Pergamon

Phytochemistry, Vol. 47, No. 8, pp. 1621–1630, 1998

Printed in Great Britain
0031-9422/98 $19.00+0.00

PII: S0031-9422(97)00833-9

JATROPHANE DERIVATIVES AND A REARRANGED JATROPHANE FROM *EUPHORBIA TERRACINA*

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(*Received in revised form* 6 *August* 1997)

Key Word Index—*Euphorbia terracina*; Euphorbiaceae; diterpenes; polyoxygenated jatrophanes; rearranged jatrophane.

Abstract—The aerial parts of *Euphorbia terracina* yielded 11 new jatrophane derivatives as well as a further diterpene displaying the novel 1(15 → 14)*abeo*-jatrophane framework. © 1998 Published by Elsevier Science Ltd. All rights reserved

INTRODUCTION

Within the family Euphorbiaceae, the sixth largest among flowering plants, the genus *Euphorbia* L., with well over 1000 species [1, 2], has been the object of numerous chemical and pharmacological investigations [3–6]. Within our recently started research program on the chemistry of this genus, we have recently reported on the isolation from the aerial parts of *E. terracina* L. of several bishomoditerpene lactones bearing the novel 17-ethyljatrophane framework [7–9]. In the present communication, we report on the isolation from the title plant and structure elucidation of further diterpene constituents

RESULTS AND DISCUSSION

An extract of *E. terracina* gave, in addition to terracinolides [7–9], 11 new highly oxygenated jatrophane polyesters **1**–**11**, and the diterpene **12**, with a novel carbon framework derived from the former by skeletal rearrangement.

The ^{1}H- and ^{13}C-NMR data of compounds **1**–**4** (Tables 1 and 2) were very similar to each other, which suggested that the compounds were closely related (compound **4** could only be obtained in mixtures with **2** or **3**). The characteristic signals in the high-field zone of the ^{1}H NMR spectrum indicated the presence of *iso*butyrate (2-methylpropionate) and/or 2-methylbutyrate residues. The molecular formulae were established in each case from a combination of ^{13}C NMR and HRMS data. After discounting the contribution of the ester residues, all four compounds were shown to be triacyl derivatives of the same parent oxygenated diterpene with the molecular formula $C_{20}H_{32}O_7$, six hydroxyl groups, a ketone carbonyl, a *trans*-disubstituted C=C bond and an exocyclic methylene C=CH_2. The structure, therefore, contains two carbocycles. Extensive NMR experiments, particularly spin decoupling and 2D heteronuclear correlations (HMQC/HMBC, see Table 3), led to the conclusion that the parent diterpene was based on the jatrophane framework functionalized at C-2, 3, 5, 7, 8, 9 and 15 (hydroxyl groups), and C-14 (ketone carbonyl). The *trans*-disubstituted C=C bond connects C-11 and C-12, and the exocyclic methylene is situated between C-6 and C-17. The locations of the ester residues at C-5, C-7 and C-8 was suggested by ^{1}H chemical shifts and confirmed through observation of various long-range H—C—O—COR correlations [7–9].

The stereochemical aspects were investigated by means of NOE experiments (Table 3), aided by consideration of coupling constants values and literature data on jatrophane derivatives. The structures of related bishomojatrophane lactones [7–9] were also taken into account. Twelve-membered carbocycles such as that present in compounds **1**–**4** are known to be conformationally quite flexible. In spite of this, the NMR spectra of these compounds are rather sharp, which means that the molecules are most likely undergoing fast interconversions between two or more conformations. In order to obtain an insight into this aspect, molecular mechanics calculations have been performed on this bicyclic backbone. A detailed discussion of the conformational behaviour of the jatrophane system will be published elsewhere [10], but we will comment here on some outstanding aspects. The hydrogen H-4 was taken as the reference point for the

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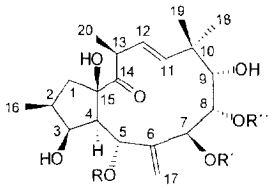

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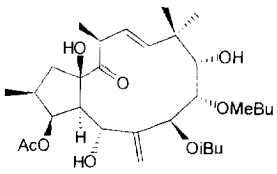
2 R=R′=R″= iBu
3 R=R″= MeBu R′= iBu
4 R, R′, R″= 2 iBu, MeBu



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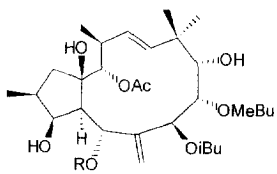
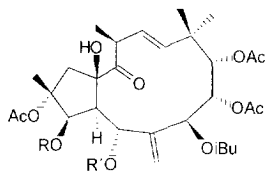
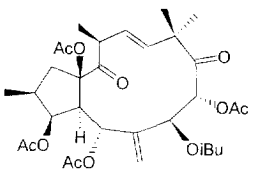


6 R=iBu
7 R=MeBu



8 R=Ac R′=iBu
9 R=Ac R′=Ph
10 R=BzOCH$_2$CO R′=Ac



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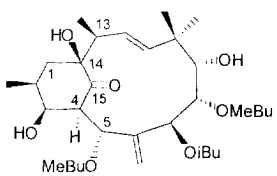

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evaluation of NOEs and put arbitrarily in the depicted α orientation, as in the terracinolides [7–9]. The existence of a NOE between H-4 and H-13 indicates that H-13 is also α orientated. Other NOEs (Table 3) reveal that H-7 and H-11 are equally situated below the mean molecular plane, whereas H-8, H-9, H-12 and H-19 lie above it. On the basis of these assumed configurations and molecular mechanics calculations, this jatrophane system turns out to exhibit two main conformations (Scheme 1), which differ in the spatial orientation of the C6-C17 exo-methylene group with respect to the macrocycle (in order to avoid a blurred structure drawing, the acyl groups have been manually eliminated from the optimized conformation and substituted for hydrogen atoms). In one of the conformations (type 1, see Scheme 1), the exo-methylene group points inwards, which causes H-4 and H-5 to be almost anti-coplanar and $J_{4,5}$ to be in the range 9–11 Hz. In the other conformation (type 2), the exo-methylene points outwards and $J_{4,5}$ has a small value (0–4 Hz, corresponding to a dihedral angle of 75–95°). A further factor controlling the conformation of the macrocycle is the configuration at C-13, where the methyl group (C-20) tends to occupy an equatorial-like arrangement. The strong NOE of H-20 with H-12 and the absence of NOE between H-20 and H-11 supports this idea.

Both types of conformations allow the prediction of NOEs between various hydrogen pairs such as H-4/H-7, H-9/H-18, H-9/H-19, H-11/H-13, H-11/H-18, H-12/H-19, etc. These effects are actually observed in most cases (Table 3) and were the basis for the proposed configurations at the stereogenic centres. But in addition to these, other NOEs arise specifically in only one conformation type. For instance, the NOEs between the hydrogen pairs H-4/H-5, H-5/H-8 (strong) and H-3/H-17 (weak) are only possible in the type 2 conformation. A very small $J_{4,5}$ value is predicted for this conformation, which is in accord with the experimental value (Table 1). It thus seems that compounds **1**–**4** display very predominantly a type 2 conformation.

Compound **5**, a triester with an acetate, an isobutyrate and a methylbutyrate group, was closely related to **1**–**4**, as judged from the chemical shift data and coupling constant values (Tables 1 and 2). The marked differences in the chemical shifts of H-3 and H-5 suggested, however, an acyloxy group at C-3 and a free OH at C-5. The NMR data, including HMBC correlations, indicated the relative positions of the ester groups. Coupling constants and NOE measurements indicate that **5** behaves conformationally as **1**–**4**.

More pronounced structural changes were evident in the case of compounds **6** and **7** (Tables 1 and 2). The ketone carbonyl group at C-14 was replaced by an acylated secondary alcohol. Both compounds were tetraacyl derivatives of the same parent jatrophane heptaol, with *iso*butyrate, 2-methylbutyrate and acetate residues being bound to C-7, C-8 and C-14, respectively (HMBC results). The only difference between **6** and **7** was the acyl group at C-5, which was an *iso*-butyrate in the former and a 2-methylbutyrate in the latter. Coupling constant values suggested the same configurational and conformational features as above. The practically zero value of the coupling constant $J_{13,14}$ may be compatible in principle with either configuration at C-14, but the absence of visible NOEs of H-14 with protons of the opposite part of the twelve-membered ring (H-5, H-17) favour the proposed configuration.

Compounds **8**–**10** were also closely related to each other as well as to **1**–**5**. They also bear a carbonyl group at C-14 but, in relation to the latter, they display

Table 1. ^{1}H NMR data of jatrophane derivatives **1**–**7**

H	**1***	**2***	**3***	**4***	**5†**	**6‡**	**7‡**
1α	2.45 *dd* (14; 11)	2.44 *dd* (14; 11)	2.43 *dd* (14; 11)	2.44 *dd* (14; 11)	2.40 *m*§	2.10 *m*§	2.15 *m*§
1β	1.45 *m*§	1.50 *dd* (14; 7.5)	1.45 *m*§	1.45 *m*§	1.65 *m*§	1.55 *m*§	1.69 *m*§
2	2.30 *m*§	2.30 *m*§	2.30 *m*§	2.30 *m*§	2.40 *m*§	2.10 *m*§	2.15 *m*§
3	4.18 *ddd*	4.19 *ddd*	4.18 *ddd*	4.18 *ddd*	5.59 *dd*	4.16 *ddd*	4.16 *ddd*
	(8; 4; 3.5)	(8; 4; 3.5)	(8; 4; 3.5)	(8; 4; 3.5)	(4; 4)	(7.5; 4; 3)	(7.5; 4; 3)
4	2.76 *br s*	2.75 *br s*	2.74 *br s*	2.74 *br s*	2.85 *br s*	2.35 *m*§	2.35 *m*§
5	5.23 *s*	5.23 *s*	5.21 *s*	5.21 *s*	4.05 *d* (1.5)	5.80 *br s*	5.79 *br s*
7	5.38 *s*	5.37 *s*	5.34 *s*	5.35 *s*	5.38 *s*	5.40 *s*	5.42 *s*
8	4.98 *s*	4.93 *s*	4.97 *s*	4.95 *s*	4.79 *s*	5.18 *s*	5.18 *s*
9	3.54 *s*	3.57 *s*	3.53 *s*	3.54 *s*	3.48 *s*	3.62 *br s*	3.61 *br s*
11	5.97 *d* (16)	5.96 *d* (16)	5.95 *d* (16)	5.95 *d* (16)	5.96 *d* (16)	5.77 *d* (16)	5.76 *d* (16)
12	5.40 *dd* (16; 9.5)	5.40 *dd* (16; 9.5)	5.40 *dd* (16; 9)	5.40 *dd* (16; 9)	5.26 *dd* (16; 9.5)	5.55 *dd* (16; 9)	5.55 *dd* (16; 9)
13	3.70 *dq* (9.5; 6.5)	3.69 *dq* (9.5; 6.5)	3.68 *dq* (9; 7)	3.68 *dq* (9; 7)	3.66 *dq* (9.5; 6.5)	2.45 *dq* (9; 7)	2.45 *dq* (9; 7)
14		—		—	—	4.98 *s*	4.98 *s*
16	1.16 *d* (7)	1.14 *d* (7)	1.13 *d* (7)	1.13 *d* (7)	1.00 *d* (6.5)	1.10 *d* (6.5)	1.10 *d* (6.5)
17	5.21 *br s*	5.23 *br s*	5.21 *br s*	5.22 *br s*	5.26 *br s*	5.08 *s*	5.07 *s*
	5.05 *br s*	5.05 *br s*	5.03 *br s*	5.04 *br s*	5.10 *d* (1)	5.02 *s*	5.01 *s*
18	1.07 *s*	1.07 *s*	1.06 *s*	1.06 *s*	1.06 *s*	1.05 *s*	1.05 *s*
19	1.20 *s*	1.19 *s*	1.18 *s*	1.06 *s*	1.08 *s*	1.24 *s*	1.25 *s*
20	1.24 *d* (6.5)	1.24 *d* (6.5)	1.22 *d* (7)	1.22 *d* (7)	1.28 *d* (6.5)	1.20 *d* (7)	1.20 *d* (7)
OAc	—		—	—	2.04 *s*	2.11 *s*	2.11 *s*
OCOR	2.40–2.30 *m*	2.60 *sept* (7)	2.60 *sept* (7)	2.60 *sept* (7)	2.65 *sept* (7)	2.60 *sept* (7)	2.61 *sept* (7)
	1.70–1.40 *m*	2.60–2.50 *m*§	2.35 *m*§, 1.65 *m*	2.50 *sept* (7)	2.40 *m*§	2.57 *sept* (7)	2.50 2.35 *m*§
	1.14 *d*, 1.00 *d*	1.21 *d*, 1.20 *d*	1.45 *m*§, 1.18 *d* (7)	2.45–2.25 *m*§	1.65 *m*§, 1.45 *m*	2.40–2.30 *m*§	1.65 *m*§, 1.45 *m*§
	0.92 *d* (7)	1.13 *d*, 1.12 *d*	1.09 *d*, 1.07 *d* (7)	1.65 *m*, 1.45 *m*§	1.24 *d*, 1.22 *d*	1.55 *m*§, 1.45 *m*§	1.20–1.10§
	0.93 *t*, 0.85 *t*	(7)	0.84 *t*, 0.79 *t*	1.18 *d*, 1.09 *d*	1.12 *d* (7)	1.20–1.10§	1.20 *d* (7)
	0.81 *t* (7.5)		(7.5)	1.07 *d* (7)	0.86 *t* (7.5)	0.87 *t* (7.5)	0.87 *t* (7.5)
				0.80 *t* (7.5)			0.83 *t* (7.5)

δ in ppm and J (parentheses) in Hz (400 MHz, $CDCl_3$, 22 C).
* 3-OH: 3.10 *d* (3); 9-OH: 2.15 *br s*; 15-OH: 4.30 *s*.
† 5-OH: 4.45 *s*, 9-OH: 2.00 *s*, 15-OH: 5.00 *s*.
‡ 3-OH: 2.80 *d* (7.5); 9-OH: 2.00 *s*; 15-OH: 3.00 s.
§ Overlapped signal.

Table 2. ^{13}C NMR data of jatrophane derivatives **1–7**

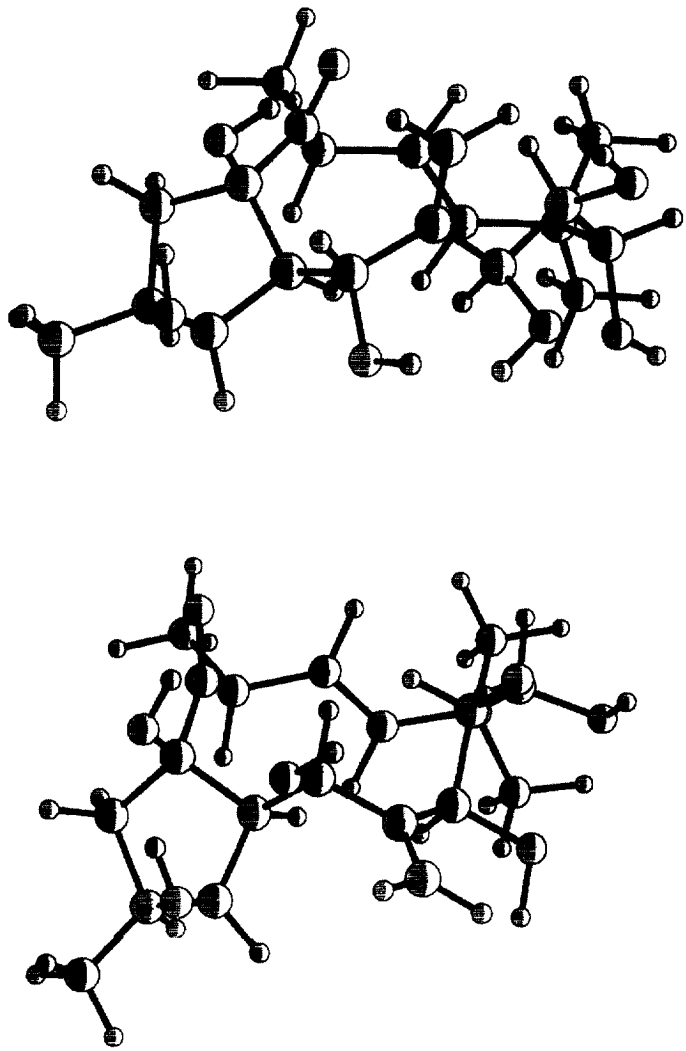
C	1	2	3	4	5	6	7
1	44.9	45.0	44.9	45.0	45.2	45.1	45.2
2	38.0	38.0	37.9	38.0	37.7	35.9	35.9
3	75.6	75.6	75.5	75.6	76.1	77.0	77.1
4	50.1	50.2	50.1	50.2	51.2	47.0	47.0
5	68.5	68.6	68.5	68.6	68.8	71.0	71.1
6	145.6	145.5	145.4	145.4	145.2	145.4	145.3
7	68.9	69.0	69.0	69.1	68.7	69.3	69.1
8	72.0	72.2	71.9	72.1	71.5	72.2	72.2
9	81.6	81.4	81.6	81.6	81.9	81.1	81.4
10	41.0	41.0	40.9	41.0	41.0	40.9	40.9
11	137.9	137.8	137.8	137.9	137.8	134.5	134.4
12	128.5	128.5	128.5	128.5	128.1	130.0	130.0
13	44.3	44.3	44.3	44.3	44.6	37.3	37.3
14	212.8	212.7	212.7	212.7	212.8	80.6	80.6
15	88.7	88.5	88.6	88.6	88.9	84.2	84.2
16	14.9	14.9	14.9	14.9	14.1	15.0	15.0
17	110.6	110.6	110.5	110.6	112.1	109.2	109.2
18	26.7	26.7	26.7	26.7	26.5	26.3	26.3
19	23.3	23.3	23.3	23.3	23.1	24.2	24.2
20	19.9	19.9	19.8	19.9	19.8	23.6	23.6
OAc	—	—	—	—	170.1 21.2	171.2 20.7	171.1 20.7
OCOR	175.3/175.2/ 174.3, 41.3/ 41.2/41.0, 26.6/26.5/ 16.6/16.3, 11.7/11.6/11.3	175.8/175.5/ 174.7, 34.1 (×3), 19.2/18.9/18.8, 18.6	175.5/174.3, 175.2, 41.2/40.9, 34.0, 26.6/26.4, 16.6/16.2, 11.5/11.4	175.5/175.3, 174.6, 41.0, 34.1 (×2), 18.9/18.7 (×2), 18.6, 16.6, 11.4	175.6, 175.3, 41.1, 34.1, 26.6, 18.9/18.7, 11.6	175.7, 175.3, 173.8, 41.3, 26.6, 34.1 (×2), 18.7, 16.2, 11.6	175.3, 175.2, 173.8, 41.3/41.0, 26.7/26.5, 34.1, 18.9/18.7, 16.6/16.1, 11.5/11.4

δ in ppm (100 MHz, $CDCl_3$, 22°C).
Signals have been assigned by means of 2D-NMR experiments.

Table 3. NOE and HMBC data for jatrophanes **1** and **3**

H	NOE with H	C	HMBC with H	C	HMBC with H
3	2, 4, 17	2	1	13	11, 20
4	2, 3, 5, 7, 13	3	1, 4, 5	14	1, 4, 20, 15-OH
5	4, 8, 15-OH	4	5	15	4, 15-OH
7	4, 8, 17	5	17, 17′	17	5, 7
8	5, 7, 9, 19	6	7, 8, 17, 17′	19	11
9	8, 18, 19	7	9	CO_{MeBu}	5, 7, 8 (**1**)
11	13, 18	8	9	CO_{MeBu}	5, 8 (**3**)
12	19	9	18, 19	CO_iBu	7 (**3**)
13	1α, 4, 11, 20	10	9, 18, 19		
17	17′	11	9, 18, 19		
17′	17	12	20		

an additional oxygen function at C-2. In fact, the NMR and MS data indicated that **8** and **9** were the hexaacyl derivatives of the same heptahydroxy jatrophane (Tables 4 and 5). Consideration of the chemical shift values and HMBC correlations revealed the presence of acetoxy groups at C-3, C-8 and C-9, an *iso*-butyrate group at C-7, and a free OH group at C-15 (long-range correlation of 15-OH with C-14). The only difference found resided in the acyl residue at C-5, which was a second *iso*butyrate group in **8** and a benzoate group in **9**. But the most novel situation was present in the case of **10**. While the same parent jatrophane with *six* acyl groups and a free OH group seemed to be present, the ^{13}C NMR data (Table 4) unequivocally indicated the presence of *seven* ester carbonyls. Furthermore, an AB system (J = 16 Hz)



Scheme 1. Calculated conformations of type 1 (above) and type 2 (below) for jatrophoanes **1–4** (for the sake of clarity, the acyl groups have been substituted for hydrogen atoms).

was visible in the ^{1}H NMR spectrum at δ 4.99 and 4.80. These signals showed long-range correlations with *two* carbonyl signals at δ 166.3 and 165.8. The former of these further showed a long-range correlation with the signal of H-3. An additional evidence came from NOE measurements: irradiation of H-16 (methyl group) produced a NOE at the doublet at δ 4.80 and at the *ortho* protons of the aromatic ring. The only way of explaining these facts was by assuming that the 3-OH group was acylated with benzoyloxyacetic acid, a most unusual feature, which has not been observed in natural products so far, to the best of our knowledge. An intense peak at *m/z* 163 in the mass spectrum, which coincided in mass with that expected for the benzoyloxyacetyl cation ($PhCOOCH_2{\equiv}O^+$), strongly supported the above conclusion. A structurally related case is the presence of hydroxyacetate and acetoxyacetate residues in diterpenes isolated from *E. paralias* [11] and *E. segetalis* (see accompanying communications).

The main difference in compound **11** to those previously discussed was the presence of two ketone carbonyl groups (Table 5). When compared with the NMR data of jatrophanes **1–4**, the absence of a signal attributable to H-9 and the marked downfield shift of the ^{13}C signal of C-10 were outstanding spectral features. The second ketone group, therefore, was at C-9. No free OH groups were present (IR) but five ester residues, four acetates and one isobutyrate, were present as shown by their carbonyl ^{13}C NMR signals. Through HMBC correlations they were located at C-3, C-5, C-8 (acetates) and at C-7 (*iso*butyrate). The fourth acetate group was consequently bound to the tertiary alcohol group at C-15, a fact revealed by the marked upfield shifts in the signals of C-1 and C-14, and by a downfield shift of the C-15 signal. It is worth mentioning here that, in contrast to the other jatrophane derivatives discussed above, **11** showed a rather large value (9 Hz) for $J_{4,5}$ similar to that observed in esulon A [12]. This suggested that compound **11** had

Table 4. ^{1}H NMR data of jatrophane derivatives **8**–**11**

H	**8***	**9***†	**10**‡	**11**
1α	2.79 *d* (15)	2.87 *d* (15)	2.78 *d* (15)	2.90 *dd* (15; 8)
1β	2.00 *d* (15)	2.08 *d* (15)	2.02 *d* (15)	2.10 *dd* (15; 4)
2	—	—	—	2.34 *m*
3	5.67 *d* (5.5)	5.77 *d* (5.5)	5.80 *d* (5)	5.56 *t* (3.5)
4	3.36 *dd* (5.5; 2.5)	3.51 *dd* (5.5; 2.5)	3.38 *dd* (5; 2.5)	2.76 *dd* (9; 3.5)
5	5.28 *br s*	5.49 *br s*	5.31 *br s*	5.66 *br d* (9)
7	5.64 *s*	5.70 *s*	5.65 *s*	5.82 *s*
8	4.96 *br s*	5.10 *s*	5.00 *s*	5.31 *s*
9	4.92 *s*	4.96 *s*	4.92 *s*	
11	5.98 *d* (16)	6.02 *d* (16)	5.96 *d* (16)	5.96 *d* (16)
12	5.47 *dd* (16; 9.5)	5.52 *dd* (16; 9.5)	5.46 *dd* (16; 9.5)	5.89 *dd* (16; 8.5)
13	3.84 *dq* (9.5; 7)	3.88 *dq* (9.5; 7)	3.83 *dq* (9.5; 7)	3.42 *dq* (8.5; 7)
16	1.54 *s*	1.57 *s*	1.60 *s*	1.00 *d* (6.5)
17	5.11 *br s*	5.14 *br s*	5.16 *br s*	5.50 *s*
	4.96 *br s*	5.04 *br s*	5.13 *br s*	5.45 *s*
18	0.93 *s*	0.95 *s*	0.94 *s*	1.21 *s*
19	1.26 *s*	1.33 *s*	1.26 *s*	1.29 *s*
20	1.24 *d* (7)	1.26 *d* (7)	1.27 *d* (7)	1.39 *d* (7)
OAc	2.16 *s*, 2.10 *s*	2.19 *s*, 2.10 *s*	2.17 *s*, 2.07 *s*	2.13 *s*, 2.10 *s*
	2.04 *s*, 2.00 *s*	2.04 *s*, 2.00 *s*	2.03 *s*, 2.02 *s*	2.04 *s*, 1.89 *s*
OCO*i*Pr	2.60 *sept* (7)	2.55 *sept* (7)	2.58 *sept* (7)	2.46 *sept* (7)
	2.49 *sept* (7)	1.20 *d*, 1.17 *d* (7)	1.19 *d*, 1.16 *d* (7)	1.17 *d*, 1.10 *d* (7)
	1.22 *d*, 1.18 *d*			
	1.16 *d*, 1.14 *d* (7)			

δ in ppm and J (parentheses) in Hz (400 MHz, $CDCl_3$, 22 C).

* 15-OH: 4.05 *s*.

† OBz: 8.05 *dd* (7.5; 2), 7.52 *tt* (7.5; 2), 7.42 *t* (7.5).

‡ $OCOCH_2OCOPh$: 8.07 *dd* (7.5; 1.5), 7.57 *tt* (7.5; 1.5), 7.44 *t* (7.5), 4.99 *d* (16), 4.80 *d* (16).

a strong preference to remain in a type 1 conformation, a conclusion supported for instance by a clear NOE between H-5 and H-17. However, the observation of another clear NOE between H-5 and H-8, only possible in a conformation of type 2, indicated that the latter plays a significant role in the conformational behaviour of **11**.

Compound **12** had many features in common with **3**, among them the molecular formula, $C_{34}H_{54}O_{10}$, the functional groups (one ketone, three hydroxyl groups, three ester moieties) and the type of ester residues. Nevertheless, the NMR spectra were different (see Table 6). The hydrogen connectivities, as deduced from extensive decoupling experiments, were also the same as in **3**. The clue for the structure came from a careful examination of the HMBC correlations. A distinct one was visible between the signals from H-3 and from the keto carbonyl group. This and a second correlation between H-20 and a signal at δ 79.8 from an oxygenated carbon could not be explained on the basis of the jatrophane framework, as both would mean the less likely observation of four-bond correlations. The 1(15 → 14)*abeo*-jatrophane structure **12** accounts for these facts. Furthermore, a clear NOE between H-2 and H-13, which are too far of each other in the jatrophane system, not only supports the proposed carbon framework but also excludes the possibility of the formation, mechanistically also feasible, of the isomeric 4(15 → 14)*abeo*-jatrophane system.

The aforementioned novel carbocyclic system has not been described so far in the literature, to the best of our knowledge. It is probably formed from **3** by a rearrangement of the α-ketol type [13, 14] (Scheme 2). The α-ketol rearrangement may be induced to occur by either acid or basic catalysis. In order to exclude the possibility of compound **12** being fortuitously formed by some type of catalytic effect during isolation, the putative precursor **3** was treated with acetic acid, with or without added sodium acetate, at either room temperature or in a water bath. Aside from a partial recovery of the starting compound, only ill-defined decomposition products were obtained. This excludes the possibility of **12** being an artifact formed during the isolation.

The structures proposed for compounds **1**–**11** are essentially coincident in their stereochemical details with those of the bishomojatrophane lactones reported previously [7–9]. This supports the idea that the latter compounds are biogenetically formed by attachment of a C_2 unit to C-17 of a jatrophane precursor of the type described here [7–9].

Table 5. ^{13}C NMR data of jatrophane derivatives **8–11**

C	**8**	**9***	**10†**	**11**
1	51.1	50.8	51.4	44.6
2	88.8	89.1	88.3	38.6
3	77.4	77.9	78.1	76.3
4	47.4	47.5	47.6	49.6
5	67.3	68.8	67.8‡	71.5
6	144.7	144.1	143.6‡	137.3
7	67.0	66.9	67.1	63.4
8	70.6‡	70.8‡	70.5‡	73.8
9	80.0‡	80.2‡	80.1‡	204.7
10	40.5	40.6	40.6	49.0
11	137.6	137.6	137.8	135.0
12	129.3	129.5	129.2	133.3
13	43.9	44.0	43.8	43.2
14	211.6	211.7	211.6	203.9
15	87.4	87.5	87.0	90.4
16	20.4	20.6	20.3	13.6
17	112.2‡	112.8‡	113.8	122.5
18	26.1‡	26.2‡	26.0	23.7
19	23.2‡	23.2‡	23.3	25.9
20	19.8	19.8	20.0	20.1
OAc	170.2/169.8/169.5/169.4	170.2/169.9/169.6/169.5	170.0/169.9/169.6/169.3	170.1/169.7/169.0/168.8
	22.3/21.1/20.6/20.5	22.3/21.2/20.7 (×2)	22.3/21.1/20.7/20.6	21.2/20.9/20.7/20.4
OCO*i*Pr	175.5/175.0	175.4	175.6	176.3
	34.0/33.7	33.7	33.8	33.7
	19.3/18.8	19.2/18.3	19.2/18.3	19.4/18.0
	18.6/18.2			

δ in ppm (100 MHz, $CDCl_3$, 22 C).
Signals have been assigned by means of 2D-NMR experiments.
* OBz: 165.1, 132.9, 130.2, 129.8, 128.2.
† $OCOCH_2OCOPh$: 166.3 ($OCOCH_2$), 165.8 (benzoate), 133.4, 129.9 (×2), 128.4, 61.0.
‡ Broadened signal.

EXPERIMENTAL

All types of spectral and physical measurements as well as chromatographic systems are as previously reported [7–9].

Plant material

The plant material has been previously described [7–9].

Extraction and chromatography

The initial phases of treatment of the plant material have been already detailed [7–9]. From fr. B, after CC on silica gel (elution with hexane–Et_2O 1:2 → hexane–Et_2O 1:5) and, where necessary, prep. TLC and/or HPLC, the following compounds were isolated (in order of increasing polarity): **1** (26 mg), **2** (27 mg), **3** (104 mg), **4** (40 mg, mixed with **2** and **3**), **7** (7 mg), **12** (7 mg), **6** (11 mg), **8** (22 mg), **5** (5 mg), **11** (11 mg), **9** (40 mg) and **10** (23 mg).

(2S,3S,4S,5R,7S,8S,9S,11E,13S,15R)-3,5,7,8,9,15-*Hexahydroxyjatropha*-6(17),11-*dien*-14-*one* 5,7,8-*tris*(2-*methylbutyrate*) (**1**). Oil, $[\alpha]_D$ +71° ($CHCl_3$; *c* 1.9); IR ν_{max}^{film} cm^{-1}: 3450 (*br*, OH), 1744, 1728, 1713 (*br*, ester and ketone C=O); EIMS (probe) *m/z* (rel. int.): 636.3876 $[M]^+$ (1), 618 $[M-H_2O]^+$ (1), 590 $[M-CO-H_2O]^+$ (1), 302 $[M-CO-3\times$ *sec*BuCOOH$]^+$ (50), 206 (30), 96 (33), 85 (42), 57 (100). Calc. for $C_{35}H_{56}O_{10}$, M_r = 636.3873; NMR: Tables 1 and 2.

(2S,3S,4R,5R,7S,8S,9S,11E,13S,15R)-3,5,7,8,9,15-*Hexahydroxyjatropha*-6(17),11-*dien*-14-*one* 5,7,8-*tris*(2-*methylpropionate*) (**2**). Oil, $[\alpha]_D$ +78° ($CHCl_3$; c 1); IR ν_{max}^{film} cm^{-1}: 3450 (*br*, OH), 1744, 1736, 1709 (*br*, ester and ketone C=O); EIMS (probe) *m/z* (rel. int.): 594.3390 $[M]^+$ (1), 576 $[M-H_2O]^+$ (1), 548 $[M-CO-H_2O]^+$ (1), 460 $[M-CO-H_2O-i$PrCOOH$]^+$ (1), 372 $[M-CO-H_2O-2\times i$PrCOOH$]^+$ (8), 302 $[M-CO-3\times i$PrCOOH$]^+$ (53), 284 $[M-CO-H_2O-3\times i$PrCOOH$]^+$ (23), 206 (54), 96 (61), 71 (100), 57 (24). Calc. for $C_{32}H_{50}O_{10}$, M_r = 594.3404; NMR: Tables 1 and 2.

(2S,3S,4R,5R,7S,8S,9S,11E,13S,15R)-3,5,7,8,9,15-*Hexahydroxyjatropha*-6(16),11-*dien*-14-*one* 5,8-*bis*(2-*methylbutyrate*) 7-(2-*methylproprionate*) (**3**). Oil, [α]

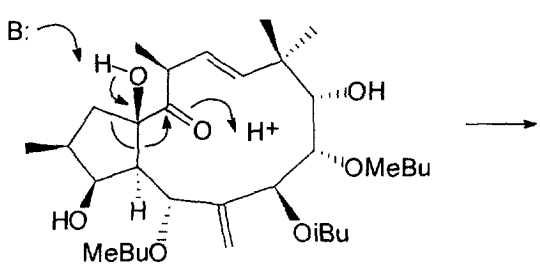
Table 6. ^{1}H- and ^{13}C-NMR data of the rearranged jatrophane **12**

H		C	
1α	2.15 *m**	1	40.2
1β	1.70 *m**	2	33.0
2	2.20 *m**	3	74.0
3	3.74 *m*	4	52.9
4	3.69 *dd* (10.5; 2.5)	5	74.9
5	5.78 *d* (10.5)	6	140.9
7	5.95 *s*	7	65.4
8	5.08 *s*	8	72.8
9	3.40 *d* (5)	9	82.6
11	6.00 *d* (16)	10	40.1
12	5.24 *dd* (16; 9.5)	11	134.8
13	2.90 *dq* (9.5; 6.5)	12	128.4
16	1.05 *d* (7)	13	42.3
17	5.58 *s*	14	79.8
	5.36 *s*	15	211.0
18	1.02 *s*	16	22.9
19	1.23 *s*	17	123.9
20	1.10 *d* (6.5)	18	27.6
OCOR	2.45 *sext*, 2.25 *sext* (7)	19	17.3
	2.54 *sept* (7)	20	15.3
	1.80–1.40 *m*, 1.10–1.00 *m*	OCOR	177.3/175.6, 176.0
	1.21 *d*, 1.19 *d* (7)		41.3/41.2, 34.2
	0.93 *t*, 0.87 *t* (7.5)		26.6/26.4, 16.6/16.2
			19.1/18.3, 11.6/11.4

δ in ppm and J (parentheses) in Hz, 400 MHz (^{1}H) and 100 MHz (^{13}C), $CDCl_3$, 22°C.

Signals from free OH groups: 3-OH, 3.00 *d* (4); 15-OH, 3.90 *s*.

* Overlapped signal.



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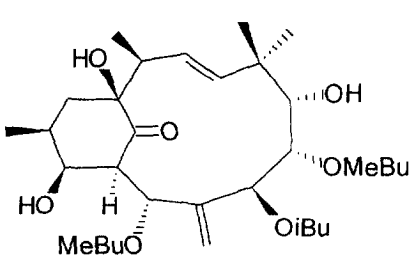

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Scheme 2. Skeletal rearrangement of the jatrophane to the 1(15→14) *abeo*-jatrophane framework.

+71.5° ($CHCl_3$; c 6.5); IR ν_{max}^{film} cm^{-1}: 3400 (*br*, OH), 1748, 1728, 1713, 1700 (*br*, ester and ketone C=O); EIMS (probe) *m/z* (rel. int.): 622.3710 $[M]^+$ (1), 604 $[M-H_2O]^+$ (1), 576 $[M-CO-H_2O]^+$ (2), 534 $[M-i\text{PrCOOH}]^+$ (1), 302 $[M-CO-2\times sec\text{BuCOOH}-i\text{PrCOOH}]^+$ (39), 206 (36), 96 (40), 85 (45), 57 (100). Calc. for $C_{34}H_{54}O_{10}$, M_r = 622.3717; NMR: Tables 1 and 2.

(2S,3S,4R,5R,7S,8S,9S,11E,13S,15R)-3,5,7,8,9,15-*Hexahydroxyjatropha*-6(17),11-*dien*-14-*one bis*(2-*methylpropionate*) (2-*methylbutyrate*) (**4**). Oil, which could not be completely separated from **2** and **3**; NMR: Tables 1 and 2.

(2S,3S,4R,5R,7S,8S,9S,11E,13S,15R)-3,5,7,8,9,15-*Hexahydroxyjatropha*-6(17),11-*dien*-14-*one* 3-*acetate* 7-(2-*methylpropionate*) 8-(2-*methylbutyrate*) (**5**). Oil, $[\alpha]_D$ +66.5° ($CHCl_3$; c 0.5); IR ν_{max}^{film} cm^{-1}: 3450 (*br*, OH), 1744, 1728, 1713 (*br*, ester and ketone C=O); EIMS (probe) *m/z* (rel. int.): 580.3251 $[M]^+$ (2), 474 $[M-CO-H_2O-HOAc]^+$ (7), 466 $[M-3H_2O-HOAc]^+$ (22), 396 $[M-2H_2O-HOAc-i\text{PrCOOH}]^+$ (15), 344 $[M-CO-H_2O-sec\text{BuCOOH}-i\text{PrCOOH}]^+$ (8), 284 $[M-CO-H_2O-HOAc-i\text{PrCOOH}-sec\text{BuCOOH}]^+$ (14), 266 $[M-CO-2H_2O-HOAc-i\text{PrCOOH}-sec\text{BuCOOH}]^+$ (16), 206 (18), 96 (55), 85 (52), 71 (44), 57 (100). Calc. for $C_{31}H_{48}O_{10}$, M_r = 580.3247; NMR: Tables 1 and 2.

(2S,3S,4R,5R,7S,8S,9S,11E,13S,14S,15R)-3,5,7,8,9,14,15-*Heptahydroxyjatropha*-6(17),11-*diene* 5,7-*bis*(2-*methylpropionate*) 8-(2-*methylbutyrate*) 14-*acetate* (**6**). Oil, $[\alpha]_D$ +30.5° ($CHCl_3$; c 0.8); IR ν_{max}^{film} cm^{-1}: 3490 (*br*, OH), 1744, 1728, 1713 (*br*, ester and ketone C=O); EIMS (probe) *m/z* (rel. int.): 634 $[M-H_2O]^+$ (2), 592 $[M-HOAc]^+$ (2), 574 $[M-H_2O-HOAc]^+$ (2), 532 $[M-H_2O-$*sec*BuCOOH$]^+$ (7), 444 $[M-H_2O-$*sec*BuCOOH$-$*i*PrCOOH$]^+$ (6), 293 (70), 207 (74), 96 (98), 71 (100), 57 (63). FAB MS *m/z*: 653.3886 $[M+H]^+$. Calc. for $C_{35}H_{57}O_{11}$, M_r = 653.3900; NMR: Tables 1 and 2.

(2S,3S,4R,5R,7S,8S,9S,11E,13S,14S,15R)-3,5,7,8,9,14,15-*Heptahydroxyjatropha*-6(17),11-*diene* 7-(2-*methylpropionate*) 5,8-*bis*(2-*methylbutyrate*) 14-*acetate* (**7**). Oil, $[\alpha]_D$ +22° ($CHCl_3$; c 0.6); IR ν_{max}^{film} cm^{-1}: 3480 (*br*, OH), 1745, 1740, 1732, 1720 (*br*, ester and ketone C=O); EIMS (probe) *m/z* (rel. int.): 648 $[M-H_2O]^+$ (1), 546 $[M-H_2O-$*sec*BuCOOH$]^+$ (4), 458 $[M-H_2O-$*sec*BuCOOH$-$*i*PrCOOH$]^+$ (3), 307 (35), 207 (46), 109 (40), 96 (70), 85 (75), 71 (56), 57 (100). FAB MS *m/z*: 667.4080 $[M+H]^+$. Calc. for $C_{36}H_{59}O_{11}$, M_r = 667.4057; NMR: Tables 1 and 2.

(2R,3R,4R,5R,7S,8S,9S,11E,13S,15R)-2,3,5,7,8,9,15-*Heptahydroxyjatropha*-6(17),11-*diene*-14-*one* 2,3,8,9-*tetraacetate* 5,7-*bis*(2-*methylpropionate*) (**8**). Oil, $[\alpha]_D$ +8.5° ($CHCl_3$; c 0.7); IR ν_{max}^{film} cm^{-1}: 3460 (*br*, OH), 1759, 1744, 1728, 1713 (*br*, ester and ketone C=O); EIMS (probe) *m/z* (rel. int.): 708 $[M]^+$ (21), 648 $[M-HOAc]^+$ (5), 620 $[M-$*i*PrCOOH$]^+$ (6), 560 $[M-HOAc-$*i*PrCOOH$]^+$ (4), 532 $[M-2\times$ *i*PrCOOH$]^+$ (15), 518 $[M-HOAc-$*i*PrCOOH$-C_2H_2O]^+$ (12), 500 $[M-2\times HOAc-$*i*PrCOOH$]^+$ (14), 472 $[M-HOAc-2\times$*i*PrCOOH$]^+$ (30), 430 $[M-HOAc-2\times$*i*PrCOOH$-C_2H_2O]^+$ (36), 412 $[M-2\times HOAc-2\times$*i*PrCOOH$]^+$ (33), 282 (63), 197 (62), 109 (70), 96 (84), 71 (100). FAB MS *m/z*: 709.3452 $[M+H]^+$. Calc. for $C_{36}H_{53}O_{14}$, M_r = 709.3435; NMR: Tables 4 and 5.

(2R,3R,4R,5R,7S,8S,9S,11E,13S,15R)-2,3,5,7,8,9,15-*Heptahydroxyjatropha*-6(17),11-*diene*-14-*one* 2,3,8,9-*tetraacetate* 5-*benzoate* 7-(2-*methylpropionate*) (**9**). Oil, $[\alpha]_D$ −11° ($CHCl_3$; c 1.3); IR ν_{max}^{film} cm^{-1}: 3470 (*br*, OH), 1748, 1728, 1720 (*br*, ester and ketone C=O); EIMS (probe) *m/z* (rel. int.): 742.3204 $[M]^+$ (14), 682 $[M-HOAc]^+$ (4), 654 $[M-$*i*PrCOOH$]^+$ (4), 594 $[M-HOAc-$*i*PrCOOH$]^+$ (8), 532 $[M-C_6H_5COOH-$*i*PrCOOH$]^+$ (12), 472 $[M-HOAc-$*i*PrCOOH$-C_6H_5COOH]^+$ (11), 430 $[M-HOAc-$*i*PrCOOH$-C_6H_5COOH-C_2H_2O]^+$ (10), 412 $[M-2\times HOAc-$*i*PrCOOH$]^+$ (6), 197 (20), 105 (100). Calc. for $C_{39}H_{50}O_{14}$, M_r = 742.3200; NMR: Tables 4 and 5.

(2R,3R,4R,5R,7S,8S,9S,11E,13S,15R)-2,3,5,7,8,9,15-*Heptahydroxyjatropha*-6(17),11-*diene*-14-*one* 2,5,8,9-*tetraacetate* 3-(*benzoyloxyacetate*) 7-(2-*methylpropionate*) (**10**). Oil, $[\alpha]_D$ −3.5° ($CHCl_3$; c 1.8); IR ν_{max}^{film} cm^{-1}: 3480 (*br*, OH), 1765, 1750, 1745, 1730 (*br*, ester and ketone C=O); EIMS (probe) *m/z* (rel. int.): 800.3225 $[M]^+$ (13), 740 $[M-HOAc]^+$ (4), 680 $[M-2\times HOAc]^+$ (5), 652 $[M-HOAc-$*i*PrCOOH$]^+$ (3), 610 $[M-HOAc-$*i*PrCOOH$-C_2H_2O]^+$ (3), 592 $[M-2\times HOAc-$*i*PrCOOH$]^+$ (6), 550 $[M-2\times HOAc-$*i*PrCOOH$-C_2H_2O]^+$ (7), 532 $[M-3\times HOAc-$*i*PrCOOH$]^+$ (8), 472 $[M-4\times HOAc-$*i*PrCOOH$]^+$ (7), 163 $[PhOCH_2CO]^+$ (63), 105 (100). Calc. for $C_{41}H_{52}O_{16}$, M_r = 800.3255; NMR: Tables 4 and 5.

(2S,3S,4R,5R,7S,8R,11E,13S,15R)-3,5,7,8,15-*Pentahydroxyjatropha*-6(17),11-*diene*-9,14-*dione* 3,5,8,15-*tetraacetate* 7-(2-*methylproprionate*) (**11**). Oil, $[\alpha]_D$ +30° ($CHCl_3$; c 0.7); IR ν_{max}^{film} cm^{-1}: 1759, 1744, 1728, 1713 (*br*, ester and ketone C=O); EIMS (probe) *m/z* (rel. int.): 620.2834 $[M]^+$ (20), 605 $[M-Me]^+$ (7), 560 $[M-HOAc]^+$ (5), 500 $[M-2\times HOAc]^+$ (4), 472 $[M-HOAc-$*i*PrCOOH$]^+$ (6), 204 (51), 176 (46), 123 (67), 96 (100), 71 (68). Calc. for $C_{32}H_{44}O_{12}$, M_r = 620.2832; NMR: Tables 4 and 5.

(2S,3S,4R,5R,7S,8S,9S,11E,13S,14S)-3,5,7,8,9,14-*Hexahydroxy*-1(15 → 14)abeo-*jatropha*-6(17),11-*dien*-15-*one* 5,8-*bis*(2-*methylbutyrate*) 7-(2-*methylpropionate*) (**12**). Oil, $[\alpha]_D$ +62° ($CHCl_3$; c 0.5); IR ν_{max}^{film} cm^{-1}: 3500 (*br*, OH), 1745, 1740, 1730, 1720 (*br*, ester and ketone C=O); EIMS (probe) *m/z* (rel. int.): 520 $[M-$*sec*BuCOOH$]^+$ (3), 502 $[M-$*sec*BuCOOH$-H_2O]^+$ (3), 432 $[M-$*sec*BuCOOH$-$*i*PrCOOH$]^+$ (7), 330 $[M-2\times$*sec*BuCOOH$-$*i*PrCOOH$]^+$ (22), 231 (33), 85 (70), 71 (73), 57 (100). FAB MS *m/z*: 623.3810 $[M+H]^+$. Calc. for $C_{34}H_{55}O_{10}$, M_r = 623.3795; NMR: Table 6.

Acknowledgements—J.A.M., J.F.S.-C. and A.Y. thank the IVEI for financial support of this research (project CPE-053).

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