrum, it was concluded that A was tricyclic with the remaining oxygen function necessarily an ether.

The ^1H NMR spectrum of A (Fig. 1) disclosed one vinyl Me group and three olefinic protons, Ha, Hc and Hd. Decoupling experiments after the addition of the shift reagent Eu(dpm)$_3$ (Fig. 2) showed that the olefinic protons constituted an AXY system and hence were attributable to a $-CH{=}CH_2$ group. Since the remaining two substituents on the diene system were presumably ring carbon atoms, two partial structures (I and II) were considered. Both were in accord with the ^{13}C NMR spectrum (Table 1) which showed four vinyl carbon resonances, two of which arose from fully substituted olefinic carbon atoms, one from a methylene group and one from a methine group.[4] At this stage distinction between I and II was not possible.



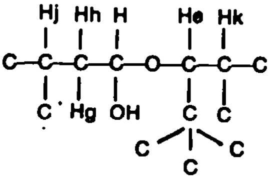
I



II

The ^1H NMR spectrum of A showed the presence of two $\underline{H}{-}\overset{|}{\underset{|}{C}}{-}O$ protons, one at δ 4.30 (He), the other at δ 5.05 (Hb). The low field position of the latter signal led us to conclude that the C atom bearing Hb was attached to both O atoms. This was confirmed by the presence of a signal at 96.18 ppm in the ^{13}C NMR spectrum of A characteristic of a C atom linked to two O atoms, while the signal at 71.69 ppm was identified as the resonance from a C atom attached to one O atom.[4]

It was thus apparent that A had to contain a hemiacetal group, further information concerning which was obtained from a detailed examination of the ^1H NMR spectrum. The doublet (J = 7 Hz) at δ 4.30 indicated that He was coupled to one other proton, Hk, which was attached to a saturated C atom. The signal arising from Hb appeared as a double doublet (J = 7 Hz, 6 Hz) in the europium-shifted spectrum indicating coupling to two protons, Hg and Hh, on the neighbouring C atom and for which a geminal coupling constant of 16 Hz could be identified. It was apparent however that Hg was coupled (J = 8 Hz) to one other proton, Hj, whereas Hh was not, which indicated a dihedral angle of ~90° between Hh and Hj. From this additional information, the partial structure (III) could be constructed for the hemiacetal system. The signal for Hj could be seen in the 0.6 M europium-shifted spectrum as a doublet (J = 8 Hz) at δ 4.20 showing that Hj was coupled only to Hg and consequently that the carbon atom bearing Hj had to be attached to two fully substituted C atoms.



III

Since A was tricyclic, it seemed probable that the hemiacetal was part of a ring system which, to accommodate the above findings had to be at least 7-membered (partial structure IV).

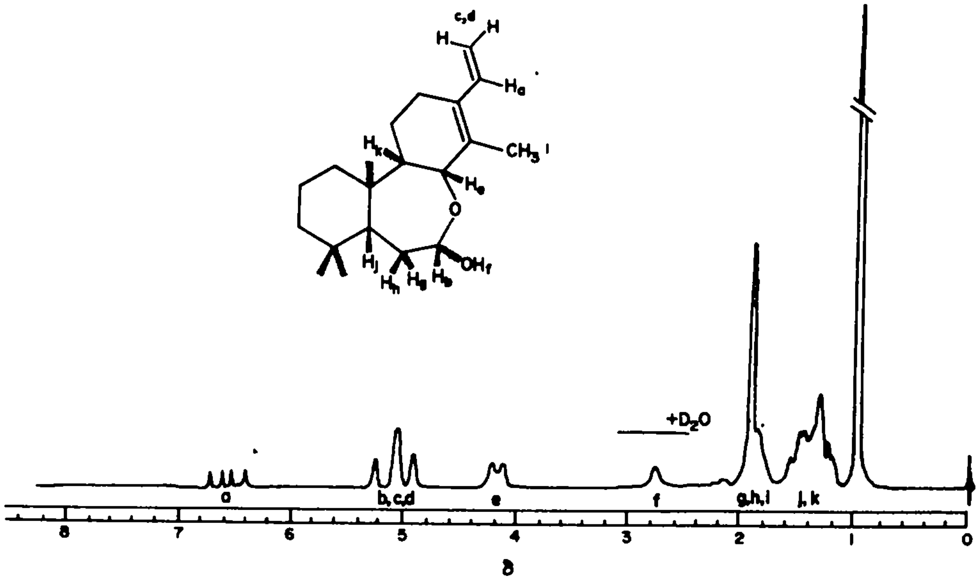


Fig. 1. ^1H NMR spectrum of diterpenoid A.

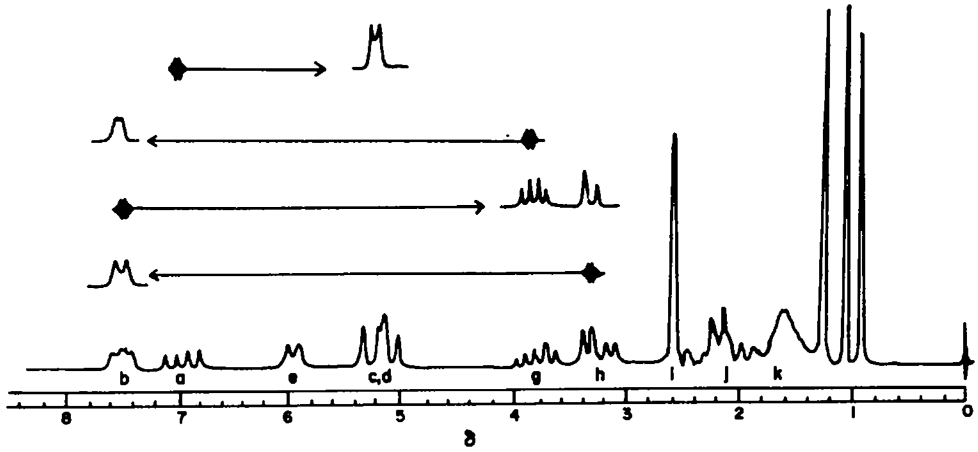
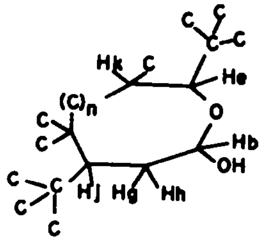


Fig. 2. ^1H NMR spectrum of diterpenoid A with 0.2 M Eu(dpm)$_3$ added, and decoupling experiments.

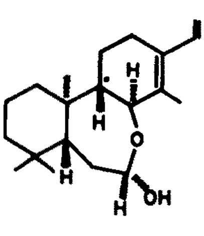


IV

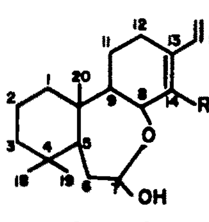
Jones oxidation of A gave a non-hydroxylic compound, $C_{20}H_{30}O_2$ ($\nu_{max}^{CCl_4}$ 1740 cm^{-1}), the ^1H NMR spectrum of which showed that the resonance for Hb was absent while the signal for Hg now appeared as a double doublet (δ 2.78, $J = 16$ Hz, 8 Hz) and that for Hh as a doublet (δ 2.50, $J = 16$ Hz). The CO carbon resonance at 176.4 ppm in the ^{13}C NMR spectrum of the oxidised product clearly indicated that the compound was a cyclohexanolide and thus that the hemiacetal was in a 7-membered ring.[4]

Diterpenoid A was then tentatively formulated as a cassane[5] (2) since it was tricyclic, contained one vinyl Me group and one vinyl group and, as could be seen from the europium shifted spectrum (Fig. 2), possessed three tertiary Me groups. In an endeavour to interrelate the hemiacetal ether O atom with the diene system, an attempt was made to prepare the dienol acid (4). Surprisingly, this simple transformation proved impossible to effect, the lactone (6) being completely resistant to hydrolysis. The hemiacetal too was inert to reductive ring opening by sodium borohydride, but treatment with lithium aluminium hydride in refluxing tetrahydrofuran gave a dienediol (5). Attempts to effect selective allylic oxidation to give a conjugated dienone were fruitless however, complex mixtures arising with each oxidant employed.

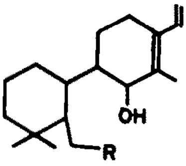
While chemical interrelation of the diene and hemiacetal functions proved impossible to effect, a literature survey reveal no other cassane diterpenoid having a structure similar to that (2) proposed for A which might



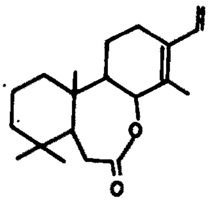
1



2: R = CH_3
3: R = CHO



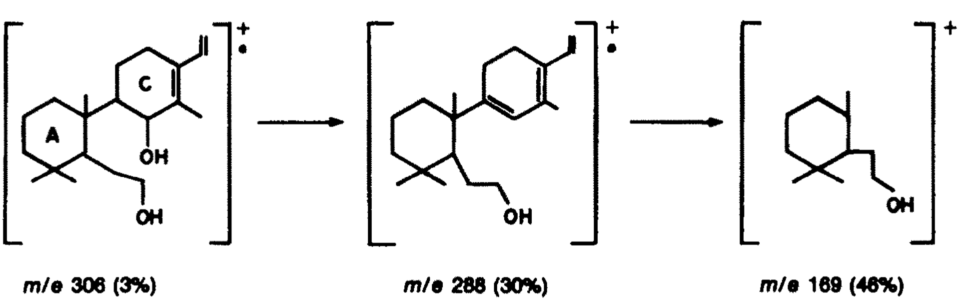
4: R = CO_2H
5: CH_2OH



6

be used for correlation purposes. Consequently in order to confirm the novel structure of the diterpenoid and establish its stereochemistry, a single crystal X-ray analysis was undertaken.

Certain spectroscopic features however provided additional support for structure 2 for A. The europium shifted spectrum (Fig. 2) showed that the protons on the vinyl Me group were shifted downfield more than the olefinic proton (Ha) which in turn was shifted more than Hc and Hd. This is precisely the order one would expect for structure 2 assuming complexation of the shift reagent with the OH group. Again, while the mass spectra of the hemiacetal and the lactone provided little structural information the mass spectrum of the dienediol (5) in which ring B is cleaved showed a major fragmentation ion at *m/e* 169 interpreted (Scheme 1) as arising from the facile cleavage of the bond linking ring A to ring C.



Scheme 1. Mass spectral fragmentation of dienediol (5).

A single crystal X-ray structure analysis of diterpenoid A has unambiguously confirmed structure (A) and has in addition revealed the relative stereochemistry shown in 1. A view of one molecule is shown in Fig. 3.

Diterpenoid B was present in only minor amounts in the roots of *A jacquemontii*. The close similarity of its ^1H NMR spectrum with that of A required it to be structurally closely related. The same hemiacetal system and vinyl group were present; however B did not contain a vinyl Me group. Significantly a new signal at δ 10.1 was present indicating an aldehyde proton. That B was the related conjugated dienal (3) followed from the IR absorption at $\nu_{max}^{CCl_4}$ 1675 cm^{-1} and the UV absorption (λ_{max}^{EtOH} 273 nm, ϵ 12,000). Further confirmation for this structure and, in all probability, the same configuration of the OH group as in A (1) came from dilution studies on the IR spectrum of B which indicated the presence of intramolecular H-bonding ($\nu_{max}^{CCl_4}$ 3450 cm^{-1}) interrelating the hemiacetal and aldehyde functionalities.

EXPERIMENTAL

M.ps were determined on a Kofler hot-stage apparatus. Microanalyses were obtained by Mrs. W. Harkness and her staff. Mass spectra were recorded by Mr. A. Ritchie on an AEI-GEC MS12 instrument. IR spectra of CCl_4 solns were recorded by Mrs. F. Lawrie and her staff on a Perkin Elmer 225 spectrophotometer. UV spectra were recorded for EtOH solns on a Unicam SP800 spectrophotometer. ^1H NMR spectra were recorded by Mr. J. Gall on a Varian HA 100 spectrometer and ^{13}C NMR spectra by Dr. D. S. Rycroft on a Varian XL 150 spectrometer for solns in deuteriochloroform; signals are reported in ppm from TMS as internal standard. Light petroleum refers to the fraction of b.p. 60–80°.

Isolation. Air dried, powdered roots (2 kg) of *Acacia jacquèmontii*, collected from the campus of Rajasthan University, were extracted with hot light petroleum and hot benzene. The combined extracts (10 l) were evaporated to dryness and the residual gum (30 g) was chromatographed on Brockman Alumina [250 g deactivated with 10% aq HOAc (5 ml)]. Light petroleum eluted *n*-triacontanol, m.p. 85–86° (lit.[2] 86.3–86.5°) and *diterpenoid* A (1), needles, 1.45 g, m.p. 210–211° (from EtOAc–light petroleum) (Found: C, 78.9; H, 10.6. $C_{20}H_{32}O_2$ requires: C, 78.95; H, 10.55%), ν_{max} 3610, 2950, 1640, 1295, 1022, 988 and 900 cm^{-1}; NMR signals at δ 0.94 (9H, s), 1.02–1.60 (14H, m), 1.84 (3H, bs, Hi), 2.72 (1H, s, Hf), 4.30 (1H, d, J = 7 Hz, He), 5.05 (3H, m, Hb, Hc, Hd), and 6.72 (1H, dd, J = 17.5 and 10 Hz, Ha); NMR signals after addition of 0.2 M equiv $Eu(dpm)_3$ at δ 0.94, 1.02, and 1.27 (each 3H, s), 1.30–2.42 (12H, m), 2.60 (3H, bs, Hi), 3.38 (1H, dd, J = 16 and 6 Hz), 3.80 (1H, m, Hg), 5.29 (2H, m, Hc, Hd), 5.97 (1H, d, J = 7 Hz, He), 6.92 (1H, dd, J = 17.5 and 10 Hz, Ha), and 7.59 (1H, dd, J = 8 and 6 Hz, Hb); ^{13}C NMR signals at 40.63[a] (t, C-1), 18.71 (t, C-2), 41.83[a] (t, C-3), 34.42[b] (s, C-4), 47.88 (s, C-5), 31.61 (t, C-6), 96.18 (d, C-7), 71.69 (d, C-8), 55.68 (d, C-9), 38.83[b] (s, C-10), 21.65[c] (t, C-11), 25.71[c] (t, C-12), 133.01 (s, C-13), 133.01 (s, C-14), 135.08 (d, C-15), 112.62 (t, C-16), 16.13 (q, C-17), 33.22 (q, C-18), 22.34 (q, C-19) and 15.24 ppm (q, C-20); mass spectral peaks at *m/e* 304 (M^+, 49%), 286 (59), 271 (30), 257 (30), 166 (41), 149 (47), 138 (50) and 123 (100).

Elution with benzene–light petroleum (1:2) afforded *diterpenoid B* (3), needles, m.p. 259–260° (from benzene–light petroleum) (Found: C, 75.6; H, 9.65. $C_{20}H_{30}O_3$ requires: C, 75.45; H, 9.1%) ν_{max} 3450, 2950 and 1675 cm^{-1}; λ_{max} 218 and 273 nm (ϵ

[a–c] These assignments may be reversed, but those given are considered to be the most likely.

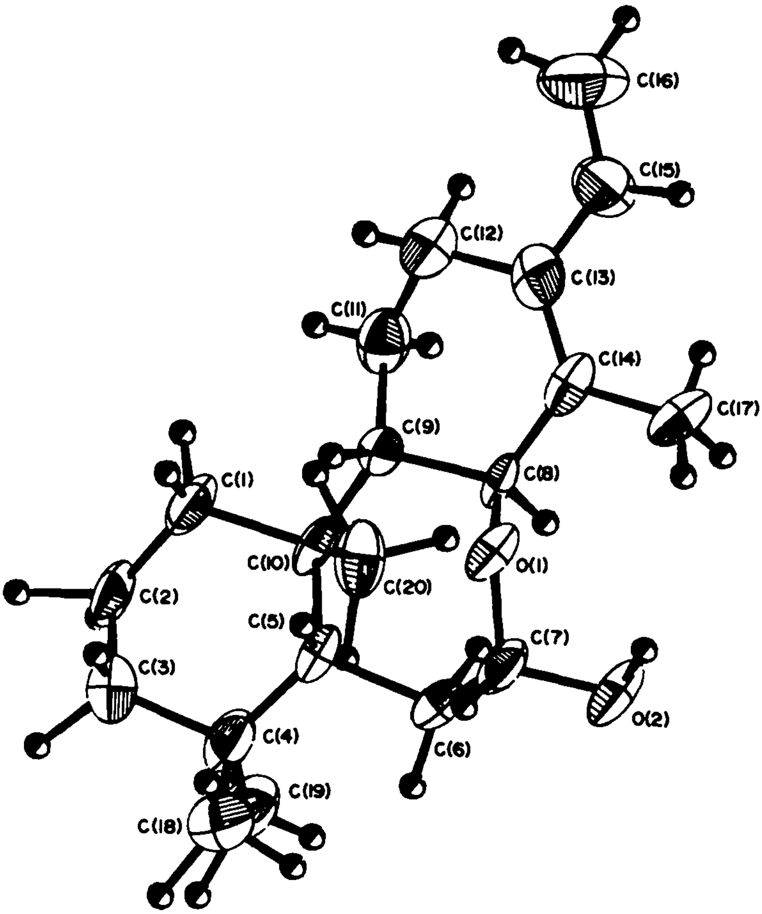


Fig. 3.

17,000 and 12,100); NMR signals at δ 0.94 (9H, s), 1.12–1.99 (14H, m), 4.6–5.2 (3H, m), 5.52 (1H, d, $J = 10$ Hz), 5.60 (1H, d, $J = 16.5$ Hz), 7.18 (1H, dd, $J = 16.5$ and 10 Hz), and 10.10 (1H, s); on addition of deuterium oxide, the signal at 4.6–5.2 became 4.84 (1H, d, $J = 7$ Hz) and 5.03 (1H, dd, $J = 8$ and 6 Hz); mass spectral peaks at *m/e* 318 (M^+, 21%), 149 (73), 134 (90) and 123 (100).

Elution with benzene–light petroleum (2:3) afforded *n*-triacontanoic acid, m.p. 90–91° (lit.[2] 93.6–93.9°), while benzene-light petroleum (1:1) gave tectol, m.p. 216–218° (lit.[3] 216–218°), identical (mixed m.p.; IR) with an authentic sample. Benzene–light petroleum (4:1) eluted β-amyrin, m.p. 198–199° (lit.[2] 197–200°) and benzene eluted β-sitosterol, m.p. 136–137° (lit.[2] 139–140°).

Jones oxidation of diterpenoid A (1). A soln of diterpenoid A (60 mg) in acetone (10 ml) was oxidised with Jones reagent. Work-up gave the *lactone* (6), pale yellow needles, 50 mg (80%), m.p. 118–120° (from EtOAc–light petroleum) (Found: C, 79.3; H, 9.9. $C_{20}H_{30}O_2$ requires: C, 79.5; H, 9.9%), ν_{max} 2920, 1740, 1270, 1010 and 900 cm^{-1}; λ_{max} 238 nm, ϵ 17,000; NMR signals at δ 0.92 (3H, s), 1.10 (6H, s), 1.2–1.8 (12H, m), 1.90 (3H, bs), 2.50 (1H, d, $J = 16$ Hz), 2.78 (1H, dd, $J = 16$ and 8 Hz), 4.84 (1H, d, $J = 7$ Hz), 5.15 (1H, bd, $J = 10$ Hz), 5.25 (1H, bd, $J = 18$ Hz), and 6.75 (1H, dd, $J = 18$ and 10 Hz); ^{13}C NMR signals at 39.01^d (t, C-1), 18.59 (t, C-2), 41.40^d (t, C-3), 34.98^e (s, C-4), 52.26 (s, C-5), 31.43 (t, C-6), 176.43 (s, C-7), 80.23 (d, C-8), 54.01 (d, C-9), 39.20^e (s, C-10), 21.65^f (t, C-11), 24.50^f (t, C-12), 134.64^g (s, C-13), 129.24^g (s, C-14), 134.35 (d, C-15), 114.18 (t, C-16), 16.09 (q, C-17), 33.32 (q, C-18), 21.46 (q, C-19) and 14.02 (q, C-20); mass spectral peaks at *m/e* 302 (M^+, 45%), 287 (25), 165 (50), 164 (100), 137 (70), 136 (75) and 123 (95).

Attempted hydrolysis of the lactone (6). A soln of 6 (30 mg) in MeOH (20 ml) was refluxed for 8 hr with 1 M NaOH (3 ml). Tlc indicated only the presence of starting material. Additional NaOH (70 mg) was added and the soln refluxed for a further 12 hr. Again no hydrolysis occurred.

Reductive ring opening of the hemiacetal (1). A soln of diterpenoid A (50 mg) in THF (20 ml) was refluxed for 6 hr with LAH (50 mg). Work-up gave the *diol* (5), colourless needles, (48 mg, 96%), m.p. 155–156° (from EtOAc-light petroleum) (Found: C, 77.9; H, 11.0. $C_{20}H_{34}O_2$ requires: C, 78.3; H, 11.1%); mass spectral peaks at *m/e* 306 (M^+, 3%), 288 (30), 169 (46), 138 (48), 125 (85) and 95 (100). The diol (5, 30 mg) was kept for 15 hr with pyridine (3 ml) containing Ac_2O (0.2 ml). Work-up gave the *diacetate* as a yellow oil (25 mg, 81%), ν_{max} 2940, 1740, 1230 and 900 cm^{-1}; NMR signals at δ 0.95 (3H, s), 1.10 (6H, s), 1.2–1.85 (14H, m), 1.95 (3H, bs), 2.19 (6H, s), 4.65–5.05 (3H, m), 5.20 (2H, m) and 6.72 (1H, dd, $J = 17$ and 10 Hz).

Attempted oxidation of the dienediol (5). Attempts to effect allylic oxidation of 5 using MnO_2, Jones reagent and pyridinium chlorochromate were completely unsuccessful, complex mixtures being produced in each case.

Crystal data. $C_{20}H_{32}O_2$, $M = 304$. Orthorhombic, $a = 10.336(1)$, $b = 24.230(2)$, $c = 7.308(1)$ Å, $U = 1830.20$ Å^3, $D_m = 1.09$ (by flotation $Z = 4$, $D_c = 1.10$, $F(000) = 672$. Space group P 222 from systematic absences.

Crystallographic measurements and structure determination.† Intensity measurements and the determination of unit-cell parameters were carried out on a Hilger and Watts Y290 computer-controlled diffractometer. Exposure of a small crystal to graphite-monochromated Mo radiation yielded 896 [$I > 2.5\sigma(I)$, $\sigma(I) = \sqrt{(I + B_1 + B_2)}$] independent reflections using the $\theta - \omega$ scan technique in the range 2θ 0–54°. The intensities were

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†Crystallographic data and details of molecular geometry have been deposited with the Cambridge Data Centre.

modified by the appropriate Lorentz and polarisation factors, but absorption effects were considered small and were ignored.

The structure was solved by application of the multisolution direct-methods program MULTAN, an *E* map based on 250 reflections ($|E| > 1.2$) revealing the complete structure. Positional and isotropic temperature factors for all non-hydrogen atoms were refined during the course of 5 cycles of full-matrix least-squares calculations which converged when R was 0.156. In the remaining 7 cycles of full-matrix least-squares calculations, which converged when R was 0.078, positional and anisotropic temperature factors for all non-hydrogen atoms were refined, hydrogen atoms (either located from difference syntheses or placed by calculation) were included as fixed contributors, and the data were weighted according to the scheme $\underline{w} = (\underline{A} + \underline{B}|F_o| + \underline{C}|F_o|^2)^{-1}$. The final values of the parameters $\underline{A}$, $\underline{B}$ and $\underline{C}$ were 4.441, −0.299 and 0.014 respectively. Calculation of an electron-density distribution and a difference synthesis revealed no errors in the structure.

REFERENCES

[1] R. N. Chopra, S. L. Nayar and I. C. Chopra, *Glossary of Indian Medical Plants*. New Delhi, Council of Scientific and Industrial Research (1956).

[2] W. Karrer, *Konstitution und Vorkommen der organischen Pflanzenstoffe*. Birkhäuser, Basel (1958).

[3] W. Sandermann and M. Simatupang, *Chem. Ber.* **97**, 588 (1964).

[4] J. B. Stothers, *Carbon* 13 *NMR Spectroscopy*. Academic Press, New York (1972).

[5] R. M. Coates, *Fortschr. Chem. org. Naturstoffe* 33, 161 (1976).