

SCAPANIAPYRONE A, A NOVEL AROMATIC CONSTITUENT
OF THE LIVERWORT Scapania undulata

R. Mues

(Fachrichtung Botanik 15.1, Universität des Saarlandes,
D-6600 Saarbrücken 11, Federal Republic of Germany)

Siegfried Huneck

(Institute of Plant Biochemistry of the Academy of Sciences of the G.D.R.,
DDR-4050, Halle/Saale, German Democratic Republic)

and Joseph D. Connolly and David S. Rycroft

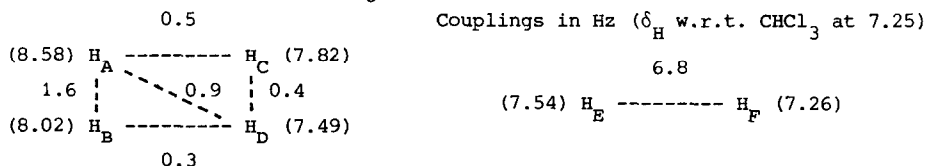
(Department of Chemistry, University of Glasgow, Glasgow G12 8QQ, Scotland)

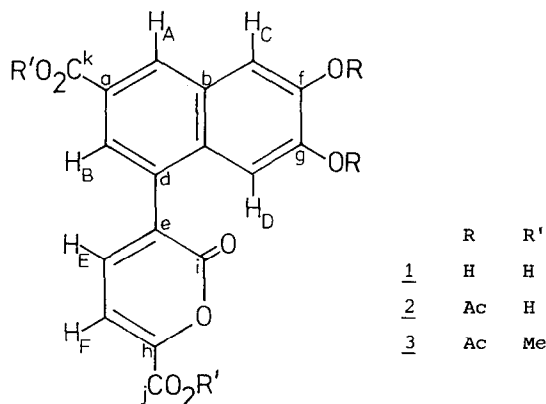
Summary: Scapaniapyrone A, a polar constituent of the liverwort Scapania undulata, has been assigned the novel structure 1 by combining evidence from the proton-coupled ^{13}C n.m.r. spectrum and a 2D long-range $\delta_{\text{C}}/\delta_{\text{H}}$ correlation spectrum.

A useful strategy for the solution of structural problems in aromatic systems involves using the proton-coupled ^{13}C n.m.r. spectrum in conjunction with a 2D long-range $\delta_{\text{C}}/\delta_{\text{H}}$ correlation spectrum. To a large extent this combination eliminates the need to perform selective decoupling experiments to identify pairs of coupling nuclei. The use of this strategy has been illustrated recently¹ in the structural elucidation of ekeberginine, a new carbazole alkaloid from Ekebergia senegalensis. A much more demanding test is provided by scapaniapyrone A, a polar yellow compound isolated from the liverwort Scapania undulata. The aromatic nature was suggested by the ^1H and ^{13}C n.m.r. spectra, where all the signals are deshielded to below 6 and 107 p.p.m. respectively.

The high resolution mass spectrum of scapaniapyrone A revealed the molecular formula $\text{C}_{17}\text{H}_{10}\text{O}_8$. The u.v. spectrum (EtOH) showed bands at 265 nm ($\epsilon = 14,600$) and 309 nm ($\epsilon = 12,800$). Addition of alkali shifted these to 279 nm ($\epsilon = 18,300$) and 309 nm ($\epsilon = 14,100$), suggesting the presence of phenolic hydroxyl groups. Acetylation with acetic anhydride in sulphuric acid afforded a diacetate 2 which, on treatment with CH_2N_2 , was converted into a dimethyl ester 3 [ν_{max} 1780, 1750, 1730 cm^{-1}] which lacked hydroxyl absorption. Thus scapaniapyrone A has two phenolic hydroxyl groups and two carboxyl groups, which account for six of the eight oxygen atoms. The line-narrowed proton spectrum (CDCl_3) of the dimethyl ester diacetate 3 reveals a coupled two-spin system (J 6.8 Hz) and a four-spin system as shown (Fig. 1). H_A and H_B are

Figure 1. ^1H N.m.r. Data (200 MHz, CDCl_3 solution) of the Dimethyl Ester Diacetate 3





meta-coupled in view of the 1.6 Hz coupling. The other couplings are very small and must involve coupling paths of five or more bonds.

Scapaniapyrone A (1) is insoluble in CDCl_3 and n.m.r. spectra were mostly run in d_6 -DMSO. Both the ^1H and ^{13}C n.m.r. spectra are much broader than those of the dimethyl ester diacetate 3. Indeed two of the carbon resonances of 1 are very broad at room temperature and disappear on heating to 70°C . At this stage we were unable to write a working structure for scapaniapyrone A and therefore proceeded to elucidate the structure from scratch by extending a starting fragment logically on the basis of long-range C...H couplings. The directly bonded H-C relationships were first assigned using 2D $\delta_{\text{C}}/\delta_{\text{H}}$ correlation. Then the proton-coupled ^{13}C spectrum was analysed and the multiplicities and coupling constants of all the carbons listed. Finally all the 2D long-range $\delta_{\text{C}}/\delta_{\text{H}}$ correlations were analysed and tabulated. The data appear in Table 1 along with the arbitrary labels used to ease the presentation of the structural elucidation arguments. The number of correlations corresponds to the number of couplings observed (except for C_D where the correlation of the 1 Hz coupling is presumably too weak). It is assumed in the structural elucidation that the observed correlations arise from two- and three-bond couplings, but the arguments used do not rely on assuming that a particular correlation arises from a two- or a three-bond coupling.

It is clear from the chemical shifts of the protonated carbons that three of them (C_C , C_D , and C_F) are shielded by oxygen substituents. Two are deshielded on acetylation and are therefore ortho to the phenolic hydroxyl groups [C_D δ 107.5 \rightarrow δ 119.5; C_C δ 111.5 \rightarrow δ 123.0]. Comparison of the shifts with quercetin as a model² suggests that the phenolic hydroxyl groups are ortho as in part structure 4. This is supported by the observation that both C_F and C_G correlate with H_C and H_D , C_F more strongly with H_D , and C_G more strongly with H_C . In the coupled spectrum C_F and C_G both appear as doublets of doublets (J ca. 7 and ca. 3 Hz). The larger coupling in each case is assigned to $^3\text{J}_{\text{CH}}$. The structure of scapaniapyrone A can be argued from 4 in the following manner:

(i) Neither H_C nor H_D has an ortho proton; therefore the coupling of C_C to H_A must be through three bonds as shown in part structure 5.

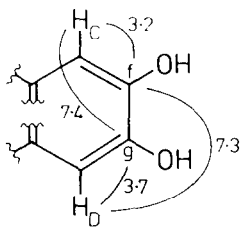
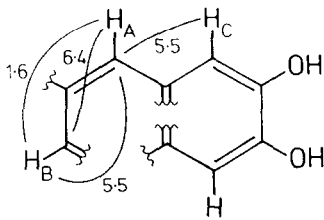
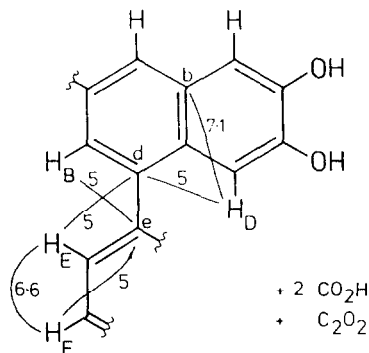
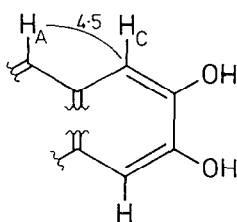
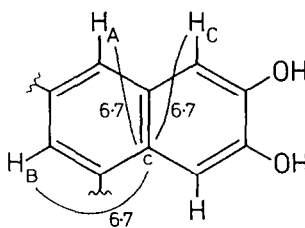
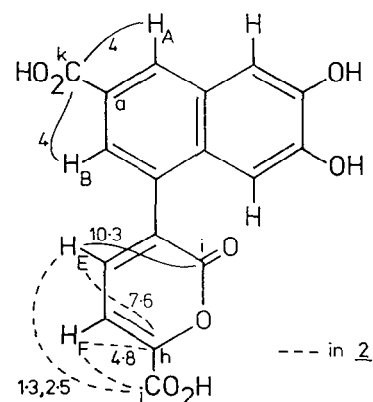
(ii) The part structure can be developed as in 6 since H_B is meta to H_A ($^4J = 1.6$ Hz) and both C_B and C_A couple to H_A and H_B respectively. C_A also couples to H_C .

(iii) C_C shows equal coupling to H_A , H_B , and H_C (6.7 Hz) and must be located as shown

in 7, thus establishing the naphthalene unit apart from the bond between C_C and C_D .

(iv) H_D couples to two other carbons, b and d . The latter is also coupled to H_E . These carbons are assigned as in part structure 8, thus completing the naphthalene unit. H_B couples to C_e which is also coupled to H_F , the vicinal partner of H_E (3J 6.6 Hz). Therefore C_e is three bonds from H_B and H_F , and C_d is three bonds from H_E , thus completing the justification for 8.

(v) At this stage we have accounted for all the available structural components except two carboxyl groups, two oxygen atoms, and two additional carbon atoms. The signal arising from the carbon atom which lies between C_A and C_B also remains to be identified. Structure 9 (\equiv 1) emerges from the following arguments. C_k couples equally to H_A and H_B , and must be ortho to these two protons. The signals for C_h and C_j are both broad in scapaniapyrone A but the corresponding signals in the coupled spectrum of the diacetate 2 are sharp doublets of doublets (Table 1). Although a 2D long-range δ_C/δ_H correlation experiment was not performed for the diacetate 2, the protons which couple to C_h and C_j must be H_E and H_F since the structure around the other protons is already complete. The size of the couplings to C_h precludes four-bond coupling and therefore C_h is bonded to C_F . C_i couples strongly (10.3 Hz) to H_E and must be three bonds away from it. C_j must then be attached to C_h . C_j and C_k are assigned as the two carboxyl groups so that the remaining two oxygen atoms can be attached to

468579

C_h and C_i to form a pyrone ring and complete structure 9. The remaining signal, a singlet C_a , is assigned to the carbon atom bonded to C_A , C_B , and the carboxyl group C_k .

We have recently found that addition of TFA to a d_6 -DMSO solution of 1 sharpens the signals of C_h and C_i , and we suspect that selective complexation of a paramagnetic metal ion impurity is responsible for the relaxation enhancement. The broadest signal in the 1H spectrum is H_F followed by H_E ; addition of a small amount of nickel acetate selectively increases the broadening of H_F and H_E , whereas these signals become sharper when the original sample is dissolved in aqueous $NaHCO_3$ and reprecipitated with aqueous HCl. We are currently working on the structural elucidation of other compounds from *Scapania undulata* related to 1. The only compound at all similar to 1 that has been isolated previously from a liverwort is 6,7-dihydroxy-4-(3,4-dihydroxyphenyl)-naphthalene-2-carboxylic acid³ from *Pellia epiphylla*.

Table 1. N.m.r. Data (200 MHz, d_6 -DMSO solution) of Scapaniapyrone A (1) and Its Diacetate (2).

Label	δ_C^*		δ_H^{**}		Mult.***	Couplings/Hz		2D long-range correlations
	<u>1</u>	<u>2</u>	<u>1</u>	<u>2</u>		<u>1</u>	<u>2</u>	
D	107.5	119.5	6.97	7.74	d	158.4	165.7	-
F	109.8	110.7	7.24	7.30	d, br	174.6	176.2	E
C	111.5	123.0	7.34	8.12	dd	159.7, 4.5	166.0, 5	A
B	124.0	127.2	7.65	7.96	dd	163.1, 6.4	164.2, 6.8	A
A	129.5	131.1	8.32	8.7	dt, br	162.4, 5.5	165.0, 5	B, C
E	142.8	143.2	7.70	7.78	d	166.7	168.2	-
a	124.6	128.3			s			-
b	128.1	131.0			dd	7.1, 1	7.2, 1.6	D
c	129.0	131.5			q	6.7	6.9	A, B, C
d	130.71	133.2			t	5	4.3	E, D
e	130.73	130.5			t	5	6.9, 4.8	B, F
f	147.7	141.9			dd	7.3, 3.2	8.1, 4.9	D, C
g	149.6	143.4			dd	7.4, 3.7	7.6, 4.8	C, D
h	150.7	149.5			br (dd)****		7.6, 4.8	-
i	160.1	160.0			d	10.3	10.2	E
j	160.8	160.6			br (dd)****		2.5, 1.3	-
k	167.6	166.9			t	4	4.5, 3.7	A, B

* W.r.t. d_6 -DMSO at δ 39.5

** W.r.t. d_5 -DMSO at δ 2.49

*** In the proton-coupled carbon spectrum.

**** In the diacetate 2.

References

1. D. Lontsi, J.F. Ayafor, B.L. Sondengam, J.D. Connolly, and D.S. Rycroft, Tetrahedron Letters, 1985, 26, 4249.
2. F.W. Wehrli, J. Chem. Soc., Chem. Commun., 1975, 663.
3. M. Rischmann, R. Mues, H. Geiger, H.J. Laas, T. Eicher, Phytochemistry, 1988, in press.

(Received in UK 26 September 1988)