BISINDOLE ALKALOIDS OF *PANDACA CADUCIFOLIA*

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ABSTRACT.—Two novel bisindole alkaloids have been isolated from *Pandaca caducifolia* (Mgf): ervafolidene (10) and epi-ervafolidene (11). Their structure has been established by spectral analysis (especially ^{13}C nmr) and by comparison with the known alkaloid ervafolene (3), also isolated from the plant. Several unusual reactions of 3 are described, among which is a rearrangement pertaining to the pandoline moiety of the molecule.

In 1975, we announced the isolation of several dimeric indole alkaloids from *Pandaca caducifolia* Mgf. (1) (Apocynaceae). Their structure elucidation remained unsolved until the recent work by Husson *et al.* on similar alkaloids of *Stenosolen heterophyllus* (Vahl) Mgf (2), in which two major constituents, ervafoline (1) and epi-ervafolidine (2b) yielded only to X-ray crystallography. The structures of six other related dimers were subsequently deduced from the spectroscopic data (2), including ervafolene (3), which is also present in *Pandaca caducifolia*. It is the purpose of this communication to describe ervafolene (3) and the novel ervafolidenes 10 and 11. Their chemistry and some of their rearrangements will be briefly described.

RESULTS AND DISCUSSION

Ervafolene (3) showed a molecular ion at m/z 628 analyzed for $C_{40}H_{44}N_4O_3$. Its spectral properties were reminiscent of those of ervafoline (1) ($C_{40}H_{44}N_4O_4$). Its structure was determined by Husson *et al.* to be 3 on the basis of its mass and high field nmr spectra. Our ^{13}C nmr spectrum for 3 is in full agreement with the proposed structure, in that it shows the presence of two extra olefinic methines (125.3 and 134.3 ppm) instead of the two high field oxymethines (51.7 and 57.0 ppm) of 1. By comparison to 3, all the carbons of the rearranged "pseudo-aspidosperma" part of 1 (lower half of the molecule on figure 1) were observed to be within ±0,5 ppm. Carbons relevant to the other part of the molecule were also found ±2 ppm except for the two above mentioned sets of carbons.

The ^1H nmr spectrum (240 MHz) for 3 showed all the resonances expected for such a molecule, except for a one-proton multiplet at δ 5.6 ppm corresponding to one of the aromatic protons shielded by the aromatic nucleus of the other part of the dimer. This proton was linked to C–12 or C–12' as shown by the observation of the residual splitting in the off-resonance decoupled ^{13}C nmr spectrum (3). Inspection of molecular models built after X-ray data showed it to be H–12'. All other spectral properties of 3 were very close to those of 1 and are reported in the experimental part.

Catalytic hydrogenation of 3 produced a single 14',15'-dihydro derivative 4 (M[+·] at m/z: 630), with unaffected uv chromophore. Its ^1H nmr spectrum showed the now uncovered shielded aromatic proton at 5.55 ppm. NaBH₃CN reduction of 3, which is a classical way of modifying the anilinoacrylic chromophore yielded two derivatives 5 and 7. The minor and more polar component 5, was identified as the 2,16-dihydro derivative (uv: maxima at 213, 253 and 299 nm). Its mass spectrum was greatly modified with respect to 3 and was dominated by fragmentations of the lower half of the molecule, i.e., peaks at m/z: 500 (M[+·] −130 (a)) and m/z: 428 (M[+·] −202 (b)). These features were expected for this

Fig.1
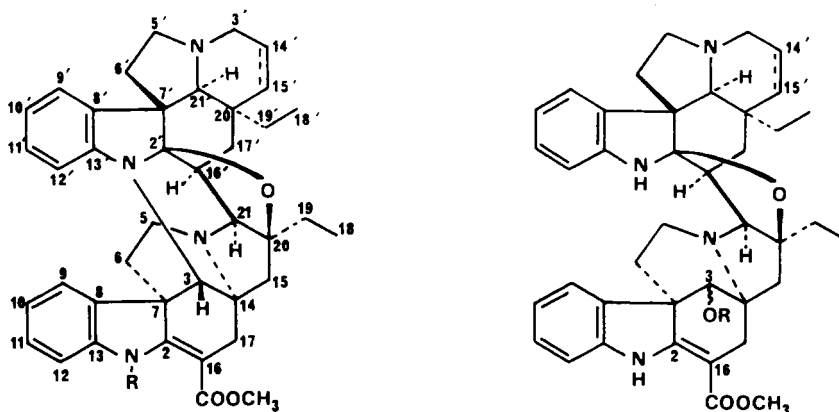
1 ; R=H ; 14',15'-β epoxy
   = ervafoline

3 ; R=H ; = ervafolene

4 ; R=H ; dihydro 14',15'

5 ; R=H ; 2,16-dihydro ;

6 ; R=COCH₃ ; 2,16-dihydro ;

2a ; C_3"S" ; 14',15'-β epoxy
    = ervafolidine

2b ; C_3"R" ; 14',15'-β epoxy
    = epi-ervafolidine

10 ; C_3"S" ;
    ◻ ervafolidene

11 ; C_3"R" ;
    ◻ epi-ervafolidene

12 ; C_3"S" ; R=COCH₃ ;

13 ; C_3"R" ; R=COCH₃ ;

14 ; C_3"S" ; 2 ,16 -dihydro

15 ; C_3"R" ; R=COCH₃ ; 2,16-dihydro

type of product and served as a proof of the existence of an anilinoacrylic chromophore. In its ¹H nmr spectrum the shielded aromatic proton, H–12', was even more shielded (5.05 ppm) as a result of the more severe interactions between the two halves of the molecule. Acetylation of **5** yielded a single derivative **6**, displaying an extra amide vibration in the ir spectrum (1650 cm⁻¹). The fragmentation pattern in the ms was, however, identical to that of **5** (m/z: 500(100%), 428).

The major product of the NaBH₃CN reduction, **7**, was an isomer of **5** (M⁺· at m/z 630) having an uv spectrum which consisted of a superimposition of an indole and indoline chromophores (λmax at 217, 226, 257, 287, 294 nm). Its structure **7** was unraveled by close examination of its ¹³C nmr spectrum and through comparison with the spectra of vincadine (**8**) (**4**) and of the other dimeric alkaloids of this family (see table 1). Formation of **7** proceeds through a 1,2-indoleninium ion, fragmentation of the 3,7 bond of which is assisted by N–1'. This fragmentation is made irreversible by formation of a stable aromatic indole nucleus and by NaBH₃CN reductive trapping of the 1'–3 immonium ion. The vincadifformine to vincadine transformation (**5**) and similar rearrangements of pandine (**6**), akuammicine (**7**) and vincadifformine (**8**) provide precedent for this type of reductive fragmentation. Spectral properties of **7** were unexceptional except a downfield shift of the aromatic H–12' to 6.20 ppm indicating a release of the intramolecular interactions.

TABLE 1.   Nmr ^{13}C of derivatives **1, 3, 7, 8, 2a, 10, 11, 12, 13.**

	1	3	7	8*	2a	10	11	12	13
C(2)'........	103.4	103.8	106.6		104.5	104.9	105.2	105.0	105.2
C(3)'........	47.0	49.2	52.2		45.6	46.0	49.1	45.3	48.6
C(5)'........	52.9	52.2	53.8		53.5	53.8	53.9	53.8	54.0
C(6)'........	34.4	37.3	35.6		36.0	34.8	38.4	35.0	34.8
C(7)'........	58.1	56.6	53.5		54.4	54.4	55	54.8	55.2
C(8)'........	133.8	133.8	136.4		134.4	134.4	135.9	136.2	130.7
C(9)'........	122.4	122.4	121.4		122.9	122.8	122.3	122.4	122.2
C(10)'.......	117.5	117.3	119.1		118.8	118.8	118.7	118.0	118.4
C(11)'.......	126.8	126.9	127.6		127.7	127.4	127.3	127.3	127.4
C(12)'.......	109.1	109.1	105.9		109.5	109.6	109.5	109.6	109.1
C(13)'.......	147.6	147.2	148.2		146.6	146.5	146.3	147.1	146.4
C(14)'.......	51.7	125.3	123.8		53.0	123.8	124.2	124.2	124.3
C(15)'.......	57.0	134.3	133.6		56.8	133.9	133.8	134.0	133.8
C(16)'.......	44.4	44.9	40.2		44.5	44.6	45.6	45.3	45.9
C(17)'.......	29.3	31.4	27.2		26.8	32.2	26.7	30.1	26.9
C(18)'.......	8.3	8.5	7.7		7.3	7.6	7.7	7.7	7.6
C(19)'.......	33.4	31.4	32.0		32.8	32.5	32.9	32.8	33.1
C(20)'.......	36.1	37.8	39.7		35.5	39.5	39.7	39.8	39.7
C(21)'.......	70.4	73.7	69.1		70.4	67.5	68.4	68.2	68.7
C(2)........	161.2	161.2	132.7	133.7	160.6	160.7	158.7	159.4	158.7
C(3)........	58.3	58.2	47.4		69.2	68.6	77.3	70.8	76.1
C(5)........	52.3	52.2	53.8	54.0	54.2	53.8	53.7	53.8	53.1
C(6)........	38.7	38.6	24.5	26.2	33.5	33.0	34.9	33.2	38.7
C(7)........	51.7	51.8	111.2	111.5	50.9	50.8	54.3	49.2	54.0
C(8)........	137.0	137.6	128.5	127.5	136.5	136.2	131.4	132.8	130.7
C(9)........	126.8	126.2	117.5	117.9	124.8	124.6	122.3	123.3	123.7
C(10)........	120.4	120.3	117.9	118.7	121.4	121.4	120.8	121.2	120.9
C(11)........	127.8	127.6	121.4	121.4	127.7	127.1	128.8	128.7	128.6
C(12)........	108.9	108.6	110.7	110.6	108.9	108.4	108.9	107.9	109.1
C(13).......	143.5	143.2	134.6	135.7	143.8	143.3	144.9	144.1	144.3
C(14).......	61.0	60.9	63.3		65.0	64.9	64.9	63.8	64.1
C(15).......	39.3	39.4	38.9		41.6	41.4	41.0	41.6	41.0
C(16).......	91.2	90.9	38.9	40.9	91.9	90.5	90.6	89.8	90.3
C(17).......	32.8	32.7	45.5	42.8	26.8	26.9	26.7	26.9	26.9
C(18).......	9.5	9.5	9.3		9.2	9.1	9.0	9.0	9.0
C(19).......	32.1	32.7	33.3		30.4	30.2	34.6	34.6	34.8
C(20).......	87.7	87.4	87.7		90.6	91.5	93.4	92.7	93.1
C(21).......	77.7	77.5	78.5		76.6	76.2	77.3	76.3	77.7
C=O........	168.7	168.6	174.9		168.2	168.1	167.8	168.1	167.8
OCH$_3$......	51.1	51.1	52.6		51.1	50.8	51.0	51.1	51.3
OCOCH$_3$.....								21.5	20.8
OCOCH$_3$.....								170.4	169.5

Only relevant peaks of 8 are given.

A similar fragmentation occurred upon attempted acid hydrolysis of **3** which yielded compound **9** having an indole + indoline chromophore in its uv spectrum. Its mass spectrum showed a molecular ion at *m/z* 586, corresponding to the loss of the methoxycarbonyl group and incorporation of the elements of water. All the available spectroscopic information led to structure **9**, which is readily accounted for by a mechanism involving a decarboxylation followed by a frag-
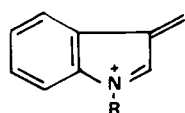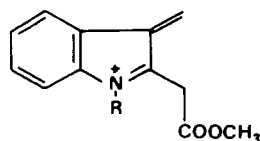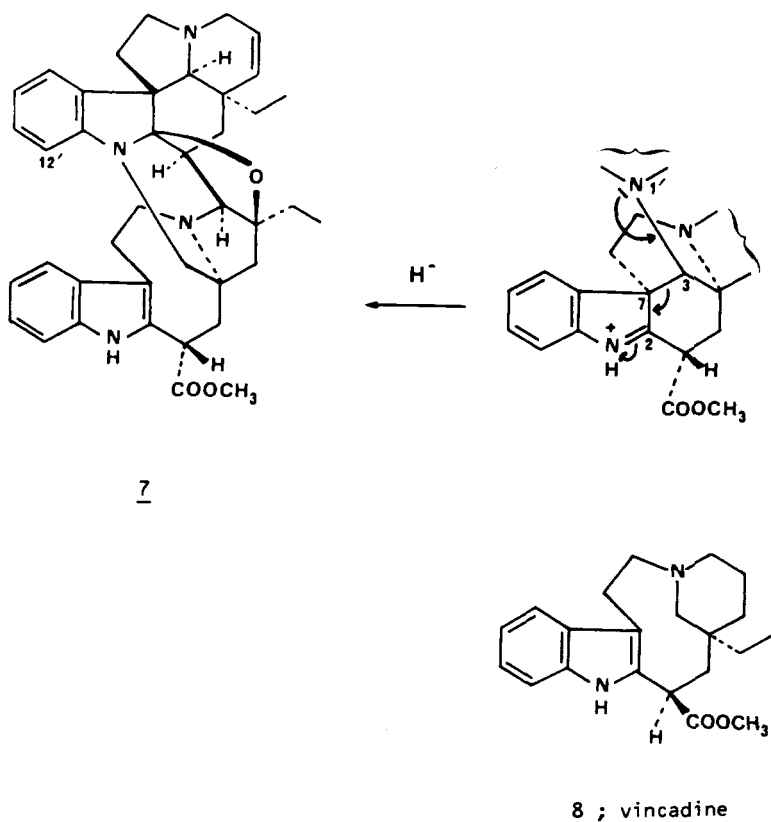
Fig.2

a ; R=H ; 130   b ; R=H ; 202

Fig. 3

7

8 ; vincadine

mentation leading to a stabilized indole nucleus. Trapping of the resulting immonium by water gave a carbinolamine in equilibrium with an aldehyde; surprisingly, the carbinolamine ether also present in the molecule survived the drastic reaction conditions.

In sharp contrast with the chemical inertness to cleavage of molecules **3, 4, 5, 6, 7** and **9**, they readily gave fragments under electron impact corresponding to the rupture of up to three bonds. Thus ervafolene (**3**) split into two halves (on each side of the ether bonds), characterized by ions at m/z 279 and 333; these ions are found at 281 and 333 in dihydroervafolene (**4**) indicating that the former ion is related to the aspidosperma moiety, whereas the latter belongs to the "lower half" of the molecule. In the abnormal reduction product **7**, this ion is shifted at m/z 335 as a consequence of the reduction of the 2,16 double bond. Even though the structures of these compounds were known, it is difficult to formulate structures and mechanisms for these fragmentations.

The two other dimers, ervafolidene (**10**) and epi-ervafolidene (**11**) possessed the same formula, $C_{40}H_{46}O_4N_4$ (M+· at m/z 646), and very close physical data. Formally, they corresponded to the products of H_2O addition to ervafolene (**3**), an addition which could proceed only in one of two ways: addition across a double bond or addition across a single bond with rupture of that bond. The first possibility was ruled out on the basis of the ¹H nmr spectra which showed intact 14'–15' and 2–16 double bonds. Confronted with the numerous possibilities offered by the second hypothesis, Husson et al. submitted one of their "split dimers" epi-ervafolidine (**2b**) to X-ray crystallography. Comparison of the ¹³C nmr spectra of **2a, 10** and **11** demonstrated a great resemblance between **2a** and **10**, the difference between them being due to an epoxide–olefin interchange as between **1** and **3**.

Fig.4
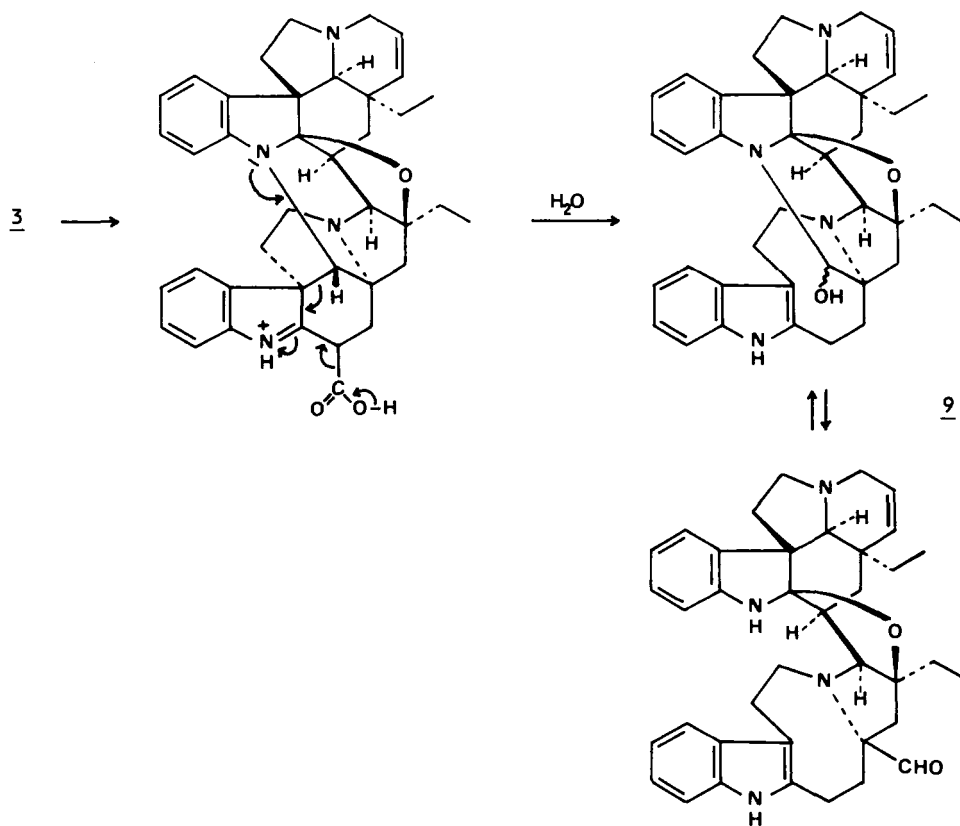
The epimeric structure **11** was given to the second derivative to account for the large chemical shift difference between the C–3 of **11** and **10**.

Compounds **10** and **11** yielded acetates **12** and **13** whose ^{13}C nmr spectra were recorded in the hope of confirming the carbons attributions for **10** and **11**; however only minor differences were noted between the spectra of the alcohols and of their acetates. ^1H nmr spectra of **12** and **13** were informative with regard to stereochemistry at C–3:

In compound **13** the acetate methyl appears at δ 1.75 ppm and H–3 at 5.60 ppm, whereas in **12** these two signals are displayed at 2.42 and 5.32 ppm. This is an effect of the aromatic ring magnetic anisotropy; the substituent at C–3, equatorial in ring D, is on top of the benzene ring in the shielding area, while the axial substituent is near the plane of the benzene ring in the deshielding area.

Fig.5

12   13
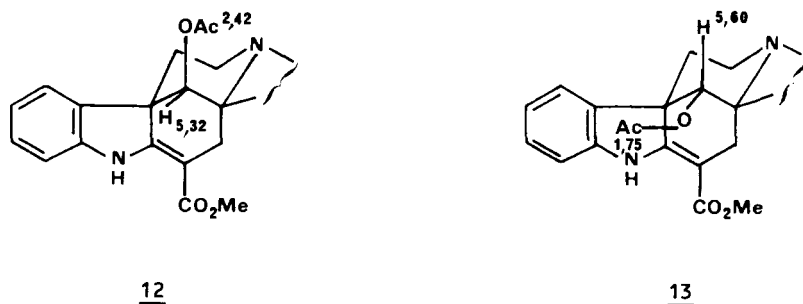
Ervafolidene (10) and acetyl epi-ervafolidene (13) were submitted to the NaBH₃CN, AcOH reduction of the 2,16 double bond which this time was eventless. In the two cases a single compound was obtained with a dihydro indole chromophore only in the uv, since no participation could be expected from N–1'.

Among the intriguing properties of these molecules, mention must be made again of the unexpected stability of their carbinolamine ether component. This moiety was resistant to hydrolysis, reduction, or acetylation under forcing conditions. This non-classical behaviour, most probably due to steric crowding about the center of the molecule, has been one of the reasons why it was difficult to formulate correct hypotheses for structure 3, 10, 11. Another difficulty was the presence of an hitherto unknown rearranged form of the pseudo aspidosperma alkaloids.

EXPERIMENTAL[1]

ERVAFOLENE (3).—Amorphous, [α]D+236 (c=1.0; MeOH); uv λ max (MeOH) nm (log ε): 212(4.46), 256(4.09), 326(4.32), infl. 310(4.24); ir (CHCl₃) cm⁻¹: 3380, 1680, 1620; ms m/z (rel. int.): M⁺· 628(100), 599(38), 414(30), 333(33), 325(26), 314(26), 279(22), 221(34), 214(25), 194(26), 180(31), 168(36), 167(30), 154(33), 144(31), 136(33), 135(41), 130(27), 122(40), 121(41), 108(42), 107(40); ¹H nmr: 9.23 (s, 1H), 7.3–6.3 (m, 7H), 5.8 (bs, 2H), 5.6 (m, 1H), 3.87 (s, 1H), 3.74 (s, 3H), 0.97 (t, J=7Hz, 3H), 0.86 (t, J=7Hz, 3H).

CATALYTIC HYDROGENATION OF ERVAFOLENE (3→4).—Alkaloid 3 (60 mg) was dissolved in 3 ml of methanol and hydrogenated with 3 mg PtO₂ during 50 hr. Filtration, evaporation, and purification with prep. tlc [methylene chloride-methanol (93:7)] gave 4 (40 mg). Amorphous, [α]D+223 (c=0.6; CHCl₃); uv λ max (MeOH) nm: 217, 257, 326, infl. 307; ir (CHCl₃) cm⁻¹: 3380, 1690, 1620; ms m/z (rel. int.): M⁺· 630(100), 598(19), 573(8), 416(14), 333(11), 315(10), 297(8), 285(6), 281(6), 249(5), 221(5), 214(4), 208(6), 194(6), 182(6), 180(7), 168(14), 167(10), 154(7), 138(9), 130(6), 124(98), 122(6), 109(8); ¹H nmr: 9.2 (s, 1H), 7.3–6.2 (m, 7H), 5.6 (m, 1H), 3.9 (s, 1H), 3.75 (s, 3H), 0.97 (t, J=7Hz, 3H), 0.80 (t, J=7Hz, 3H).

NaBH₃CN REDUCTION OF ERVAFOLENE (3→5+7).—Ervafolene (3) (550 mg) was dissolved in 10 ml of acetic acid, and 180 mg NaBH₃CN was added, little by little. After stirring at room temperature for 90 min., the mixture was diluted with water, made alkaline with NH₄OH and extracted with chloroform. The crude product, subjected to prep. tlc [benzene-ether-methanol (60:40:10)] gave 5 (50 mg, the most polar) and 7 (335 mg).

—minor product 5: [α]D+54 (c=0.7; MeOH); uv λ max (MeOH) nm (log ε): 214(4.24), 253(4.10), 299(3.63); ir (CHCl₃) cm⁻¹: 3400, 1735, 1605; ms m/z (rel. int.): M⁺· 630(62), 601(6), 500(100), 487(18), 428(80), 416(22), 414(12), 335(5), 315(6), 279(6), 277(6), 251(6), 208(8), 194(9), 180(8), 170(11), 156(8), 154(6), 144(18), 135(22), 130(15), 122(18), 121(18), 108(13), 107(12); ¹H nmr: 7.3–6.2 (m, 7H), 5.82 (bs, 2H), 5.05 (m, 1H), 4.25 (bs, 1H), 3.77 (s, 3H), 0.98 (t, J=7Hz, 3H), 0.9 (t, J=7Hz, 3H).

—major product 7: [α]D+11 (c=1.0; MeOH); uv (MeOH); uv λ max (MeOH) nm (log ε): 217(4.51), 226(4.53), 257(4.18), 287(3.97), 294(3.96); ir (CHCl₃) cm⁻¹: 3450, 1735, 1610; ms m/z (rel. int.): M⁺· 630(65), 601(25), 572(26), 543(9), 428(10), 416(15), 349(55), 335(66), 322(11), 315(18), 308(100), 295(25), 291(30), 282(59), 281(60), 279(52), 277(32), 253(22), 251(23), 215(65), 169(21), 156(32), 144(40), 134(92), 122(76), 121(70), 108(98), 107(28); ¹H nmr: 8.83 (s, 1H), 7.6–6.5 (m, 7H), 6.2 (m, 1H), 5.75 (bs, 2H), 4.3 (dd, 1H), 3.77 (s, 3H), 0.98 (t, J=7Hz, 3H), 0.72 (t, J=7Hz, 3H).

ACETYLATION OF 5 (5→6).—Compound 5 (34 mg) was dissolved in pyridine (1 ml) and 1 ml of Ac₂O was added. The mixture was heated 95°C for 5 hr, solvents were removed in vacuo and the crude product purified by prep. tlc [benzene-ether-methanol (60:40:5)] gave 6 (20 mg): uv λ max (MeOH) nm (log ε: 214(4.26), 253(4.24), 290(3.15); ir (CHCl₃) cm⁻¹: 1735, 1650, 1600; ms m/z (rel. int.): M⁺· 672(54), 643, 629, 615, 500(100), 487, 428, 377, 315, 308, 293, 280, 251, 220, 205, 194, 180, 170, 168, 156, 144, 135, 130, 122, 121, 108, 107; ¹H nmr: 7.3–6.3 (m, 7H), 5.82 (bs, 2H), 5.3 (m, 1H), 4.6 (d, J=6Hz, 1H), 3.6 (s, 3H), 2.45 (s, 3H), 0.92 (t, J=7Hz, 6H).

ACID-HYDROLYSIS OF ERVAFOLENE (3→9).—Ervafolene (3) (20 mg) in 5 ml HCl conc. was refluxed for 45 min. The reaction mixture was then poured into water, neutralized with NH₄OH and extracted with chloroform. After drying and evaporation, the crude product purified by prep. tlc (benzene-ether-methanol (60:40:5)] gave 9 (13 mg): uv λ max (MeOH) nm: 214, 225, 255, 285, 292; ir (CHCl₃) cm⁻¹: 3300, 1660, 1600; ms m/z (rel. int.): M⁺· 586(48), 572(55), 570(100), 568, 557, 541, 428, 370, 308, 295, 291, 277, 275, 263, 250, 215, 211, 183, 180, 167, 156, 144, 135, 134, 130, 122, 121, 108, 107.

ERVAFOLIDENE (10).—Ervafolidene (10) gave mp 212° (acetone); $[\alpha]_D+56$ (c=1.5; MeOH); uv λ max (MeOH) nm (log ϵ): 214(4.25), 300(4.05), 325(4.10), 245 infl.; ir (CHCl$_3$) cm^{-1}: 3380, 3280, 3240, 1690, 1615; ms m/z (rel. int.): M$^{+\cdot}$ 646(85), 628(5), 617(5), 585(4), 460(10), 446(9), 444(9), 432(40), 430(35), 369(38), 352(25), 337(15), 323(25), 321(20), 296(35), 295(35), 294(30), 293(35), 279(23), 267(35), 265(25), 263(20), 251(20), 249(20), 247(20), 238(30), 228(35), 214(45), 206(25), 195(40), 180(43), 170(45), 169(58), 168(100), 167(65), 180(30), 156(45), 154(70), 144(40), 135(50), 130(45), 124(45), 122(70), 121(57), 108(70), 107(55); ^{1}H nmr: 8.92 s, 1H), 7.3–6.3 (m, 8H), 5.55 (bs, 1H), 3.85 (s, 1H), 3.77 (s, 3H), 1.3 (t, $J=7$Hz, 3H), 0.7 (t, $J=7$Hz, 3H).

EPI-ERVAFOLIDENE (11).—Amorphous, $[\alpha]_D+35$ (c=2.0; MeOH); uv λ max (MeOH) nm (log ϵ): 215(4.39), 299(4.16), 325(4.22); ir (CHCl$_3$) cm^{-1}: 3400, 3300, 1690, 1615; ms m/z (rel. int.): M$^{+\cdot}$ 646(100), 628(30), 614(5), 432(33), 430(35), 414(5), 379(9), 369(15), 351(15), 323(25), 296(35), 294(25), 279(10), 267(20), 256(7), 238(9), 228(12), 214(12), 195(10), 185(10), 180(10), 168(30), 160(15), 156(15), 154(20), 144(15), 135(25), 130(15), 122(35), 121(25), 108(30), 107(15); ^{1}H nmr: 8.96 (s, 1H), 7.4–6.4 (m, 8H), 5.55 (bs, 2H), 4.15 (s, 1H), 3.76 (s, 3H), 1.02 (t, $J=7$Hz, 3H), 0.8 (t, $J=7$Hz, 3H).

ACETYLATION OF ERVAFOLIDENE (10→12).—Ervafolidene 10 (160 mg) was dissolved in pyridine (1 ml) and 2 ml Ac$_2$O was added. After 24 hr at room temperature, solvents were removed *in vacuo* and the crude product purified by prep. tlc (benzene–ether–methanol (60:40:5)] gave 12 (100 mg): amorphous; uv λ max (MeOH) nm (log ϵ): 215(4.31), 298(4.15), 323(4.15), 245 infl.; ir (CHCl$_3$) cm^{-1}: 3390, 3300, 1740, 1690, 1615; ms m/z (rel. int.): M$^{+\cdot}$ 688(45), 634, 631, 601, 570, 474, 421, 414, 411, 407, 393, 390, 379, 363, 361, 351, 347, 344, 333, 323, 301, 295, 293, 291, 275, 267, 265, 247, 239, 228, 214, 206, 196, 180, 170, 168, 167, 154, 150, 144, 135, 130, 122, 121, 108, 107; ^{1}H nmr: 9.03 (s, 1H), 7.4–6.4 (m, 8H), 5.6 (bs, 2H), 5.32 (s, 1H), 3.78 (s, 3H), 2.42 (s, 3H), 1.05 (t, $J=7$Hz, 3H), 0.7 (t, $J=7$Hz, 3H).

ACETYLATION OF EPI-ERVAFOLIDENE (11→13).—Compound 11 (155 mg) was acetylated with the same process, and gave 13 (110 mg): mp 290° (acetone); uv λ max (MeOH) m, (log ϵ): 213(4.41), 297(4.14), 324(4.15); ir (CHCl$_3$) cm^{-1}: 3385, 3320, 1740, 1690, 1615; ms m/z (rel. int.): M$^{+\cdot}$ 688(72), 656, 629, 628, 599, 569, 474, 421, 413, 411, 407, 393, 390, 379, 363, 361, 351, 347, 344, 333, 323, 319, 301, 295, 294(100), 293, 291, 289, 275, 267, 265, 247, 239, 228, 222, 214, 208, 206, 196, 182, 180, 170, 168, 167, 160, 156, 154, 144, 138, 135, 134, 130, 122, 121, 108, 107; ^{1}H nmr: 8.95 (s, 1H), 7.5–6.5 (m, 8H), 5.60 (bs, 3H), 3.8 (s, 3H), 1.75 (s, 3H), 1.09 (t, $J=7$Hz, 3H), 0.7 (t, $J=7$Hz, 3H).

NaBH$_3$CN REDUCTION OF ERVAFOLIDENE (10→14).—Compound 10 (7 mg) was reduced with NaBH$_3$CN (5 mg) and AcOH (2 ml) in the same manner as ervafolene (3) (see above) and gave 14 (4 mg): amorphous; uv λ max (MeOH) nm: 217, 245, 293; ir (CHCl$_3$) cm^{-1}: 3390, 3320, 3270, 1730, 1610; ms m/z: M$^{+\cdot}$ 648, 381, 371, 353, 341, 327, 280, 278, 249, 222, 210, 208, 196, 194, 182, 180, 170, 167, 156, 154, 144, 143, 140, 135, 130, 124, 122, 107.

NaBH$_3$CN REDUCTION OF 13 (13→15).—In the same manner, 13 (10 mg) gave 15 (5 mg:, amorphous; uv λ max (MeOH) nm: 217, 245, 295; ir (CHCl$_3$) cm^{-1}: 3330 (broad band), 1740, 1615; ms m/z: M$^{+\cdot}$ 690, 423, 413, 395, 383, 381, 363, 353, 352, 335, 321, 307, 280, 278, 267, 251, 249, 247, 222, 210, 208, 196, 194, 184, 180, 170, 168, 156, 154, 144, 143, 135, 130, 122, 121, 108, 107.

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LITERATURE CITED

1. M. Zeches, M.-M. Debray, G. Ledouble, L. Le-Men-Olivier, and J. Le Men, *Phytochemistry*, 14, 1122, (1975).
2. (a) A. Henriques, C. Kan-Fan, A. Ahond, C. Riche and H.-P. Husson, *Tetrahedron Lett.*, 3707, (1978).
    (b) A. Henriques, S. K. Kan, and M. Lounasmaa, *Acta Chem. Scand.*, B33, 775, (1979).
    (c) A. Henriques, C. Kan, H.-P. Husson, S. K. Kan, and M. Lounasmaa, *Acta Chem. Scand.*, B34, 509, (1980).
    (d) A. Henriques, Thése Doctorat és Sciences Physiques, Orsay (1981).
    (e) A. Henriques and H.-P. Husson, *Tetrahedron Lett.*, 567, (1981).
    (f) A. Henriques, C. Kan, A. Chiaroni, C. Riche, H.-P. Husson, S. K. Kan, and M. Lounasmaa, *J. Org. Chem.*, 803, (1982).
3. B. Birdsall, N. J. M. Birdsall, and J. Feeney, *J.C.S. Chem. Comm.*, 326, (1972).
4. E. Wenkert, E. W. Hagaman, N. Kunesch, N. Y. Wang, and B. Zsadon, *Helv. Chim. Acta*, 59, 2711, (1976).
5. M.-J. Hoizey, L. Olivier, J. Lévy, and J. Le Men, *Tetrahedron Lett.*, 1011, (1971).
6. J. Le Men, M.-J. Hoizey, G. Lukacs, L. Le Men-Olivier, and J. Lévy, *Tetrahedron Lett.*, 3119, (1974).
7. G. F. Smith and J. T. Wrobel, *J. Chem. Soc.*, 792, (1960).
8. C. Djerassi, H. Budzikiewicz, J.-M. Wilson, J. Gosset, J. Le Men, and M.-M. Janot, *Tetrahedron Lett.*, 235, (1962).
9. N. Kunesch, A. Cavè, E. W. Hagaman, and E. Wenkert, *Tetrahedron Lett.*, 21, 1727, (1980).