Communications to the Editor

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STRUCTURE AND NMR SPECTRA OF BOERAVINONE C, A NEW ROTENOID ANALOGUE FROM BOERHAAVIA DIFFUSA LINN

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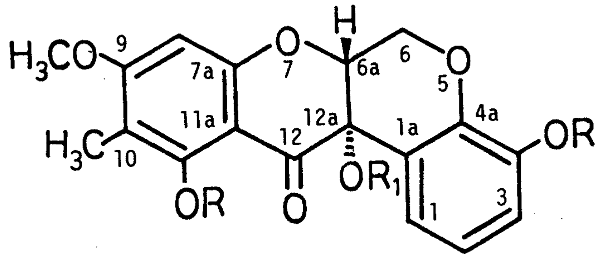
A new rotenoid analogue, boeravinone C, has been isolated from the root of Boerhaavia diffusa Linn (Nyctaginaceae) and its structure has been determined by means of 2-D NMR. The ^{1}H-NMR of boeravinone C showed unusual splitting patterns due to ABC spin systems. These splitting patterns were analyzed by simulation.

KEYWORDS —— Boerhaavia diffusa; Nyctaginaceae; rotenoid; boeravinone C; 2-D NMR; NMR simulation

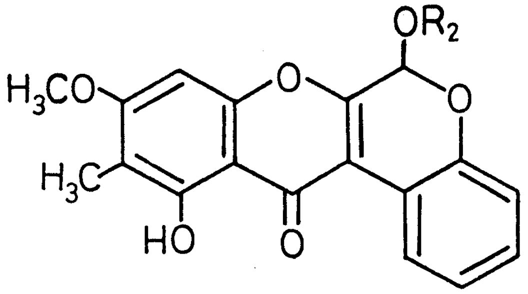
In a preceding communication,[1] we described the structures of two new rotenoids, boeravinone A (2) and B (3), which were isolated from the ether extract of the dried roots of Boerhaavia diffusa Linn (Nyctaginaceae) collected in Nepal. This communication deals with the structure of a new 12a-hydroxy rotenoid, boeravinone C, which showed an unusual splitting pattern due to ABC spin systems.

Boeravinone C (1a), $C_{18}H_{16}O_7$, pale yellow needles (from $CHCl_3$), mp 248 - 249°C, $[\alpha]_D$ - 47° (acetone), showed uv λ_{max}^{EtOH} nm (log ε): 331_{sh} (3.05), 293.5 (3.94), 212_{sh} (4.01), and 207.4 (4.03). The IR (KBr) spectrum of 1a showed absorptions at 3550, 3440 (OH), 1630 (conj. CO), 1580, 1510, and 1480 cm^{-1} (phenyl) and the EIMS exhibited the M^+ peak at m/z 344 and fragment ion peaks at m/z 326 ($M^+ - H_2O$), 181, and 163.

The ^{1}H- and ^{13}C-NMR spectra (in pyridine-d_5) of 1a indicated the presence of a carbonyl (δ_C 195.60), a hydroxyl (δ_H 12.56), four aromatic CH groups (δ_H 8.34, 7.27, 7.06, and 6.25; δ_C 122.23, 117.20, 121.41, and 90.93), a methoxyl (δ_H 3.71; δ_C 55.97), and a tert-methyl group (δ_H 2.15; δ_C 7.04). Further, the ^{1}H-NMR spectrum showed signals with a complex splitting pattern in the 4.67 - 4.93 region, which were



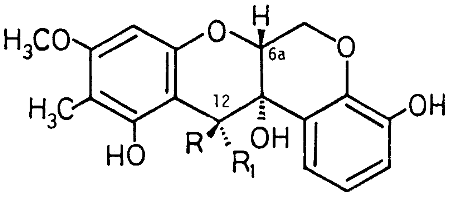
1a: R, R_1 = H
1b: R = $COCH_3$, R_1 = H
1c: R, R_1 = $COCH_3$



2: $R_2 = CH_3$
3: R_2 = H

ascribed to an O-CH-CH$_2$-O grouping (6a-H and 6-H$_2$) by the ^{1}H-^{13}C COSY experiment (Fig. 1 and Table I).

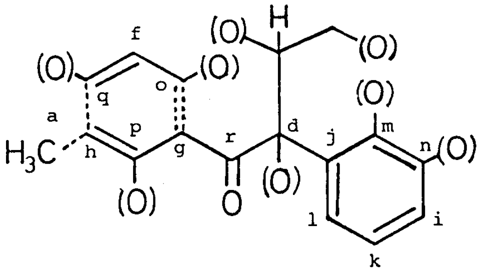
Acetylation of 1a gave an amorphous diacetate (1b), ν 1760 cm^{-1} (CO), δ_H 2.29 and 2.53 (Ac x 2), and an amorphous triacetate (1c), ν 1760 and 1745 cm^{-1} (CO), δ_H 1.74, 2.31, and 2.49 (Ac x 3). It was found that further acetylation of 1b proceeded slowly to give 1c and both showed no ^{1}H-signal due to a proton geminal to the acetoxyl group. Therefore, 1a has an aliphatic tert-hydroxyl and two phenolic hydroxyls.



4: R = H, R$_1$ = OH

5: R = OH, R$_1$ = H

Reduction of 1a with NaBH$_4$ in MeOH yielded solely an alcohol (4), C$_{18}$H$_{18}$O$_7$, mp 208 - 209°C, δ_H 5.59 (s, CH-OH) (Table I). On the other hand, reduction of 1a with LiBH$_4$ in anhydrous ether afforded epimeric alcohols; the major alcohol (5), C$_{18}$H$_{18}$O$_7$, had mp 203 - 205°C, δ_H 6.17 (s, CH-OH) (Table I), while the minor product was identified as 4.



(—— : connectivity was detected;
--- : connectivity was not detected)

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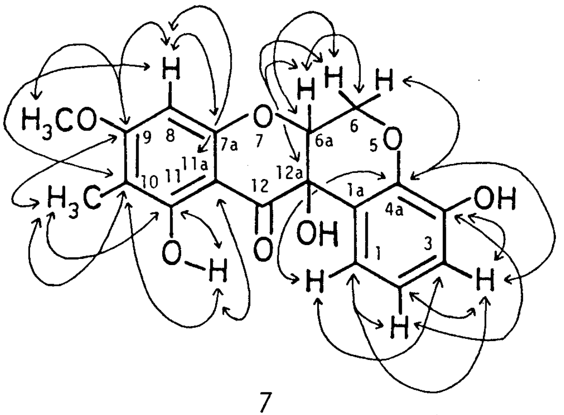

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The 2-D INADEQUATE spectrum[2] of boeravinone C (1a) (in acetone-d$_6$) indicated the gross structure to be 6, in which the correlated peaks of all the coupled ^{13}C-^{13}C pairs, except those of the carbons a and h, g and o, and h and q, were clearly observed.

Then we applied the ^{1}H-^{13}C long-range COSY[3] to 1a in order to determine the connectivities of the carbons a, g, h, and q, and the substituent groups. As shown in formula 7, the carbon signals at δ_C 102.98 (g, C-11a), 106.80 (h, C-10), 166.87 (q, C-9), 144.20 (m, C-4a), and 162.68 (p, C-11) are correlated with the proton signals at δ_H 6.20 (8-H), at δ_H 1.97 (10-CH$_3$) and 6.20 (8-H), at δ_H 3.93 (9-OCH$_3$) and 1.97 (10-CH$_3$), at δ_H 4.47 (6-H), and at δ_H 11.98 (11-OH), respectively. Some of the other significant long-range correlations observed are also shown by arrows.

Although long-range correlation could not be detected between the carbon 7a and 6a-proton, an ether linkage should exist between C-6a and C-7a, in view of the molecular formula. Thus, the plane structure of boeravinone C is represented by the formula 7.

The relative stereochemistry of the B and C rings was determined on the basis of NOE experiments with the reduction products 4 and 5. Irradiation at 6a-H (δ_H 4.56) and 12-H (δ_H 5.59) in 4 caused the increase of signal intensity of 12-H and 1- and 6a-H, respectively, and irradiation at 1-H (δ_H 8.36) gave rise to the increase of signal intensity of 2- and 12-H. On the other hand, irradiation at 6a-H (δ_H 5.27) and 12-H (δ_H 6.17) in 5 caused the increase of signal intensity of 6-H and 1-H,

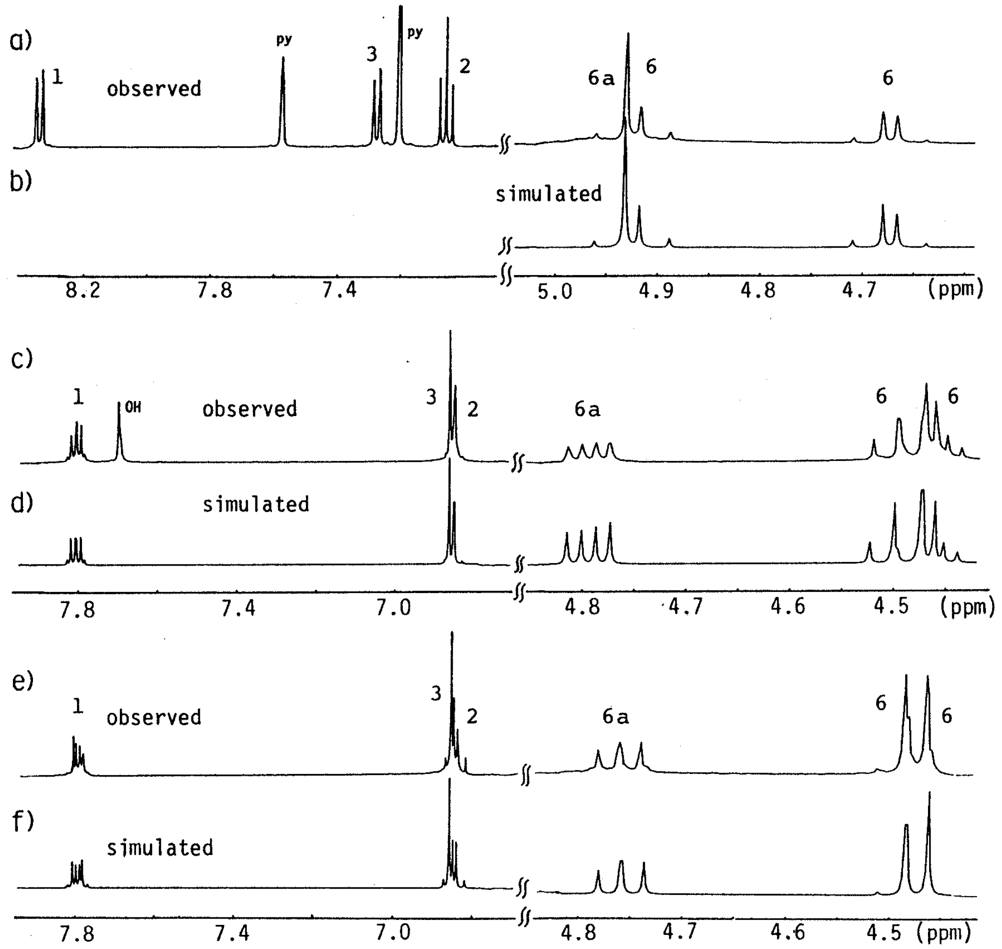

Fig. 1. Comparisons of Observed and Simulated ^{1}H-NMR Spectra of Complex Splitting Patterns of Boeravinone C (1a) in Pyridine-d_5, Acetone-d_6, and Acetone-d_6 + D_2O

a, b) Observed and simulated ^{1}H-NMR spectra of 1-, 2-, 3-, 6a-, and 6-protons in pyridine-d_5.

c, d) Observed and simulated ^{1}H-NMR spectra of 1-, 2-, 3-, 6a-, and 6-protons in acetone-d_6.

e, f) Observed and simulated ^{1}H-NMR spectra of 1-, 2-, 3-, 6a-, and 6-protons in acetone-d_6 + D_2O.

respectively. These observations led us to conclude that the B/C ring junction of boeravinone C is trans.

From the foregoing evidence, the structure of boeravinone C was assigned to 1a. The absolute configuration is currently under investigation.

As mentioned before, the ^{1}H-NMR spectrum of 1a showed a complicated splitting pattern due to an ABC spin system. This spectral pattern changed markedly when the solvent was changed from pyridine-d_5 to acetone-d_6 or acetone-d_6 + D_2O.[4)] Since these splitting patterns could not be interpreted in the first-order analysis, a simulative approach was applied by calculating the positions and intensities of respective resonance lines in these three spin systems. For this purpose, the JEOL program COMIC was used and the results are reproduced in Fig. 1. Comparisons of observed and simulated splitting patterns gave excellent agreement in each case.

Table I. ^{1}H-(400 MHz) and ^{13}C-(100 MHz) NMR Data of Boeravinone C and Its Derivatives (Coupling Constants in Parentheses)

position	boeravinone C (1a) (pyridine-d_5)		boeravinone C (1a) (acetone-d_6)		(acetone-d_6 +D_2O)	alcohol (4) (pyridine-d_5)		alcohol (5) (pyridine-d_5 +D_2O)
	δ_H a)	δ_C b,c)	δ_H a)	δ_C b,c)	δ_H d)	δ_H	δ_C b,c)	δ_H d)
1	8.34 dd (7.5,1.9)	122.23 d	7.81e) (8.20, 1.35)e)	123.21 d	7.80e) (8.82, 0.84)e)	8.36 dd (8.0,1.5)	121.69 d	7.61 dd (8.0,1.0)
1a	———	122.13 s	———	121.91 s	———	———	127.02 s	———
2	7.06 t (7.5)	121.41 s	6.87e) (8.20, 7.98)e)	121.95 d	6.85e) (8.82, 8.39)e)	7.02 t (8.0)	119.61 d	6.98 t (8.0)
3	7.27 dd (7.5,1.9)	117.20 s	6.86e) (7.98, 1.35)e)	117.12 d	6.86e) (8.39, 0.84)e)	7.23 dd (8.0,1.5)	116.73 d	7.22 dd (8.0,1.0)
4	———	147.50 s	———	146.97 s	———	———	147.25 s	———
4a	———	144.31 s	———	144.20 s	———	———	143.25 s	———
6	4.67e) 4.92 (11.64, -10.23, 4.66)e)	62.25 t	4.46e) 4.49 (11.50, -10.02, 4.44)e)	62.72 t	4.47e) 4.48 (9.95, -9.98, 6.66)e)	4.62 dd (9.5,7.5) 4.89 dd (11.0,9.5)	62.98 t	4.74 dd (9.6,4.5) 4.92 dd (11.5,9.6)
6a	4.93e) (11.64, 4.66)e)	77.16 d	4.80e) (11.50, 4.44)e)	77.40 d	4.76 e) (9.95, 6.66)e)	4.56 dd (11.0,4.5)	74.01 d	5.27 dd (11.5,4.5)
7a	———	160.69 s	———	161.52 s	———	———	153.17 s	———
8	6.25 s	90.93 d	6.20 s	91.64 d	6.22 s	6.24 s	91.21 d	6.39 s
9	———	165.76 s	———	166.87 s	———	———	158.80 s	———
10	———	106.18 s	———	106.80 s	———	———	106.31 s	———
11	———	162.02 s	———	162.68 s	———	———	157.50 s	———
11a	———	102.57 s	———	102.98 s	———	———	105.33 s	———
12	———	195.60 s	———	195.59 s	———	5.59 s	71.33 d	6.17 s
12a	———	66.67 s	———	67.23 s	———	———	64.66 s	———
9-OMe	3.71 s	55.97 q	3.93 s	57.00 q	3.93 s	3.65 s	55.39 q	3.72 s
10-Me	2.15 s	7.04 q	1.97 s	7.62 q	1.97 s	2.30 s	8.35 q	2.41 s
11-OH	13.44 s	———	11.98 s	———	———	———	———	———

δ values in ppm and coupling constants in Hz. a) ^{1}H-^{1}H correlation spectra were measured. b) The multiplicities of carbon signals were determined by means of the DEPT method and are indicated as s, d, t, and q. c) ^{1}H-^{13}C correlation spectra were measured. d) Only ^{1}H-NMR spectrum was measured. e) Chemical shifts and coupling constants were determined by means of the simulation and rounded to three decimal places.

It is interesting that the coupling constants between 6a-H and 6-H_2 and between aromatic protons in 1a changed considerably when D_2O was added to the acetone-d_6 solution. This may be due to the change of the solvation state or the aggregation state, which may cause the conformational change. This problem is still under investigation.

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REFERENCES AND NOTES

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4) In $CDCl_3$, 1a also showed a complex ^{1}H-NMR pattern, which we are unable to interpret.

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