Pergamon

0031-9422(94)00860-4

Phytochemistry, Vol. 39, No. 1, pp. 91–97 1995

0031 9422/95 $9.50 + 0.00

SESQUITERPENOIDS AND CYCLIC BISBIBENZYLS FROM THE LIVERWORT *REBOULIA HEMISPHAERICA*

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(*Received in revised form* 21 *September* 1994)

Key Word Index—*Reboulia hemisphaerica*; Grimaldiaceae; liverwort; cyclomyltaylan-5α-ol; cadina-4,11-dien-14-al; cadina-4,11-dien-14-ol; 14-acetoxy-cadina-4,11-diene; cadina-4,11-dien-14-oic acid; marchantin M, N, O.

Abstract—Five new sequiterpenoids and three new marchantin-type compounds were isolated from the Taiwanese liverwort *Reboulia hemisphaerica* together with the previously known marchantinquinone and marchantin C. The structures were established by spectral analysis. Marchantinquinone displayed prominent antiplatelet activities. Three chemotypes are observed for this species.

INTRODUCTION

Reboulia hemisphaerica is a common thallus liverwort species distributed widely in moist areas of low altitude around the world [1]. Previously, chemical constituents of the Japanese and the French species had been investigated. From the former, sesquiterpenes, cyclic bisbibenzyls e.g. riccardin C, **1**, and a hopanetriol were identified [2]. From the French species, Becker *et al.* [3, 4] also isolated several sesquiterpenoids and one hopanediol, α-zeroin (**2**), but no bisbibenzyl ether was detected [3, 4].

When a preliminary GC-MS analysis of the oil of *R. hemisphaerica*, collected in the northern suburb of Taipei city, Yangming Shan (YMS, 500 m), was obtained, we found that this volatile oil was very rich in sesquiterpenoids. Moreover, in the sesquiterpene region, nearly all the GC peaks and the corresponding mass spectra were identical with those from the oil of *Mannia subpilosa* [5]†, which was collected in the southern suburb of Taipei city, Shankon (SK, 100 m). In order to verify the latter species, fresh sample with female receptacles collected from the same location of SK, as well as an old specimen, were sent again for identification, and both specimens were proved to be indeed *R. hemisphaerica*.

In spite of the identity of the sesquiterpenes of the two species, their aromatic components, i.e. the macrocyclic ethers, are nonetheless different [5, 6]. In this paper, we report the identification and characterization of these sesquiterpenoids and cyclic bisbibenzyl ethers from the Taiwanese liverwort *R. hemisphaerica*.

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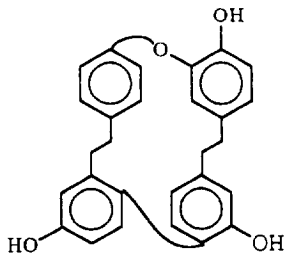
†In this paper, the liverwort species was reported as *Mannia subpilosa* and structures **5**–**8** were drawn in their enantiomeric forms.

RESULTS AND DISCUSSION

Five distinct GC peaks appeared in the oxygenated sesquiterpene region of liverwort oils of *R. hemisphaerica* from both YMS and SK. The earliest eluted peak showed a molecular ion of *m/z* 220, ascribable to $C_{15}H_{24}O$. The ^1H and ^{13}C NMR spectra (Table 1) of this isolated compound (**3**) disclosed four singlet methyls, two cyclopropyl protons (δ0.87 and 0.90), and one secondary hydroxyl group (δ3.62, *s* and 86.0). Since there was no double bond in the structure, this compound must be tetracyclic. Very few sesquiterpenes of tetracarbocylic skeleton have been identified previously, therefore, cyclomyltaylane (**4**), a component isolated from *Bazzania tridens* [7] recently, was immediately suggested to be the plausible skeleton. A further HMBC experiment (Table 1) subsequently confirmed the assumption and the disposition of the hydroxyl group at C-5. The *exo*-configuration of the oxymethine proton was assigned according to the NOESY observation as shown in Fig. 1. Two other cyclomyltaylanols have also been isolated from liverworts [8–10]. It is noteworthy that the hydrocarbon cyclomyltaylane (**4**) was observed by GC-MS in the YMS oil as well. The skeleton of cyclomyltaylane has only been found in constituents of liverworts.

Among the GC peaks of the volatile oil, the two most abundant components, **5** and **6**, were easily isolated upon repeated chromatography. Their ^1H NMR spectra (Table 2) resembled each other except that one had a conjugated aldehyde group and the other reduced to a primary alcohol. From a consideration of the mass spectral ($[M]^+$ 218 and 220) and ^{13}C DEPT data (Table 3), the skeleton of these two derivatives appeared to be either a cadinane or a guainane. On the basis of ^1H–^1H and ^{13}C–^1H COSY correlations, the assignment of the conjugated functional group at C-4 as well as the cadinane skeleton was



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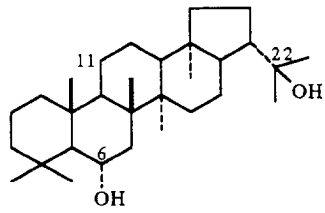

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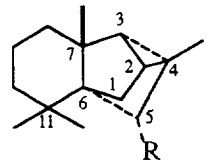
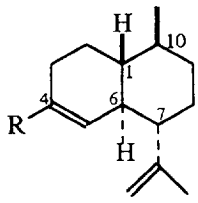
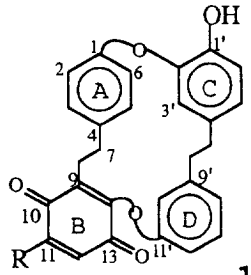


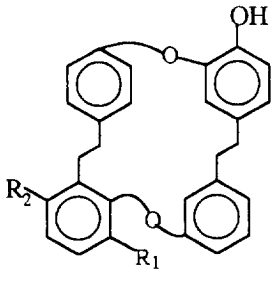
3 R = OH
4 R = H



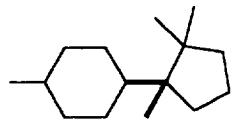
R	
5	CHO
6	CH_2OH
7	CH_2OAc
8	CO_2H



R	
9	H
11	OMe



	R_1	R_2
10	OMe	OH
12	OH	H
13	OMe	H



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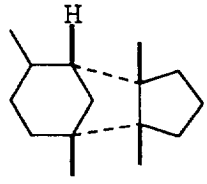

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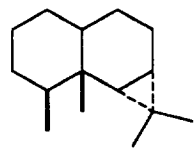

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deduced. The antiperiplanar relationships of the four protons at C-1, C-6, C-7, and C-10 were indicated by the large coupling constants (Table 2, ascertained by *J*-spectroscopy) of $J_{1,10}$, $J_{1,6}$ and $J_{6,7}$. A series of irradiations of NOE experiments (Fig. 2) further confirmed the relative configuration of these two cadinane derivatives. Therefore, these two new sesquiterpenoids were determined to be cadina-4,11-dien-14-al (**5**) and cadina-4,11-dien-14-ol (**6**), respectively.

In addition, the Taiwanese *R. hemisphaerica* biosynthesizes two other minor C-14 derivatives. 14-Acetoxycadina-4,11-diene (**7**) was isolated from the SK oil and cadina-4,11-dien-14-oic acid (**8**) from the YMS oil. Their ^1H and ^{13}C NMR data are compiled in Tables 2 and 3. Cadina-4,11-dien-14-oic acid had previously been isolated from a higher plant and named pernetic acid C [11]. The reported ^{13}C NMR shifts (Table 3) are essentially consistent with our data if the three wrong assignments are ignored [11]. The absolute configuration of the pernetic acid C in the literature with a β-isopropenyl group was determined by CD and correlation with other congeneric components from the same plant. Since our acid isolated showed the inverse Cotton effects to those of pernetic acid C from vascular plant, the absolute configuration of our acid should be the mirror image of pernetic acid C, i.e. with an α-isopropenyl group. In consideration of the biogenetic relation of the four cadinane compounds, the three other derivatives are hence suggested to have the same chirality as acid **8**, i.e. *1R*,6*S*,7*S*,10*S*, as shown in structures **5**–**7**.

Previously we reported an interesting major macrocylic ether marchantinquinone (**9**) from *R. hemisphaerica*

Table 1. ^1H and ^{13}C NMR spectral data of cyclomyltaylan-5α-ol

Atom	C-Type	δ_C	δ_H	J (Hz)	HMBC correlation
1	CH_2	28.0	1.33 (b)	*br d* (10.8)	
			1.19 (a)	*dt* (10.8, 1.0)	
2	CH	17.8	0.87	*br d* (5.5)	
3	CH	34.4	0.90	*d* (5.5)	
4	4°C	23.3	—	—	
5	CH	86.0	3.62 (exo)	*s*	12.7, 23.3, 34.4, 45.3
6	4°C	52.0	—	—	
7	4°C	45.3	—	—	
8	CH_2	32.6	1.97 (ax)	*dt* (4.3, 12.6)	19.2, 34.4, 45.3
			1.33 (eq)	*br d* (12.6)	23.3, 52.0, 86.0
9	CH_2	19.2	1.57 (ax)	*tq* (4.5, 13.8)	32.6
			1.46 (eq)	*ddq* (13.8, 2.5, 4.5)	
10	CH_2	37.3	1.83 (ax)	*dt* (4.5, 13.5)	32.1, 29.3, 19.2
			1.13 (eq)	*dt* 13.5, 4.5)	
11	4°C	32.1	—	—	
12	CH_3	12.7	1.11	*s*	17.8, 23.3, 34.4, 86.0
13	CH_3	23.2	0.99	*s*	32.6, 34.4, 45.3, 52.0
14	CH_3	25.8	0.86	*s*	29.3, 32.1, 37.3, 52.0
15	CH_3	29.3	0.96	*s*	25.8, 32.1, 37.3, 52.0

Assignments were determined by consideration of data from ^{13}C–^1H COSY, ^1H–^1H COSY, NOESY, 500 MHz ^1H NMR as well as previous assignments for cyclomyltaylane (**4**) [7].

Table 2. ^1H NMR data* of cadinadiene derivatives **5**–**8**

H	**5**	**6**	**7**	**8**
1	0.85 *dq* (2.5, 12.5)	0.77 *dq* (2, 12)		0.80
2	1.10 (ax) *dq* (3.2, 12.5)	1.14 (ax) *dq* (4,12)		1.10 (ax)
	2.10 (eq) *m*	2.04 (eq)†		2.19 (eq)
3	2.11 (ax) *tt* (2.5, 13)	2.04 (ax)†		2.13 (ax)
	2.37 (eq) *md* (18)	2.06 (eq)†		2.44 (eq) *md* (18)
5	6.63 *s*	5.52 *s*	5.58 *s*	6.94 *s*
6	1.95†	1.78 *dt* (3.4, 11.4)		1.90
7	1.90 *dt* (3, 12)	1.73 *dt* (3.3, 13)		1.86
8	1.48 (ax) *dq* (3.5, 12)	1.43 (ax) *dq* (3.8, 13.3)		1.46
	1.72 (eq)	1.59 (eq) *dq* (13.1, 3.4)		1.70
9	1.12 (ax)	1.10 (ax) *dq* (4, 14)		?
	1.75 (eq)	1.72 (eq) *m*		1.76
10	1.23 *m*	1.17 *m*		1.16
12	4.76 *br s*	4.69 *br s*	4.69 *br s*	4.74 *br s*
	4.87 *br s*	4.77 *br s*	4.77 *br s*	4.84 *br s*
13	1.69 *br s*	1.64 *br s*	1.63 *br s*	1.66 *br s*
14	9.37 *s*	3.96 *s*	4.45 *s*	—
15	0.93 *d* (6.2)	0.90 *d* (6.0)	0.91 *d* (6.0)	0.94 *d* (6.1)
14-OAc	—	—	2.04 *s*	—

*Assignments of compounds **5** and **6** were determined by consideration of data from ^{13}C–H COSY, ^1H–^1H COSY, *J*-spectroscopy, NOEDs, decoupling experiments and 500 MHz ^1H NMR of **6**.

†Obscured.

collected at SK area [12] (in this paper the liverwort was misindentified as *Mannia subpilosa*). Now two other related new minor components have been isolated from the same species. Marchantin M (**10**) showed a strong molecular ion at *m/z* 454, corresponding to a formula of $C_{29}H_{26}O_5$ by HR-MS. Most of its ^1H and ^{13}C NMR signals appeared very close to those of marchantinquinone (**9**) except the ^{13}C absorptions on the B-ring (Tables 4 and 5). Judging from the adjacent nature of the two protons (δ6.62, *d* and 6.704, *d*, J = 8.6 Hz) on ring B, the two hydroxyl and methoxy substituents must be located at either C-10 or C-13. The final assignment of the

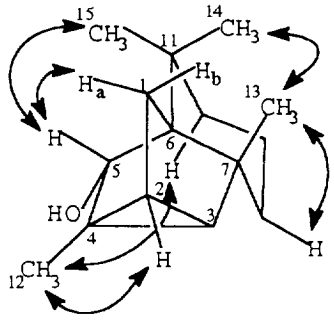

Fig. 1. Partial NOEs observed for **3**.

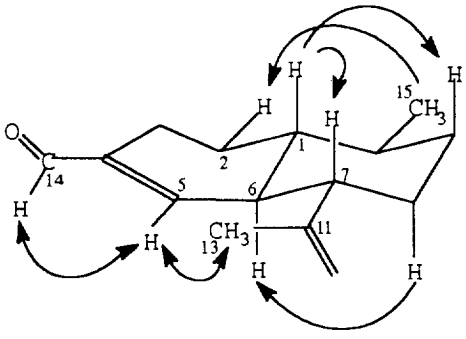

Fig. 2. Partial NOEs observed for **5**.

hydroxyl group at C-10 was based on the results of deuterium-induced ^{13}C chemical shifts. According to literature reports [13] exchange of the hydroxyl proton with deuterium results in an upfield shift of the carbons (in order of decreasing magnitude) *ipso*, *ortho* and *para* to the hydroxyl substituent. On the basis of our experiments

Table 3. ^{13}C NMR spectral data of cadinadiene derivatives **5**–**8**

C	5	6	7	8	Data of **8** from ref. [11]
1	45.8	46.3	46.0	45.5	36.8*
2	25.2	26.2	26.1	25.8	26.0
3	22.1	26.4	26.7	24.8	24.9
4	141.1	137.5	141.4	129.2	129.7
5	153.0	125.5	128.9	144.3	144.2
6	50.1	51.1	50.9	50.2	50.4
7	44.1	42.6	42.8	43.7	45.4*
8	32.5	32.5	32.5	32.6	NR
9	35.4	35.7	35.7	35.4	36.8
10	36.7	36.5	36.5	36.6	44.0*
11	147.1	148.4	148.2	147.3	147.4
12	112.5	111.6	111.6	112.4	112.4
13	19.2	19.1	19.1	19.3	19.4
14	194.7	67.4	68.7	171.8	173.4
15	19.6	19.7	19.7	19.6	19.6
14-OAc	—	—	19.6	—	—
	—	—	171.0	—	—

*Incorrect assignments.
NR: Not reported.

on several known phenolic and marchantin-type compounds, as well as data on marchantin M (**10**) (Table 5), the induced ^{13}C-shifts are evident particularly at the *ipso* ($-0.07 \sim 0.25$ ppm) and *ortho* ($-0.04 \sim -0.14$ ppm) positions. Therefore, the structure of marchantin M is established as **10**.

The molecular ion of marchantin N (**11**) had puzzled us somewhat, since the ion *m/z* 470 was stronger than that of *m/z* 468 (45 vs 20%) at 70 eV and the other way around (100 vs 40%) was observed at 20 eV. From the FAB-mass spectrum, a cluster of ions with *m/z* 470 (46%) as the center was obtained. The ^1H and ^{13}C NMR data of **11**

Table 4. ^1H NMR spectral data of marchantin compounds **10**, **11** and **13**

H	10	11	13
2, 6	6.58 *dd* (8.3, 1.8)	6.61 *dd* (8.4, 2.0)	6.56 *d* (8.4)
3, 5	6.97 *dd* (8.3, 1.8)	7.10 *dd* (8.4, 2.0)	6.94 *br d* (8.4)
7, 8	3.00 *br s* (4H)	2.85 *br s* (4H)	3.02 *br s* (4H)
10	—	—	7.05 *dd* (7.9, 1.4)
11	6.62 *d* (8.6)	—	7.18 *t* (7.9)
12	6.70 *d* (8.6)	5.73 *s*	6.81 *dd* (7.9, 1.4)
3′	5.46 *d* (1.9)	5.39 *d* (2.0)	5.51 *d* (2.0)
5′	6.70 *dd* (8.0, 1.9)	6.70 *dd* (8.0, 2.0)	6.71 *dd* (8.1, 2.0)
6′	6.86 *d* (8.0)	6.84 *d* (8.0)	6.85 *d* (8.0)
7′	2.79 *m* (2H)	2.79 *m* (2H)	2.81 *m* (2H)
8′	2.73 *m* (2H)	2.75 *m* (2H)	2.75 *m* (2H)
10′	6.66 *dd* (2.0, 1.8)	6.56 *dd* (2.6, 1.6)	6.55*
12′	6.33 *ddd* (7.7, 2.0, 0.8)	6.44 *ddd* (7.9, 2.6, 0.8)	6.40 *dd* (7.9, 2.0)
13′	6.85 *t* (7.7)	6.90 *t* (7.9)	6.88 *t* (7.9)
14′	6.21 *ddd* (7.7, 1.8, 0.8)	6.32 *ddd* (7.9, 1.6, 0.8)	6.26 *br d* (7.9)
	3.52 *s* (OMe-13)	3.52 *s* (OMe-11)	3.64 *s* (OMe-13)
	5.48 *s* (–OH)	5.46 *s* (–OH)	5.45 *s* (–OH)

*Obscured.

Table 5. ^{13}C NMR spectral data of marchantin compounds **9**–**13**

C	9	10 ($\Delta\delta_{D_2O}$)*	11 ($\Delta\delta_{D_2O}$)	12	13
1	153.1	152.65 (0.00)	152.66 (UD)†	152.8	152.6
2	121.3	121.44 (0.00)	121.61 (0.00)	121.3	121.3
3	129.8	129.90 (0.01)	129.83 (0.00)	129.6	129.7
4	137.8	139.90 (0.04)	138.59 (0.00)	139.1	139.1
5	129.8	129.90 (0.01)	129.83 (0.00)	129.6	129.7
6	121.3	121.44 (0.00)	121.61 (0.00)	121.3	121.3
7	33.8	34.27 (0.00)	33.29 (− 0.02)	35.3	35.8
8	25.7	26.27 (0.00)	26.07 (− 0.01)	30.3	30.2
9	134.0	123.95 (− 0.05)	130.10 (0.01)	136.1	136.5
10	187.9	146.34 (− 0.07)	165.45 (0.03)	122.0	122.4
11	136.8	110.84 (− 0.14)	149.98 (UD)	126.0	125.2
12	135.1	111.50 (0.03)	102.06 (− 0.01)	114.4	112.0
13	181.0	149.03 (0.00)	181.00 (UD)	148.7	152.4
14	152.5	152.50 (− 0.01)	154.39 (0.01)	139.6	141.2
1′	142.8	143.33 (− 0.10)	143.56 (− 0.25)	143.4	143.3
2′	145.4	146.01 (− 0.04)	146.22 (UD)	146.1	146.0
3′	115.6	115.75 (0.00)	115.43 (− 0.02)	115.6	115.5
4′	132.6	132.94 (− 0.01)	132.25 (− 0.01)	132.7	132.9
5′	122.7	122.14 (0.01)	122.42 (0.01)	122.4	122.3
6′	114.9	114.73 (− 0.07)	114.94 (− 0.07)	114.9	114.7
7′	34.7	35.14 (0.00)	35.14 (0.00)	34.0	34.4
8′	36.1	36.75 (0.00)	36.58 (− 0.01)	35.8	36.2
9′	143.6	142.06 (0.00)	143.00 (0.01)	143.1	141.9
10′	116.2	115.46 (0.01)	115.66 (0.00)	115.5	115.3
11′	156.8	158.05 (0.01)	157.45 (− 0.02)	156.7	158.0
12′	113.7	111.74 (0.01)	112.54 (− 0.01)	112.0	110.3
13′	128.3	127.76 (0.00)	128.28 (− 0.01)	128.9	128.0
14′	124.2	122.82 (0.00)	124.61 (0.00)	123.4	122.2
		56.42 (0.02)	56. 51 (0.01)		55.7
		(OMe-13)	(OMe-11)		(OMe-13)

*$\Delta\delta_{D_2O} = \delta_{D_2O} - \delta$.
δ_{D_2O}: Induced shifts upon addition of drops of D_2O.
δ: Original ^{13}C-shifts without D_2O addition.
†Not detected. The induced signal was too weak to be certain.

were again very similar to those of marchantinquinone (**9**) and marchantin M (**10**) except for the chemical shifts on the B-ring. The singlet proton peak at δ5.73 on the B-ring suggested the methoxy group either at C-11 or at C-12. As to the functional groups at C-10 and C-13, either a ketone (benzoquinone) or a hydroxyl (hydroquinone) group was present suggesting the molecular composition as $C_{29}H_{24}O_6$ or $C_{29}H_{26}O_6$. Although the ^{13}C-shifts of δ165.5 and 181.0 and the proton shift of δ5.73 favoured a benzoquinone skeleton for the B-ring, the deuterium-induced shift experiment was still carried out in order to prove the functional groups on the B-ring. Very minor shifts were induced on the carbons of the B-ring (Table 5), yet significant shifts occurred at C-1′ and C-6′. Hence a benzoquinone skeleton of the B-ring, the same as that in marchantinquinone (**9**), was assigned to marchantin N (**11**). Obviously, this benzoquinone structure is easily protonated under such mass spectral conditions to give a strong quasi-molecular ion of $[M + 2]^+$. The placement of the methoxy group at C-11 was mainly based on the ^{13}C NMR shifts of C-10 and C-13 as compared with data of relevent compounds [12, 14]. In addition, the HMBC data revealed that H-12 correlated with three carbons, C-14, C-10 and C-13 (δ154.4, 165.4 and 181.0, Table 5). Since for an aromatic system, *meta*-Cs usually show the strongest correlation and *para*-C is the weakest in an HMBC experiment, the proton placed at C-12 on ring B would best explain the observation.

As mentioned earlier, even though the sesquiterpene constituents of the two Taiwanese *R. hemisphaerica* oils from SK and YMS were identical, the cyclic bisbibenzyl ethers obtained were different. From the YMS oil, none of the aforementioned three marchantin-type compounds **9**–**11** were observed. Instead, the known marchantin C (**12**) [15] and its C_{13}-methyl ether (**13**) were isolated. Their ^{13}C NMR shifts are compiled in Table 5. Both **12** and **13** were recently reported in the Japanese *R. hemisphaerica* [2]. Compound **13** is named marchantin O. From the SK oil, α-zeroin (**2**) was also isolated and identified by comparison with the literature ^{13}C NMR data [16].

Marchantinquinone (**9**) showed 100% inhibition on the aggregation of washed rabbit platelets induced by thrombin (0.1 U ml^{-1}), arachidonic acid (100 μM), collagen (10 μg ml^{-1}) and PAF (2 ng ml^{-1}) at the

Table 6. Skeleton comparison of *R. hemisphaerica* from different locations

Location	Sesquiterpene	Cyclic bisbibenzyl	Triterpene
Japan	cuparane (**14**) aristolane (**16**)	riccardin C (**1**) marchantin (e.g. **12**)	hopane
France	cuparane (**14**) gymnomitrane (**15**)	(not detected)	hopane (e.g. **2**)
Taiwan	cuparane (**14**) cyclomyltaylane (**4**) cadinane (e.g. **5**–**8**)	marchantin (e.g. **9**–**13**)	hopane

100 μg ml^{-1} level. In collagen-induced aggregation, the antiplatelet effect was still obvious (25% inhibition) even down to the 2 μg ml^{-1} level [17].

In conclusion, on the basis of the sesquiterpene constituents, it seems that there are at least three chemotypes within the species of *R. hemisphaerica* as compared in Table 6. *Reboulia hemisphaerica* is distributed widely in the world, chemical analysis of this liverwort species from other localities certainly will provide more knowledge on the chemotaxonomy of this single species in the genus of *Reboulia*.

EXPERIMENTAL

NMR spectra were measured in $CDCl_3$ on Bruker AM-300WB and AM-400. EI- and HR-MS were taken at 70 eV unless otherwise specified. A DBWAX, 30 m × 0.25 mm (i.d.), fused silica capillary column was used for both GC and GC-MS. The column temp. was programmed from 50° to 220° at 5° min^{-1}. IR spectra were measured in $CHCl_3$ soln and the UV recorded in solvents as specified. Optical data were taken in $CHCl_3$ for $[\alpha]_D$ and in *n*-hexane for CD.

Plant material. Reboulia hemisphaerica (Linn.) Raddi collected from Shankon (SK), Taipei Hsien, was identified by Prof. N. Kitagawa (Nara University of Education, Japan) and the specimen from Yangming Shan (YMS), Taipei by Dr K. Yamada (Ise-shi, Japan). Both specimens are deposited at the Department of Chemistry, Tamkang University.

Extraction and isolation. For GC and GC-MS examinations, 5 g of each species was ground mechanically and extracted with EtOAc. After filtration through a small silica column, the concentrated filtrate was ready for analysis. From both SK and YMS oils, two major sesquiterpene hydrocarbons, α-cuprenene (area 10%, R_t = 20.0 min) and γ-cuprenene (5%, 20.5 min), were identified by GC-MS. In the oxygenated sesquiterpene region, five distinct peaks were observed, four of which were later determined to be **3** (7%, 29.7 min), **5** (45%, 32.5 min), **7** (2%, 33.8 min), and **6** (27%, 36.2 min) upon isolation. The other peak (4%, 33.3 min) was tentatively identified as another cadinadiene alcohol on the basis of MS ($[M]^+$ at *m/z* 220, base *m/z* 41), ^1H and ^{13}C NMR data.

For the material collected at the SK area, 35 g of frozen-crushed plants was repeatedly extracted with EtOAc and MeOH to furnish 1 g of greenish crude oil. Successive chromatographies of the oil on silica gel (*n*-hexane–EtOAc gradient) and Sephadex LH-20 ($CHCl_3$–MeOH, 1:1) afforded **5** (15 mg), **2** (20 mg) and **9** (19 mg) [12]. Compounds **3** (7 mg) and **6** (14 mg) were obtained by further purification through PGC [18]. Compounds **7** (6 mg), **10** (5 mg) and **11** (6 mg) were purified by prep. TLC from 5 and 50% EtOAc–*n*-hexane fractions, respectively. The material (300 g) collected at the YMS area was treated in the same manner to yield **8** (6 mg), **12** (6 mg) and **13** (15 mg), in addition to **5** (21 mg) and **6** (3 mg).

Cyclomyltaylan-5α-ol (**3**). $[\alpha]_D$ + 36.1° ($CHCl_3$; *c* 0.2). IR ν_{max} cm^{-1}: 3450. EI-MS *m/z* (rel. int.): 220 $[M]^+$ (32), 205 (68), 162 (77), 147 (88), 43 (90), 41 (100).

Cadina-4,11-dien-14-al (**5**). $[\alpha]_D$ + 5.8° ($CHCl_3$; *c* 0.5). IR ν_{max} cm^{-1}: 1721, 1686. UV λ_{max}^{MeCN} nm: 230 (log ε 3.61). EI-MS *m/z* (rel. int.): 218 $[M]^+$ (60), 148 (100), 107 (67), 91 (77), 79 (80), 41 (92).

Cadina-4,11-dien-14-ol (**6**). $[\alpha]_D$ + 7.1° ($CHCl_3$; *c* 0.45). IR ν_{max} cm^{-1}: 3460. UV λ_{max}^{MeCN} nm: 226 (log ε 2.92). EI-MS *m/z* (rel. int.): 220 $[M]^+$ (8), 189 (100), 135 (56), 105 (56), 91 (53), 79 (62), 41 (54).

14-Acetoxycadina-4,11-diene (**7**). EI-MS *m/z* (rel. int.): 262 $[M]^+$ (2), 202 (68), 187 (68), 91 (66), 43 (100).

Cadina-4,11-dien-14-oic acid (**8**). $[\alpha]_D$ − 5.1° ($CHCl_3$; *c* 0.2). CD: $\Delta\varepsilon_{253}$ − 0.35, $\Delta\varepsilon_{236}$ + 0.1 (lit. $[\alpha]_D$ + 32.9, $\Delta\varepsilon_{242}$ + 2.27, $\Delta\varepsilon_{220}$ − 1.20, $\Delta\varepsilon_{195}$ + 4.96 [11]). IR ν_{max} cm^{-1}: 3400–2500(br), 1690 and 1644. UV $\lambda_{max}^{n\text{-hexane}}$ nm: 216.6 (log ε 3.57). (lit. 223 (log ε 4.03) [11]). EI-MS *m/z* (rel. int.): 234 $[M]^+$ (54), 149 (100), 105 (50), 91 (64), 79 (72), 55 (62), 41 (84).

Marchantin M (**10**). UV λ_{max}^{EtOH} nm: 210.5 (log ε 4.48), 283 (log ε 3.73). EI-MS (20 eV) *m/z* (rel. int.): 454.1774 $[M]^+$ (100), $C_{29}H_{26}O_5$ calc. 454.1773, 227 (20), 213 (35), 211 (30).

Marchantin N (**11**). UV λ_{max}^{EtOH} nm: 206.5 (log ε 3.71). 276.5 (log ε 3.02); FAB-MS (pos.) *m/z* (rel. int.): 471 (19), 470 (45), 469 (26), 468 (12). EI-MS (20 eV): 470 $[M + 2]^+$ (90), 468 $[M]^+$ (100), 440 (50), 333 (60), 213 (30), 211 (36). EI-MS (70 eV): 470 $[M + 2]^+$ (46), 468 $[M]^+$ (20), 440 (12), 424 (68), 333 (28), 213 (50), 211(100).

Marchantin C (**12**). EI-MS *m/z* (rel. int.): 424.1680 $[M]^+$ (34), $C_{28}H_{24}O_4$ calc. 424.1674, 211 (48), 107 (42), 91 (35), 55 (70), 43 (100).

Marchantin O (**13**) UV λ_{max}^{EtOH} nm: 219 (log ε 4.30), 274 (log ε 3.75); IR ν_{max} cm^{-1}: 3515, 1594, and 1509; EI-MS *m/z* (rel. int.): 438.1817 $[M]^+$ (83), $C_{29}H_{26}O_4$ calc. 438.1831, 225 (27), 213 (38), 211 (100).

Acknowledgements—We thank Prof. N. Kitagawa and Dr K. Yamada for identification of specimens and the National Science Council of the Republic of China for financial support. Circular dichroism was performed at the Institute of Botany, Academia Sinica. The antiplatelet assays were carried out by Prof. Teng, Che-Ming (Pharmacological Institute, College of Medicine, National Taiwan University).

REFERENCES

1. Inoue, H. (1976) *Illustrations of Japanese Hepaticae.* Tsukiji Shokan, Tokyo.
2. Hashimoto, T., Asakawa, Y., Nakashima, K. and Tori, M. (1993) *J. Hattori Bot. Lab.* **74**, 121.
3. Morais, R. M. S. C., Harrison, L. J. and Becker, H. (1988) *J. Chem. Res. (S)* 380.
4. Morais, R. M. S. C., Harrison, L. J. and Becker, H. (1991) *Phytochemistry* **30**, 1013.
5. Wu, C.-L. (1992) *J. Chin. Chem. Soc.* **39**, 655.
6. Ma, S.-J. (1992) MS thesis. Tamkang University.
7. Wu, C.-L. and Chang, S.-J. (1992) *Phytochemistry* **31**, 2150.
8. Takaoka, D., Matsuo, A., Kuramoto, J., Nakayama, M. and Hayashi, S. (1985) *J. Chem. Soc., Chem. Commun.* 482.
9. Takaoka, D., Tani, H. and Matsuo, A. (1988) *J. Chem. Res. (S)* 130.
10. Asakawa, Y., Toyota, M., Ueda, A., Tori, M. and Fukuzawa, Y. (1991) *Phytochemistry* **30**, 3037.
11. Hosozawa, S., Miura, I., Kido, M., Munoz, O and Castillo, M. (1985) *Phytochemistry* **24**, 2317.
12. Wei, H.-C. and Wu, C.-L. (1991) *J. Chem. Res. (S)* 230.
13. Huber, E. W. and Parker, R. A. (1990) *J. Org. Chem.* **55**, 1274.
14. Toda, F. (1981) *Handbook of* ^{13}C *NMR Spectra pp.* 98–99, Sankyo, Japan.
15. Tori, M., Toyota, M., Harrison, L. J., Takikawa, K. and Asakawa, Y. (1985) *Tetrahedron Letters* **26**, 4735.
16. Elix, J. A., Whitton, A. A. and Jones, A. J. (1982) *Aust. J. Chem.* **35**, 641.
17. Liao, C.-H. (1994) MS thesis. National Taiwan University.
18. Wei, H.-C. and Wu, C.-L. (1991) *J. Chromatog.* **555**, 302.