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DITERPENES FROM *EUPHORBIA PARALIAS*

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Key Word Index—*Euphorbia paralias*; Euphorbiaceae; diterpenes; jatrophanes; segetanes; paraliane; ingenanes.

Abstract—Chemical investigation of *Euphorbia paralias* from Spain afforded 13 diterpenes of different structural types, including one with a novel skeleton.

INTRODUCTION

The genus *Euphorbia* is the largest in the spurge family, comprising more than 1000 species in today's widely accepted narrow circumscription [1]. Chemically it is characterized by the occurrence of the macrocyclic diterpenes of jatrophane or lathyrane type and a series of polycyclic diterpenes, found almost exclusively within the family Euphorbiaceae [2, 3]. The biologically active diterpenes with tigliane or ingenane skeleton have been of particular interest [4]. *Euphorbia paralias* (Sea Spurge) is a hardy perennial which inhabits sandy coasts and shingle beaches in many parts of western Europe. The specific name comes from Greek paralios, which means maritime. It is native to the entire Mediterranean, Macaronesia, and the Black sea, but is also found in Germany, the Netherlands, Switzerland and Hungary and is introduced in N. America and Australia. The plant with numerous erect stems arising from a woody stock, fleshy stem leaves, and yellowish floral leaves can reach about 70 cm. It is purgative and previous chemical investigation afforded unknown ingenanes [3].

RESULTS AND DISCUSSION

The whole plant extract of *E. paralias* L. afforded the jatrophanes **1**–**6**, the segetanes **7**–**9** [5] and **10** [5], the tetracyclic diterpene **11**, which displays a novel carbon framework, and the ingenanes **12** [6] and **13**. In addition a large quantity of the flavonol glycoside hyperin, and several widespread triterpenes were obtained (Experimental).

The ^{1}H NMR spectra of compounds **1**–**6** (Table 1) showed several signals for structural elements found within a subgroup of the jatrophanes diterpenes i.e. two double bonds, one *trans*-disubstituted ($^3J = 16$ Hz) and one exocyclic, and several ester groups. Two keto groups were present, as indicated by downfield singlets in the ^{13}C NMR spectra (Table 2). The NMR spectra of **1**–**5** (Tables 1 and 2) were similar to each other and differed mainly in the signals for the ester residues and slightly in the chemical shifts of the hydrogens geminal to the latter. The ^{1}H NMR spectrum of compound **1** (Table 1) showed signals for five acetates and a benzoate. The ^{13}C NMR spectrum (Table 2) confirmed this and the presence of the two aforementioned double bonds. Six signals for oxygenated sp^3-carbons indicated four secondary and two tertiary ester groups. Taking into account the multiplicities of the remaining signals (four quartets, a triplet, two doublets and a singlet) the calculated molecular formula for the parent polyol, $C_{20}H_{30}O_8$, supported the assumed bicyclic diterpene. By spin decoupling only short sequences were determined from the ^{1}H NMR spectrum. Further information which allowed connection of these fragments came from the HMBC spectrum (Table 3). Starting with the proton signals for the *gem*-dimethyl group, which showed all possible two- or three-bond correlations (i.e. mutual and to C-9—C-11), the sequence C-11—C-13 was connected with the *gem*-dimethyl group and with a keto group. The latter showed correlation with a singlet assigned to H-8, which itself showed further correlations to C-6 and to the benzoate carbonyl. Similarly the cross peaks between signals for H-17 and C-5—C-7, H-16 and C-1—C-3, H-1 and C-2—C-4, C-14 and C-15 as well as H-20 and C-12—C-14 incorporated all fragments into the jatrophane skeleton. As the position of the only differing

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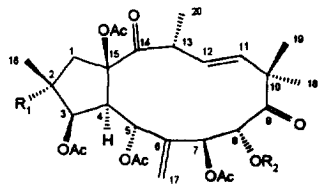
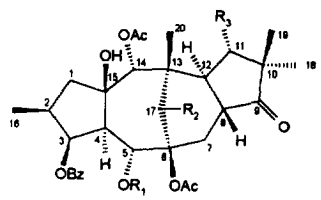
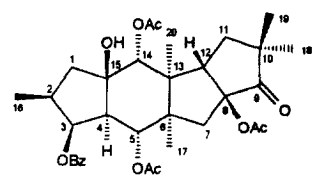


	1	2	3	4	5	6
R_1	OAc	OAc	OAc	OAc	OAc	H
R_2	Bz	iBu	Mebu	Ang	Ac	iBu



	7	8	9	10
R_1	AcOAc	Ac	AcOAc	AcOAc
R_2	H	OAc	OAc	OAc
R_3	OAc	OAc	OAc	H



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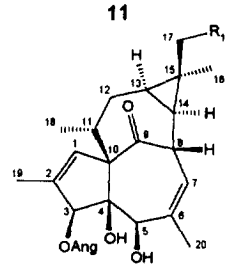


	12	13
R_1	H	OAng

ester residue, the benzoate, was already settled at C-8, the acetates occupied the positions 2, 3, 5, 7 and 15. The C-8 position of the only differing ester group in compounds **2**–**5** was in each case assumed from the chemical shift of H-8 and was confirmed either from the results of the long range correlation experiments or from the observed NOEs (Tables 3 and 4). The ^{1}H NMR spectrum of compound **6** (Table 1) showed an acetate signal less than that of compound **1**. In the ^{13}C NMR spectrum (Table 2) a tertiary oxygenated carbon was missing. In its place an upfield (shifted) methyne signal appeared which was assigned to C-2 and confirmed by an additional methyl doublet in the ^{1}H NMR spectrum. The connection of all fragments, including the assignment of the relative positions of secondary ester groups, was deduced again from the results of the HMBC experiment (Table 3). The stereochemistry at all chiral centres and the preferred conformations were deduced from the results of NOE difference spectroscopy (Table 4). A detailed discussion of the conformational behaviour will be published elsewhere but some important aspects are sum-

Table 1. ^{1}H NMR data of jatrophanes **1–6** (400 MHz, $CDCl_3$)

H	1	2	3	4	5	6
1α	3.90 *dd*	3.88 *dd*	3.88 *dd*	3.89 *dd*	3.89 *dd*	3.03 *dd*
1β	1.94 *d*	1.93 *d*	1.93 *d*	1.93 *d*	1.93 *d*	1.62 *dd*
2	—	—	—	—	—	2.18 *m*
3	5.53 *brdd*	5.51 *brdd*	5.52 *brdd*	5.52 *brdd*	5.51 *brdd*	5.49 *brdd*
4	2.94 *brdd*	2.90 *brdd*	2.91 *brdd*	2.89 *brdd*	2.92 *brdd*	2.41 *brdd*
5	5.80 *brs*	5.68 *brs*	5.70 *brs*	5.77 *brs*	5.71 *brs*	5.59 *brs*
7	5.51 *brs*	5.40 *brs*	5.40 *brs*	5.42 *brs*	5.39 *brs*	5.30 *brs*
8	5.86 *s*	5.61 *s*	5.64 *s*	5.70 *s*	5.64 *s*	5.60 *s*
11	6.31 *d*	6.22 *d*	6.23 *d*	6.27 *d*	6.23 *d*	6.21 *d*
12	5.65 *dd*	5.59 *dd*	5.60 *dd*	5.62 *dd*	5.60 *dd*	5.58 *dd*
13	3.67 *dq*	3.62 *dq*	3.63 *dq*	3.65 *dq*	3.64 *dq*	3.61 *dq*
16	1.52 *s*	1.51 *s*	1.51 *s*	1.51 *s*	1.51 *s*	0.91 *d*
17	5.29 *brs*	5.28 *brs*	5.29 *brs*	5.28 *brs*	5.26 *brs*	5.21 *brs*
17′	5.35 *brs*	5.24 *brs*	5.24 *brs*	5..23 *brs*	5.23 *brs*	5.20 *brs*
18	1.21 *s*	1.15 *s*	1.16 *s*	1.19 *s*	1.17 *s*	1.16 *s*
19	1.32 *s*	1.26 *s*	1.26 *s*	1.25 *s*	1.25 *s*	1.25 *s*
20	1.18 *d*	1.16 *d*	1.17 *d*	1.17 *d*	1.16 *d*	1.17 *d*
OAc	2.15 *s*	2.17 *s*	2.17 *s*	2.17 *s*	2.17 *s*	2.14 *s*
	2.13 *s*	2.12 *s*	2.12 *s*	2.13 *s*	2.12 *s*	2.11 *s*
	2.12 *s*	2.10 *s*	2.10 *s*	2.10 *s*	2.10 *s*	2.08 *s*
	2.11 *s*	2.08 *s*	2.06 *s*	2.10 *s*	2.10 *s*	2.04 *s*
	2.05 *s*	2.05 *s*	2.05 *s*	2.03 *s*	2.09 *s*	
					2.05 *s*	
OR	8.05 *AA′*	2.65 *qq*	2.51 *ddq*	6.11 *qq*		2.64 *qq*
	7.44 *BB′*	1.16 *d*	1.62 *ddq*	2.00 *dq*		1.15 *d*
	7.57 *C*	1.11 *d*	1.47 *ddq*	1.89 *dq*		1.10 *d*
			1.13 *d*			
			0.81 *t*			

J (Hz): comps. **1–5**: 1α,1β = 11,12 = 16; 1α,3 = 4,5 = 1; 3,4 = 4; 12,13 = 9; 13,20 = 7; comp. **6**: 1α,1β = 1β,2 = 13; 1α,2 = 6; 2,3 = 3,4 = 4; 2,16 = 13,20 = 7; 11,12 = 16; 12,13 = 9; O*i*Bu: 2,3 = 2,4 = 7; OMebu: $2,3_1 = 2,3_2 = 2,5 = 3_1,4 = 3_2,4 = 7$; $3_1,3_2 = 14$; OAng: 3,4 = 7; 3,5 = 4,5 = 1.5.

marized here and in the papers on the constituents from *E. peplus* [7] and *E. terracina* [8]. It is worth mentioning that all signals in the spectra were sharp, in spite of the flexibility of the twelve-membered ring which could adopt different conformations. The main differences between conformers are visible in the C-5—C-6 and C-13—C-14 fragments. They are best described in terms of the spatial arrangement of the 6,17 exo-methylene group, which is either perpendicular or parallel to the mean plane of the macrocyclic ring. The changed orientations are reflected in the large $J_{4,5} = 9$–11 Hz (perpendicular) or small $J_{4,5} = 0$–4 Hz (parallel) coupling. The configuration at C-13 dictates the conformation of the northern part of the molecule. The methyl group is in a quasi equatorial position while H-13 and H-12 are in antiperiplanar orientation. This implies that the *trans* double bond and the methyl groups at C-10 are inverted in each of the conformers. The jatrophanes **1–6** adopt parallel conformation, characterized by NOEs between H-4 and H-7 and H-5 and H-8 and no interaction between H-5 or H-7 and the exomethylenic H-17 (Table 4). It is remarkable that the known jatrophanes with the 6,17 exocyclic double and an identical substitution pattern, e.g. kansuinin B [9], esulon A [10] and enukokurin [11] where $J_{4,5} = 9$–10.5 Hz, adopt the perpendicular conformation. The configuration at C-13 was deduced from the NOE effect between H-5 and H-13. Further important NOE effects were observed between H-18, H-7 and H-12, between H-19 and H-11 and between H-8 and H-11. The calculated conformation [12], which is in excellent agreement with the spectroscopic results is depicted in Fig. 1. From the genus *Euphorbia*, we have obtained a large number of such jatrophanes. It thus appears that this group of diterpenes is much more widespread than previously assumed.

The structures of compounds **7** and **8** were deduced by comparison with the spectra of the co-occurring segetanes **9** and **10** (Tables 5 and 6), first found in *E. segetalis* [5]. Three derivatives of this new class of diterpenes are characterized by the presence of an unusual ester group, acetoxyacetate, so far not reported from other *Euphorbia* species. The most important information for the structure of this ester group came from the two- and three-bond correlations in the HMBC spectrum between the geminal protons of the $CH_3CO_2\underline{CH_2}CO_2$- group and both ester car-

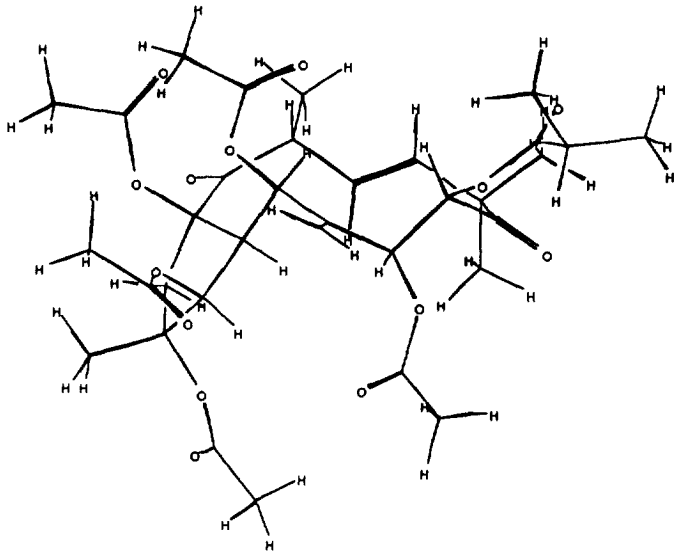


Fig. 1. Calculated conformation of jatrophane **2**; the 6, 17-exocyclic double bond is parallel with the mean plane of the macrocyclic ring; the close spatial proximity of two groups of protons is visible: (i) H-5, H-13 and H-11 and (ii): H-4, H-7 and H-12.

bonyl carbons. In the ^{1}H NMR spectrum of segetane **7** (Table 5) two H-17 signals indicated that the ester group at C-17, present in all other derivatives, was missing. All other signals resembled those of segetane **9** and differed only slightly in some chemical shifts. The ^{1}H NMR spectrum of **8** was nearly identical to that of **9**; only the geminally split signals of the acetoxyacetate were missing, obviously the group was replaced by an acetate. The HMBC results (Table 7) confirmed again the connectivities of interrupted sequences and allowed the assignment of the relative positions of the ester groups. The stereochemistry followed from the observed NOE effects (Table 8). Significant interactions were observed between H-14 and H-11, between H-18 and H-12 as well as between H-19 and H-11. The large value of the vicinal coupling $J_{8,12} = 16$ Hz is noteworthy, indicating rigid antiperiplanar orientation of the corresponding hydrogens.

The tetracyclic diterpene **11** displayed a novel carbon skeleton which, surprisingly, was also present in several further derivatives found in *E. segetalis* [5]. The ^{1}H NMR spectrum (Table 5) indicated a tetraester, with three acetates and a benzoate and a tertiary hydroxy group (D_2O-exchangeable signal at δ 3.25 *br s*). The ^{13}C NMR spectrum (Table 6) confirmed the above results and pointed additionally to a keto group. Three out of the five oxygenated carbons were secondary and two tertiary. The remaining signals for five methyl groups, one secondary and four tertiary, three methylene groups, three methyne groups and three quaternary carbons required a tetracyclic compound with a common number of methyl groups. Spin decoupling led only to short hydrogen sequences, which were connected through the results observed in an HMBC experiment. The most important correlations were those observed between proton signals for the tertiary methyl groups and the surrounding carbons. H-20 correlated with C-6, C-12, C-13 and C-14 while the H-17 signal showed cross peaks with signals for C-5, C-6, C-7 and C-13. The simultaneous correlation of both proton signals to two identical and two different carbons is only possible if both methyls are at adjacent ring junction positions. Further correlations between H-18 and H-19, both with C-9, C-10 and C-11, between H-7 and C-8, C-9 and C-12 and between H-1 and H-14, both with C-15 unify the fragments into the new skeleton, which we have named paraliane. The stereochemistry was deduced from the results of NOE experiments. The *trans*-oriented H-4 and H-5 ($J_{4,5} = 11$ Hz) were taken as reference points. The *trans* A/B rings, followed from the effect between 15-OH and H-5, and the *cis* B/C rings from the effect between H-17 and H-20. The relative orientation of the A/C rings was deduced from the interaction between H-4 and H-17. Finally, the effects between 8-OAc and H-5, between 8-OAc and the AA′-part of the benzoate and between H-12 and H-5 pointed to the *cis-anti* D ring. Further effects which corroborated the complete stereochemistry are listed in Table 8. The calculated conformation is depicted in Fig. 2 [12]. A possible biosynthetic pathway is proposed in Scheme 1. Starting with a jatrophane the tetracyclic system is formed in one step.

The structure of the ingenane **13** followed from the NMR spectra (Table 9) which were similar to those of the co-occurring 20-deoxy ingenol derivative **12** [6]. In the ^{1}H NMR spectrum a second set of the angelate signals appeared and a methyl singlet was missing. Instead, two signals forming an AB-system indicated

Table 2. ^{13}C NMR data of jatrophanes **1**–**3** and **6** (100 MHz, $CDCl_3$)

C	1	2	3	6
1	46.2 *t*	46.2 *t*	46.3 *t*	45.2 *t*
2	86.2 *s*	86.2 *s*	86.2 *s*	38.4 *d*
3	78.1 *d*	78.1 *d*	78.1 *d*	76.3 *d*
4	49.5 *d*	49.5 *d*	49.5 *d*	52.7 *d*
5	68.0 *d*	68.1 *d*	68.0 *d*	73.9 *d*
6	143.3 *s*	143.3 *s*	143.3 *s*	142.9 *s*
7	68.0 *d*	68.0 *d*	68.0 *d*	68.2 *d*
8	74.7 *d*	73.8 *d*	73.9 *d*	68.1 *d*
9	205.1 *s*	205.5 *s*	205.5 *s*	205.4 *s*
10	48.6 *s*	48.5 *s*	48.5 *s*	48.5 *s*
11	136.2 *d*	136.3 *d*	136.3 *d*	136.4 *d*
12	133.3 *d*	133.3 *d*	133.3 *d*	133.0 *d*
13	44.8 *d*	44.8 *d*	44.8 *d*	44.8 *d*
14	210.7 *s*	210.7 *s*	210.7 *s*	211.7 *s*
15	96.1 *s*	91.5 *s*	91.5 *s*	91.4 *s*
16	17.7 *q*	17.6 *q*	17.7 *q*	13.1 *q*
17	113.3 *t*	113.0 *t*	113.1 *t*	112.7 *t*
18	22.7 *q*	22.5 *q*	22.6 *q*	22.6 *q*
19	27.9 *q*	27.7 *q*	27.8 *q*	27.8 *q*
20	20.3 *q*	20.3 *q*	20.3 *q*	20.0 *q*
OAc	170.4 *s*	170.4 *s*	170.4 *s*	170.3 *s*
	170.1 *s*	170.1 *s*	170.1 *s*	169.9 *s*
	169.5 *s*	169.5 *s*	169.5 *s*	169.8 *s*
	169.3 *s*	169.2 *s*	169.2 *s*	169.2 *s*
	169.1 *s*	169.2 *s*	169.2 *s*	
	22.1 *q*	22.1 *q*	22.1 *q*	21.2 *q*
	21.3 *q*	21.4 *q*	21.4 *q*	20.9 *q*
	21.0 *q*	20.9 *q*	20.9 *q*	20.8 *q*
	20.8 *q*	20.8 *q*	20.8 *q*	20.5 *q*
	20.6 *q*	20.6 *q*	20.6 *q*	
OR	165.2 *s*	175.7 *s*	174.2 *s*	175.6 *s*
	129.3 *s*	33.5 *d*	40.4 *d*	33.5 *d*
	129.9 *d*	19.1 *q*	26.7 *t*	19.0 *q*
	128.4 *d*	18.5 *d*	16.3 *q*	18.5 *q*
	133.5 *d*		11.1 *q*	

Table 3. HMBC results with jatrophanes **1**–**3** and **6**

H	2*	6
1α	2, 3, 4, 14	2, 3, 4, 14, 15
1β	15	2, 14, 15, 16
3	1, 5, 15, CO_{Ac}	1, 15, CO_{Ac}
4	14	5, 14
5	3, 4, 6, 7, 15, 17, CO_{Ac}	3, 4, 6, 7, 17, CO_{Ac}
7	5, 6, 17, CO_{Ac}	6, 8, 17, CO_{Ac}
8	6, 9, CO_{iBu}	9, CO_{iBu}
11	10, 13, 18, 19	10, 13, 18, 19
12	10, 14	10
13	11, 12	11, 12, 14, 20
16	1, 2, 3	1, 2, 3
17	5, 7	5, 7
17′	5, 6, 7	5, 7
18	9, 10, 11, 19	9, 10, 11, 19
19	9, 10, 11, 18	9, 10, 11, 18
20	12, 13, 14	12, 13, 14

* Analogous results were observed with compounds **1** and **3**.

a 16- or 17-angeloyoxy derivative of **12**. The NOE effects between the H-16 methyl singlet and the cyclopropane signals required the angelate group at C-17.

EXPERIMENTAL

The plant was collected in May 1993 on a beach at Sagunto, province Valencia, Spain; a herbarium specimen is deposited in the herbarium of the Faculty of Biology, Department of Botany, Dr M. Guara. The fresh material (2 kg) was extracted with MeOH (8 l) for 4 days at room temp. to give 39.5 g crude extract. After removal of waxy material by treatment with MeOH at −20° the filtrate was evpd and sepd by open-column reversed-phase-chromatography (RP2) with mixts comprising MeOH and H_2O into three frs. Fr. 1 (MeOH–H_2O, 1:1) contained a mixture of flavonoid compounds and a large quantity of carbohydrates and other polar compounds. A tenth of Fr. 1 was purified to give 180 mg hyperin and 2 mg of a mixture of further flavonoids which were not further characterized. Fr. 3 (MeOH) contained lupeol, β-amyrin, betulin, cycloartenol and other triterpenes which were not quantified. Fr. 2 (MeOH–H_2O, 7:3, 4.5 g) was sepd by CC with mixts comprising petrol–methyl-*tert*-butyl ether (MTB)–MeOH of increasing polarity. Further separation by TLC and/or HPLC gave 3 mg **1**, 7 mg **2**, 3 mg **3**, 2 mg **4**, 4 mg **5**, 16 mg **6**, 16 mg **7**, 3 mg **8**, 2 mg **9**, 8 mg **10**, 19 mg **11**, 11 mg **12**, 12 mg **13**. The conditions of the final purification step are given with each compound. Known compounds were identified by comparison of their spectral data with those of authentic material or with literature data.

(2R*,3R*,4S*,5R*,7S*,8R*,13R*,15R*) - 2,3,5,7,15-*Pentaacetoxy*-8-*benzoyloxy*-9,14-*dioxojatropha*-6(17),11*E*-*diene* (**1**). TLC: petrol–MTB (4:1) $R_f = 0.65$ (2 ×); MS *m/z* (rel. int.): 712.273 $[M]^+$ (3) (calc. for $C_{37}H_{44}O_{14}$ 712.273), 652 $[M-AcOH]^+$ (0.5), 592 $[652-AcOH]^-$ (1), 550 $[592-ketene]^+$ (1), 532 $[592-AcOH]^-$ (1), 490 $[550-AcOH]^+$ (2), 430 $[490-AcOH]^+$ (1), 368 $[490-PhCOOH]^+$ (2), 340 $[368-CO]^+$ (2), 280 $[340-AcOH]^+$ (3), 262 $[280-H_2O]^+$ (3), 105 $[PhCO]^+$, 105 $[PhCO]^+$ (100).

(2R*,3R*,4S*,5R*,7S*,8R*,13R*,15R*) - 2,3,5,7,15-*Pentaacetoxy*-8-*isobutyroyloxy*-9,14-*dioxojatropha*-6(17),11*E*-*diene* (**2**). TLC: petrol–MTB (4:1), $R_f = 0.4$; MS *m/z* (rel. int.): 678.289 $[M]^+$ (7) (calc. for $C_{34}H_{46}O_{14}$ 678.289), 636 $[M-ketene]^+$ (1), 618 $[M-AcOH]^+$ (1), 576 $[636-AcOH]^+$ (2), 558 $[618-AcOH]^-$ (2), 516 $[576-AcOH]^+$ (2), 498 $[558-AcOH]^+$ (2), 488 $[576-iBuOH;\ 516-CO]^+$ (2), 456 $[516-AcOH]^+$ (4), 428 $[488-AcOH]^+$ (2), 410 $[498-iBuOH]^+$ (3), 400 $[488-iBuOH]^+$ (3), 382 $[400-H_2O]^+$ (3), 368 $[428-AcOH]^+$ (4), 358 $[400-ketene]^+$ (4), 340 $[400-AcOH]^+$ (6), 322

Table 4. NOE results with jatrophanes **1–6**

H	1*	6†
1α		2(5)
1β	16	16
2		1α(4), 3(4), 4(3)
3	4(6), 16, 17(1)	2(5), 4(5), 16, 17(1)
4	3(5), 5(4), 7(8)	2(5), 3(5), 5(2), 7(8)
5	4(5), 7(7), 8(8), 11(3), 13(5)	
7	4(10), 5(5), 8(5), 11(1), 12(3), 18	4(8), 8(7), 11(1), 12(2), 18
8	5(7), 7(5), 11(7), 19	
11	5(1), 8(3), 13(1), 19	8(2), 13(2), 19
12	7(1), 18, 20	
13	5(4), 11(4)	11(5)
16	1β(4), 3(4)	1β(2), 3(1)
17	3(2)	3(2)
17′	OBz_{AA}·(3)	
18	7(3), 12(10), 18	7(4), 12(10), 19
19	8(1), 11(5), 19	11(5), 18
20	12(3)	

* Analogous results were observed with jatrophanes **2–5**.

† No selectivity due to overlapping of signals for H-5, H-8 and H-12 (observed cumulative effects: H-4(4), H-7(10), H-13(2) and H-18).

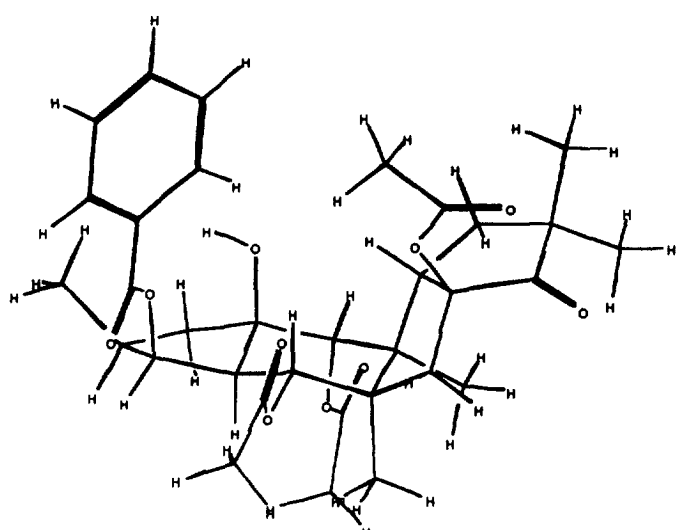
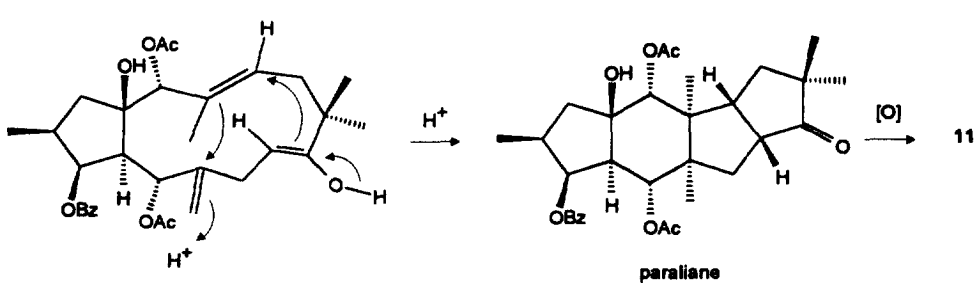


Fig. 2. Calculated conformation of paraliane **11**; the *cis* anti *cis* orientation of the B/C and C/D rings is clearly visible.



Scheme 1. A possible pathway for the formation of paralianes.

Table 5. ^{1}H NMR data of **7**, **8** and **11** (400 MHz, $CDCl_3$)

H	7	8	11
1α	2.37 *dd*	2.38 *dd*	2.16 *dd*
1β	1.60 *dd*	1.60 *dd*	1.48 *dd*
2	2.09 *m*	2.10 *m*	2.49 *dddq*
3	5.79 *dd*	5.80 *dd*	5.78 *dd*
4	3.28 *dd*	3.39 *dd*	2.37 *dd*
5	5.27 *d*	5.52 *d*	5.95 *d*
7α	1.35 *dd*	1.81 *dd*	1.86 *d*
7β	2.61 *ddd*	2.31 *brd*	2.09 *d*
8	3.71 *ddd*	3.77 *ddd*	—
11α	—	—	1.79 *dd*
11β	5.55 *d*	5.59 *dd*	2.14 *dd*
12	1.77 *dd*	2.08 *m*	4.42 *brdd*
14	5.18 *s*	5.28 *s*	4.94 *s*
16	0.94 *d*	0.93 *d*	1.04 *d*
17	3.51 *dd*	6.38 *brs*	1.09 *s*
17′	1.08 *d*		
18	0.93 *s*	0.96 *s*	1.12 *s*
19	1.20 *s*	1.23 *s*	1.25 *s*
20	1.08 *s*	1.06 *s*	0.74 *s*
OH	2.58 *s*	2.64 *s*	3.25 *s*
5-OR	4.60 *d*	1.95 *s*	1.97 *s*
	4.49 *d*		
	2.09 *s*		
6-Ac	2.08 *s*	2.07 *s*	
8-Ac			1.83 *s*
11-Ac	2.14 *s*	2.13 *s*	
14-Ac	2.14 *s*	2.17 *s*	2.12 *s*
17-Ac		1.94 *s*	
OBz	7.84 *AA′*	7.83 *AA′*	7.93 *AA′*
	7.46 *BB′*	7.46 *BB′*	7.45 *BB′*
	7.59 *C*	7.59 *C*	7.57 *C*

J (Hz): comp. **7**: 1α,1β = 17,17′ = 15; 1α,2 = 9.5; 1β,2 = 4,5 = 11.5; 2,3 = 3,4 = 3.5; 2,16 = 7; 7α,7β = 7α,8 = 12.5; 7β,8 = 4.5; 7β,17 = 2.5; 8,12 = 16; 11β,12 = 11; comp. **8**: 1α,1β = 8.12 = 16; 1α,2 = 9; 1β,2 = 4,5 = 11.5; 2,3 = 3,4 = 3.5; 2,16 = 7; 7α,7β = 7α,8 = 12.5; 7β,8 = 4; 11,12 = 11; comp. **11**: 1α,1β = 11α,11β = 14; 1α,2 = 11β,12 = 11; 1β,2 = 5.5; 2,3 = 6; 2,16 = 7; 3,4 = 4; 4,5 = 12; 7α,7β = 16; 11α,12 = 3; AcOAcO: 2_1,2_2 = 16.

Table 6. ^{13}C NMR data of compounds **7**, **8** and **11** (100 MHz, $CDCl_3$)

C	7	8	11
1	50.3 *t*	49.9 *t*	44.6 *t*
2	37.1 *d*	37.2 *d*	36.2 *d*
3	80.8 *d*	80.8 *d*	77.5 *d*
4	48.2 *d*	47.6 *d*	48.0 *d*
5	70.0 *d*	67.2 *d*	69.1 *d*
6	81.6 *s*	83.2 *s*	52.0 *s*
7	37.0 *t*	30.7 *t*	41.2 *t*
8	45.1 *d*	44.8 *d*	90.9 *d*
9	214.7 *s*	214.5 *s*	216.3 *s*
10	49.4 *s*	49.4 *s*	46.1 *s*
11	77.8 *d*	77.2 *d*	33.5 *t*
12	50.8 *d*	46.2 *d*	40.4 *d*
13	40.9 *s*	45.8 *s*	52.5 *s*
14	75.0 *d*	74.4 *d*	73.4 *d*
15	83.0 *s*	82.3 *s*	84.4 *s*
16	14.2 *q*	14.3 *q*	16.1 *q*
17	38.9 *t*	70.8 *d*	16.6 *q*
18	18.4 *q*	18.3 *q*	25.4 *q*
19	25.1 *q*	25.3 *q*	28.7 *q*
20	32.0 *q*	27.2 *q*	17.0 *q*
3-OBz	165.9 *s*	165.8 *s*	165.6 *s*
	129.3 *s*	129.5 *s*	129.9 *s*
	129.2 *d*	129.1 *d*	129.4 *d*
	128.8 *d*	128.8 *d*	128.5 *d*
	133.4 *d*	133.4 *d*	133.2 *d*
5-OR	167.0 *s*	169.6 *s*	169.9 *s*
	60.4 *t*	20.7 *q*	20.9 *q*
	170.0 *s*		
	20.3 *q*		
6-OAc	170.7 *s*	169.8 *s*	
	21.7 *q*	20.6 *q*	
8-OAc			169.7 *s*
			20.7 *q*
11-OAc	170.5 *s*	170.5 *s*	
	20.9 *q*	21.0 *q*	
14-OAc	170.0 *s*	170.2 *s*	169.8 *s*
	21.0 *q*	21.0 *q*	20.9 *q*
17-OAc		169.3 *s*	
		21.0 *q*	

$[382-AcOH]^+$ (5), 308 $[368-AcOH]^+$ (5), 298 $[358-AcOH]^+$ (9), 280 $[340-AcOH; 322-ketene]^+$ (10), 71 $[i\text{Bu}]^+$ (100).

(2R*,3R*,4S*,5R*,7S*,8R*,13R*,15R*)-2,3,5,7,15-*Pentaacetoxy*-8-(2ξ-*methylbutyroyloxy*)-9,14-*dioxojatropha*-6(17),11*E*-*diene* (**3**). TLC: petrol–MTB (4:1) R_f = 0.62 (2×); MS *m/z* (rel. int.): 692.304 $[M]^+$ (4) (calc. for $C_{35}H_{48}O_{14}$ 692.304), 632 $[M-AcOH]^+$ (1), 590 $[M-MebuOH]^+$ (1), 572 $[632-AcOH]^+$ (2), 590 $[632-MebuOH; 590-AcOH]^+$ (2), 512 $[572-AcOH]^+$ (2), 470 $[530-AcOH; 512\text{-ketene}]^+$ (4), 460 $[572-MebuOH]^+$ (4), 400 $[460-AcOH]^+$ (4), 368 $[470-MebuOH]^+$ (4), 358 $[400-ketene]^+$ (5), 340 $[400-AcOH]^+$ (7), 308 $[368-AcOH]^+$ (5), 298 $[358-AcOH]^+$ (10), 280 $[340-AcOH]^+$ (10), 85 $[Mebu]^+$ (86), 57 $[Mebu-CO]^+$ (100).

(2R*,3R*,4S*,5R*,7S*,8R*,13R*,15R*)-2,3,5,7,15-*Pentaacetoxy*-8-*angeloyloxy*-9,14-*dioxojatropha*-6(17),11*E*-*diene* (**4**). TLC: petrol–MTB (4:1, 2×) R_{tl} = 0.7; MS *m/z* (rel. int.): 690.289 $[M]^+$ (8) (calc. for $C_{35}H_{46}O_{14}$ 690.289), 630 $[M-AcOH]^+$ (1), 590 $[M-AngOH]^+$ (1), 570 $[630-AcOH]^+$ (1), 548 $[590-ketene]^+$ (1), 520 $[548-CO]^+$ (2), 470 $[570-AngOH]^+$ (2), 460 $[520-AcOH]^+$ (2), 400 $[460-AcOH]^+$ (4), 340 $[400-AcOH]^+$ (7), 298 $[340-ketene]^+$ (9), 280 $[340-AcOH]^+$ (10), 83 $[Ang]^+$ (100).

(2R*,3R*,4S*,5R*,7S*,8R*,13R*,15R*)-2,3,5,7,8,15-*Hexaacetoxy*-9,14-*dioxojatropha*-6(17),11*E*-*diene* (**5**). HPLC: RP8, MeOH–H_2O (3:2) R_t = 10.4 min

(2S*,3S*,4R*,5R*,7S*,8R*,13R*,15R*)-3,5,7,15-

Table 7. Long range correlations with compounds 7, **8** and **11**

H	7*	11
1α	2, 3, 14	4, 15, 16
1β	2, 15, 16	3
2		16
3	1, 15, CO_{OBz}	1, 15, CO_{OBz}
4	5, 6, 15	5
5	4, 7, 15, CO_{AcOAcO}	4, 6, 7, 13, 17, $CO_{5\text{-}OAc}$
7α	6, 5, 8	5, 6, 8, 12, 13
7β	6, 12, 17	5, 6, 9, 13, 17
8	9, 12	
11α		10, 13, 19
11β	12, 18, 19, CO_{Ac}	13, 18
12	8, 11, 13, 14, 20	6, 8, 11, 13, 14, 20
14	4, 15, 17, CO_{Ac}	4, 6, 12, 13, 15, $CO_{14\text{-}OAc}$
16	1, 2, 3	1, 2, 3
17	6, 7, 12, 13	5, 6, 7, 13
17′	5, 6, 20	
18	9, 10, 11, 19	9, 10, 11, 19
19	9, 10, 11, 18	9, 10, 11, 18
20	12, 13, 14, 17	6, 12, 13, 14
OH	14, 15	14, 15
AcOAcO	CO_{AcOAcO}, CO_{AcOAcO}	
AcOAcO	CO_{AcOAcO}, CO_{AcOAcO}	

* Analogous results were observed with compound **8**.

Tetraacetoxy-8-isobutyroyloxy-9,14-dioxojatropha-6(17),11E-diene (**6**). HPLC: RP8, MeOH–H_2O (3:2) R_t = 16.1 min; MS *m/z* (rel. int.): 620.283 $[M]^+$ (13) (calc. for $C_{32}H_{44}O_{12}$: 620.283), 560 $[M-AcOH]^+$ (3), 500 $[560-AcOH]^+$ (8), 472 [560 – *i*BuOH; 500 – CO]$^+$ (8), 430 $[472-42]^+$ (18), 402 $[430-CO]^+$ (19), 370 $[430-AcOH]^+$ (15), 342 [430 – *i*BuOH; 370 – CO]$^+$ (31), 310 $[370-AcOH]^+$ (19), 300 $[342-ketene]^+$ (34), 282 [342 – AcOH; 300 – $H_2O]^+$ (52), 264 $[382-H_2O]^+$ (53), 71 $[iBu]^+$ (100).

(2S*,3S*,4R*,5R*,6S*,8R*,11S*,12S*,13R*,14R*,15R*)-6,11,14,-*Triacetoxy-5-(2-acetoxyacetoxy)-3-benzoyloxy-15-hydroxy-9-oxo-segetane* (**7**). HPLC: RP8, MeOH–H_2O (3:2) R_t = 10.3 min; MS *m/z* (rel. int.): 714.289 $[M]^+$ (0.5) (calc. for $C_{37}H_{46}O_{14}$ 714.289), 654 $[M-AcOH]^+$ (62), 594 $[654-AcOH]^+$ (60), 536 $[654-AcacOH]^+$ (14), 476 [594 – AcacOH; 536 – AcOH]$^+$ (25), 414 [536 – PhCOOH]$^+$ (27), 372 $[414-ketene]^+$ (31), 354 [476 – PhCOOH; 414 – AcOH]$^+$ (77), 312 $[372-AcOH]^+$ (50), 294 $[354-AcOH]^+$ (69), 276 $[294-H_2O]^+$ (13), 266 $[294-CO]^+$ (25), 105 $[PhCO]^+$ (100), 101 $[Acac]^+$ (26).

(2S*,3S*,4R*,5R*,6R*,8R*,11S*,12S*,13R*,14R*,15R*)-5,6,11,14,17-*Pentaacetoxy-3-benzoyloxy-15-hydroxy-9-oxo-segetane* (**8**). TLC: toluene–CH_2Cl_2–MTB (4:4:1, 3×) R_f = 0.44: MS *m/z* (rel. int.): 714.289 $[M]^+$ (1) (calc. for $C_{37}H_{46}O_{14}$ 714.289), 654 $[M-AcOH]^+$ (73), 594 $[654-AcOH]^+$ (100), 534 $[594-AcOH]^+$ (9), 472 [594 – PhCOOH]$^+$ (13), 430 [534 – PhCOOH; 472 – ketene]$^+$ (15), 412 [472 – AcOH; 430 – $H_2O]^+$ (15), 370 [430 – AcOH; 412 – ketene]$^+$ (27), 352 [412 – AcOH; 370 – $H_2O]^+$ (15), 310 [370 – AcOH; 352 – ketene]$^+$ (62), 292 [352 – AcOH; 310 – $H_2O]^+$ (43), 105 $[PhCO]^+$ (39).

(2S*,3S*,4R*,5R*,6R*,8S*,12S*,13S*,14R*,

Table 8. NOE results with compounds 7 and **11**

H	7	11
1β		14(1), 16, OBz_{AA}(1)
2		1α(3), 3(5), 4(2)
3	2(3), 4(5), 16, OBz_{AA}(1), AcOAcO(1)	2(6), 4(6), OBz_{AA}(1), 5-OAc
4	3(4), 17(3)	2(2), 3(4), 17
5	8(4), 7β(1), OH(1), OBz_{AA}(1)	7β(1), 12(3), OH(1), OBz_{AA}(1)
7α		17, 20
7β		5(3)
8	5(8), 11(4), 19, OH(1)	
11	8(2), 14(3), 19	14(1), 20
12	7α(1), 17′(3), 18, 20	5(4), 11β(3), 14(2), OH(1)
14	11(6), 20, OH(1), 14-OAc	1β(1), 11α(2), 12(5), 20, OH(1)
16	1β(2), 3(2), OBz_{AA}(1)	1β(2), 3(1), OBz_{AA}(2)
17	4(2)	4(9), 5(1), 7α(5), 20, 5-OAc, 14-OAc
17′	12(1)	
18	12(15), 19, 11-OAc	11α(3), 19, 20
19	8(1), 11(7), 18	11β(5), 18, 8-OAc
20	12(10), 14(7), 14(11)-OAc	7α(6), 11α(7), 14(6), 17, 18, 14-OAc
OH		5(5), 12(3), 14(2), OBz_{AA}(8)
OBz_{AA}		5(1), OH(2), 8-OAc
5-OAc		3(1), 5(1), 17, OBz_{AA}(1)
8-OAc		5(2), 11β(2), 19, OBz_{AA}(3)

Table 9. ^{1}H- and ^{13}C-NMR data of compound **13** (400 resp. 100 MHz, $CDCl_3$)

H		C	
1	6.05 *q*	1	132.1 *d*
3	5.48 *brs*	2	135.9 *s*
5	3.67 *brs*	3	82.9 *d*
7	5.72 *ddq*	4	84.9 *s*
8	4.16 *brdd*	5	77.5 *d*
11	2.45 *ddq*	6	137.8 *s*
12	2.34 *ddd*	7	123.2 *d*
12′	1.84 *ddd*	8	43.0 *d*
13	0.92 *ddd*	9	205.1 *s*
14	1.13 *dd*	10	72.1 *s*
16	1.15 *s*	11	38.8 *d*
17	4.34 *d*	12	30.9 *t*
17′	4.22 *d*	13	24.1 *d*
18	0.98 *d*	14	23.7 *d*
19	1.79 *d*	15	34.1 *s*
20	1.76 *brs*	16	24.6 *q*
4-OH	3.12 *brs*	17	65.2 *t*
5-OH	3.46 *brs*	18	16.9 *q*
3-OAng	6.17 *qq*	19	15.8 *q*
	1.99 *dq*	20	21.9 *q*
	1.90 *dq*	OAng	168.3 *s*
16-OAng	6.06 *qq*		127.1 *s*
	2.01 *dq*		140.0 *d*
	1.92 *dq*		15.6 *q*
			20.7 *q*
		OAng	168.3 *s*
			128.0 *s*
			137.7 *d*
			15.9 *q*
			20.6 *q*

J (Hz): 1,19 = 1.5; 7,8 = 11,12′ = 5; 7,20 = 8,20 = 1; 8,14 = 12; 11,12 = 3.5; 11,18 = 7; 12,12′ = 16; 12,13 = 9; 12′,13 = 6; 13,14 = 8; 17,17′ = 12; OAng: 3,4 = 7; 3,5 = 4,5 = 1.5.

15R*)-5,8,14-*Triacetoxy*-3-*benzoyloxy*-15-*hydroxy*-9-*oxo-paraliane* (**11**). HPLC: RP8, MeOH–H_2O (3:2) R_t = 14.8 min; MS *m/z* (rel. int.): 598.278 $[M]^+$ (1) (calc. for $C_{33}H_{42}O_9$ 598.278), 538 $[M-AcOH]^+$ (26), 496 $[538-ketene]^+$ (8), 478 $[538-AcOH]^+$ (16), 418 $[478-AcOH]^+$ (4), 356 $[478-PhCOOH]^+$ (6), 296 $[418-PhCOOH; 356-AcOH]^+$ (45), 105 $[PhCO]^+$ (100).

3-O-*Angeloyl*-17-*angeloyloxy*-20-*deoxyingenol* (**13**). HPLC: RP8, MeOH–H_2O (3:2) R_t = 23 min; MS *m/z* (rel. int.): 512.277 $[M]^+$ (24) (calc. for $C_{30}H_{40}O_7$ 512.277), 412 $[M-AngOH]^+$ (12), 312 $[412-AngOH]^+$ (14), 294 $[312-H_2O]^+$ (11), 83 $[Ang]^+$ (52), 55 $[Ang-CO]^+$ (100).

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