*Phytochemistry*, Vol 28, No 4, pp 1155-1161, 1989
Printed in Great Britain

0031-9422/89 \$3 00+0 00

# PSEUDOGUAIANOLIDES AND OTHER CONSTITUENTS FROM *ANISOPAPPUS PINNATIFIDUS* AND *ANTIPHIONA* SPECIES

C. ZDERO and F BOHLMANN

Institute for Organic Chemistry, Technical University of Berlin, D-1000 Berlin 12, F R G

(*Received* 21 *June* 1988)

**Key Word Index**—*Anisopappus pinnatifidus*, *Antiphiona fragrans*, *A pinnatisecta*; Compositae, sesquiterpene lactones; pseudoguaianolides, diterpene, epoxyanol and epoxyisoeugenol derivatives, thymol derivatives.

---

**Abstract**—The aerial parts of *Anisopappus pinnatifidus* afforded 15 new pseudoguaianolides, all related to helenalin and linearifolin B, respectively, a diterpene diol and two known melampolides while the roots contain five epoxyanol and two epoxyisoeugenol derivatives Two *Antiphiona* species contain naringenin, thymol and several derivatives of the latter. One species also afforded dihydrogeigeranolide The structures were elucidated by high field $^1$H NMR spectroscopy.

---

## INTRODUCTION

The taxonomy of the South African representatives of the subtribe Inulinae (Compositae, tribe Inuleae) is still not really solved [1]. At the end of the first series of this subtribe a group of genera is placed with low chromosome numbers including the predominantly African genera *Anisopappus*, *Antiphiona*, *Calostephane* and *Mollera* [1]. As little was known on the chemistry of these genera we have collected some of the representatives for a chemical investigation and the results are discussed in this paper.

## RESULTS AND DISCUSSION

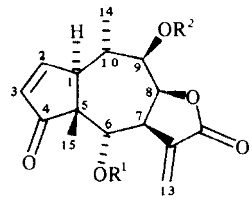
The genus *Antiphiona* with two species is only present in South West Africa. *Antiphiona fragrans* (Merxm.) Merxm. is a small shrub with strongly smelling leaves The aerial parts contain high concentrations of thymol and naringenin as well as small amounts of crystalline dihydrogeigeranolide (**33**), which has been isolated in traces as an oil from a *Geigeria* species [2], and the dihydrocinnamate **27**. The structure of the latter compound followed from its $^1$H NMR spectrum. The relative position of the ester group could be deduced by comparing the chemical shift of H-8 with that of thymohydroquinone.

The aerial parts of the second species, *A. pinnatisecta* (S Moore) Merxm. also gave naringenin but no thymol. The latter was replaced by a group of derivatives, the thymohydroquinones **28**–**30** and the corresponding quinones **31** and **32**. Furthermore, lavandulol, γ-humulene and taraxasteryl acetate were isolated The relative position of the acetate group in **28**–**30** was determined by NOE difference spectroscopy. Thus in the case of **28** a NOE between H-5, H-8 and the acetate methyl, in the case of **29** between the latter and H-7 and in the case of **30** between H-6, H-7 and the acetate methyl. In a previous paper [3] the substituents at C-3 and C-5 have been exchanged.

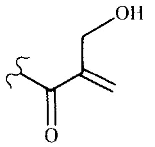
The genus *Anisopappus* originally only had three species [4] but now about 30 species, mostly tropical, have been transferred to this genus [1]. Nothing was known about their chemistry. The aerial parts of *Anisopappus pinnatifidus* (Klatt.) O Hoffm ex Hutch (=*Matricaria pinnatifida*) afforded the pseudoguaianolides **1**–**11**, the linearifolin B derivatives **12**–**15**, the urospermal derivatives **16** and **17** [5] and the diterpene **18**. The roots gave the anol derivatives **19**–**23** and the isoeugenol derivatives **24** and **25**

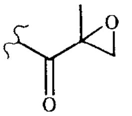
The $^1$H NMR spectrum of **1** (Table 1) indicated the presence of a pseudoguaianolide with a 2,3-double bond and a 4-oxo group as revealed by the typical group of signals at δ3.14 (*ddd*), 7 72 (*dd*) and 6 10 (*dd*). Furthermore, the characteristic signals for an isobutyrate and a hydroxymethacrylate were visible and acetylation afforded a monoacetate (**1a**). The observed downfield shift of the H-4′ signal established the proposed nature of the ester group. Spin decoupling allowed the assignment of all signals Irradiation at δ3.67 indicated that this signal was due to H-7 as the exomethylene signals collapsed to singlets Furthermore, a broadened singlet at δ5.35 was sharpened and a double doublet at δ4 76 collapsed to a doublet These findings showed that a 12,8-olide was present with ester groups at C-6 and C-9. The stereochemistry and the relative position of the ester residues were determined by NOE difference spectroscopy Saturation of H-8 gave an effect with H-7 (8%), of H-10 with H-15 (7%) and H-1 (4%), of H-15 with H-10 (12%), H-6 (10%) and H-3 (3%), of H-9 with H-8 (6%), H-1 (8%) and the signals of the isobutyrate, of H-6 with H-15 (7%), H-7 (8%), H-13′ (6%) and the methylene signals of the hydroxymethacrylate. Thus lactone **1** is a derivative of helenalin A corresponding pseudoguaianolide with identical substitution and stereochemistry is the antineoplastic lactone multigilin with a 6α-angeloyloxy and a 9β-hydroxy group [6] Accordingly, the $^1$H NMR spectra are similar.

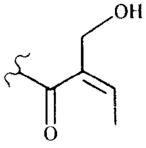
The $^1$H NMR spectra of **2** and **5** (Table 1) indicated the presence of the corresponding diangelate and the dimethacrylate, respectively, while that of **3** required a mixed diester with an angelate and a methacrylate residue. Comparison of the chemical shifts of H-6 in the spectra of **2** and **3** allowed the assignment of the relative positions of

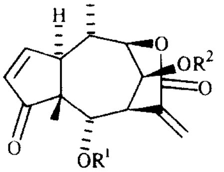


| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| R¹ | A | Ang | Meacr | Meacr | Meacr | B | B | C | A | A | C |
| R² | iBu | Ang | Ang | iBu | Meacr | Ang | iVal | Ang | Ang | iVal | iBu |

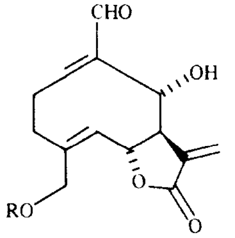
A =


B =


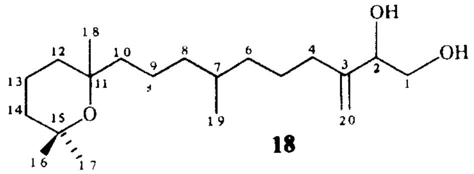
C =




| | 12 | 13 | 14 | 15 |
|---|---|---|---|---|
| R¹ | A | A | C | C |
| R² | Ang | iVal | Ang | iVal |



**16** R = H
**17** R = Ac



**18**

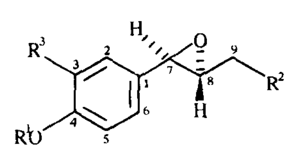
**1a**, **8a**–**15a** and **18a** are the corresponding acetates

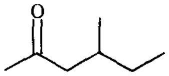
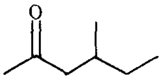
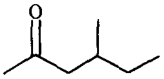
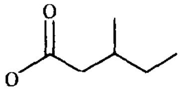
the ester groups in the latter This is also true for the other lactones (**4** and **6**–**11**). Their $^1$H NMR spectra, or those of the corresponding acetates **8a**–**11a** (Table 1), indicated the nature of the ester groups again directly from the typical $^1$H NMR signals The isovalerates **7** and **10a** could not be obtained free from the corresponding angelates.

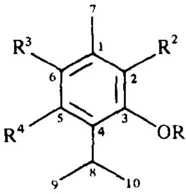
This is also true for the lactones **12**–**15** which were isolated as two pairs of their acetates **12a**/**13a** and **14a**/**15a** Inspection of the $^1$H NMR spectra (Table 2) indicated that we were dealing with δ-lactones as followed from the downfield shift of the H-13 signals and the absence of a γ-lactone IR band The spectra were very similar to that of a linearifolin B derivative [7] which only differs in the nature of the ester groups The stereochemistry was established by the observed NOE's Saturation of H-15 gave strong effects with H-10 and H-6

The diol **18** was isolated as its diacetate **18a** Inspection of its $^1$H NMR spectrum (Experimental) indicated that the compounds had only one double bond The molecular formula was deduced from *m/z* 395 ($C_{23}H_{39}O_5$) which obviously was formed by loss of methyl as a further fragment, *m/z* 352, most likely was formed by loss of acetone All data therefore indicated the presence of a diterpene diacetate with one ring The $^{13}$C NMR spectrum (Experimental) showed two singlets for oxygen bearing carbons Accordingly, an ether ring was very likely In agreement with the base peak in the mass spectrum (*m/z* 127) a ring was proposed between C-11 and C-15 The relative configuration at C-7 and C-11 could not be determined

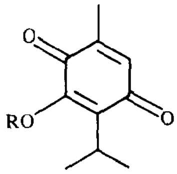
The root extract afforded a complex mixture of anol and isoeugenol epoxide derivatives. Finally the esters **19**–**25** were obtained which, however, could not be completely separated from each other The $^1$H NMR spectrum (Table 3) of **19** indicated that an epoxide of esterified anol was present The configuration of the epoxide followed from the coupling $J_{7,8}$ which typically differs from the corresponding *cis*-epoxides [8] The nature of the ester group was deduced from the sequence obtained by spin decoupling and from the mass spectrum which required a $C_6$-ester The $^1$H NMR spectrum of **20**



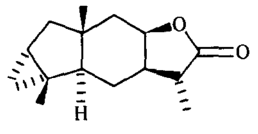
| | 19 | 20 | 21 | 22 | 23 | 24 | 25 |
|---|---|---|---|---|---|---|---|
| R¹ |  | iVal |  | iVal | iVal |  | iVal |
| R² | H | H | OiVal |  | OiVal | H | H |
| R | H | H | H | H | H | OMe | OMe |



| | 26 | 27 | 28 | 29 | 30 |
|---|---|---|---|---|---|
| R¹ | H | $COCH_2CH_2Ph$ | H | H | H |
| R² | H | H | H | OAc | OH |
| R³ | H | OH | OAc | H | H |
| R⁴ | H | H | H | OH | OAc |



**31** R = H
**32** R = Ac



**33**

(Table 3) required the presence of the corresponding isovalerate and that of **23** indicated a 9-isovaleryloxy derivative of **20** The $^1H$ NMR signals of **21** and **22** indicated isomeric diesters where in one case the isovalerate residue of **23** at C-9 was replaced by a 3-methylvalerate and in the other the phenolic hydroxyl was esterified with this C-6 ester The $^1H$ NMR spectra of **24** and **25** (Table 3) showed that the 3-methoxy derivatives of **19** and **20** were present as followed from the changed pattern of the aromatic protons while the remaining signals were similar in both series A similar isoeugenol derivative with isobutyrate groups of a *cis*-epoxide has been reported from a *Coreopsis* species [9]

The chemistry of an *Anisopappus* and two *Antiphiona* species indicates no relationships between these genera Pseudoguaianolides in addition to mainly guaianolides are reported from *Geigeria* species [10] which are placed by Merxmüller *et al* [1] in the next group of genera. However, these lactones are especially characteristic for the genus *Helenium* and related ones [11]. The proposed relationship of *Anisopappus* to *Asteriscus* [1] is also not supported by the chemistry The chemistry of *Antiphiona* is not very characteristic. Thymol and its derivatives, however, are reported from several *Inula*, *Pluchea* and *Blumea* species, all placed at least in the same subtribe.

The eudesmanolides from *Calostephane divaricatum* [12] are very different from those of the *Anisopappus* species, therefore the proposed relationship also is in doubt Further investigations are necessary to clarify the taxonomically complicated situation of this subtribe.

## EXPERIMENTAL

The air-dried plant material was collected in March 1988 in Namibia (vouchers are deposited in the SW African Herbarium at Windhoek) Extracts and separations were performed as reported previously [13] TLC (silica gel) $Et_2O$–petrol [3 1 (T1), 1 1 (T2), 1 3 (T3), 1 9 (T4)] HPLC always used RP 8, $MeOH$–$H_2O$ (7 3) flow rate 3 ml/min

The extract of *Anisopappus pinnatifidus* (voucher 88/16, collected *ca* 50 km east of Windhoek, 250 g aerial parts) gave by CC a polar fraction with $Et_2O$ and $Et_2O$–MeOH (9:1) HPLC gave 6 mg **16** ($R_t$ 0 4 min), 2 mg **17** ($R_t$ 0 9 min), 90 mg **3** ($R_t$ 5 3 min), 60 mg **1** ($R_t$ 1 7 min) and four mixtures (1–4) Fraction 1 was

Table 1. $^1$H NMR spectral data of compounds **1**–**8** and **9a**–**11a** (400 MHz, CDCl$_3$, δ values)

| H | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9a** | **10a** | **11a** | multiplicity |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 3.14 | 3.19 | 3.20 | 3.15 | 3.17 | 3.11 | 3.08 | 3.20 | 3.16 | 3.13 | 3.14 | *ddd* |
| 2 | 7.72 | 7.72 | 7.73 | 7.72 | 7.72 | 7.73 | 7.72 | 7.73 | 7.73 | 7.72 | 7.72 | *dd* |
| 3 | 6.10 | 6.11 | 6.11 | 6.11 | 6.11 | 6.11 | 6.11 | 6.12 | 6.10 | 6.10 | 6.09 | *dd* |
| 6 | 5.35 | 5.34 | 5.31 | 5.31 | 5.32 | 5.22 | 5.21 | 5.42 | 5.34 | 5.33 | 5.36 | *br s* |
| 7 | 3.67 | 3.71 | 3.70 | 3.66 | 3.68 | 3.66 | 3.64 | 3.76 | 3.71 | 3.69 | 3.71 | *dddd* |
| 8 | 4.76 | 4.85 | 4.85 | 4.76 | 4.84 | 4.86 | 4.80 | 4.84 | 4.84 | 4.77 | 4.78 | *dd* |
| 9 | 4.99 | 5.10 | 5.10 | 4.99 | 5.06 | 5.09 | 5.00 | 5.14 | 5.07 | 4.97 | 4.97 | *dd* |
| 10 | 2.50 | 2.57 | 2.58 | 2.53 | 2.55 | 2.53 | 2.47 | 2.59 | 2.56 | 2.56 | 2.52 | *ddq* |
| 13 | 6.46 | 6.49 | 6.49 | 6.47 | 6.47 | 6.48 | 6.48 | 6.49 | 6.49 | 6.49 | 6.49 | *d* |
| 13′ | 6.21 | 6.30 | 6.27 | 6.24 | 6.24 | 6.23 | 6.23 | 6.26 | 6.26 | 6.26 | 6.29 | *d* |
| 14 | 1.24 | 1.25 | 1.26 | 1.24 | 1.25 | 1.27 | 1.25 | 1.25 | 1.26 | 1.26 | 1.24 | *d* |
| 15 | 1.01 | 1.03 | 1.03 | 1.02 | 1.03 | 1.02 | 1.01 | 1.04 | 1.03 | 1.03 | 1.03 | *s* |
| 6 OCOR | 6.05 *dt* | 6.12 *qq* | 5.94 *br s* | 5.92 *br s* | 5.93 *br s* | 2.73 *d* | 2.73 *d* | 6.36 *tq* | 6.26 *br s* | 6.26 *br s* | 6.51 *q* | |
| | 5.85 *dt* | 1.95 *dq* | 5.57 *dq* | 5.57 *dq* | 5.57 *dq* | 2.70 *t* | 2.69 *d* | 1.99 *d* | 5.89 *br s* | 5.89 *br s* | 2.09 *d* | |
| | 4.27 *br d* | 1.78 *dq* | 1.88 *br s* | 1.86 *br s* | 1.87 *br s* | 1.52 *s* | 1.52 *s* | 4.23 *dt* | 4.69 *br s* | 4.68 *br s* | 4.59 *d* | |
| | 4.23 *br d* | | | | | | | 4.15 *dt* | | | 4.55 *d* | |
| OAc | | | | | | | | | 2.08 *s* | 2.07 *s* | 2.04 *s* | |
| 9 OCOR | 2.62 *qq* | 6.20 *qq* | 6.21 *qq* | 2.64 *qq* | 6.21 *br s* | 6.20 *qq* | 2.27 *dd* | 6.21 *qq* | 6.19 *qq* | 2.27 *dd* | 2.64 *qq* | |
| | 1.19 *d* | 2.04 *dq* | 2.04 *dq* | 1.21 *d* | 5.67 *dq* | 2.04 *dq* | 2.15 *tqq* | 2.04 *dq* | 2.03 *dq* | 2.15 *m* | 1.21 *d* | |
| | 1.18 *d* | 1.94 *dq* | 1.94 *dq* | 1.19 *d* | 1.96 *br s* | 1.93 *dq* | 0.97 *d* | 1.94 *dq* | 1.93 *dq* | 0.97 *d* | 1.19 *d* | |

*J* [Hz]: 1,2 = 1.5, 1,3 = 2.7, 1,10 = 2, 2,3 = 5.5, 6,7 ~ 1, 7,8 = 7.5, 7,13 = 2.5, 7,13′ = 2, 8,9 = 2, 9,10 = 11, 10,14 = 6.5, O*i*Bu 2,3 = 3,4 = 7, OCOC(CH$_2$OH)=CH$_2$ 3,3′ = 3,4 = 3′,4 ~ 1, OAng 3,4 = 7, 3,5 = 4,5 = 1.5, OMeacr 3,3′ = 3′,4 = 1, OCOC(Me) 3,3′ = 4, OAngOH 3,4 = 7, 3,5 = 1

Table 2 $^1$H NMR spectral data of compounds **1a**, **8a** and **12a**–**15a** (400 MHz, $CDCl_3$, $\delta$-values)

| H | **1a** | **8a** | **12a** | | **13a** | **14a** | | **15a** | multiplicity |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 3 13 *ddd* | 3 17 *ddd* | 3 24 | | 3 20 | 3 22 | | 3 19 | *ddd* |
| 2 | 7 73 *dd* | 7 72 *dd* | 7 64 | | 7 63 | 7 63 | | 7 61 | *dd* |
| 3 | 6 11 *dd* | 6 09 *dd* | 6.12 | | 6 11 | | 6 10 | | *dd* |
| 6 | 5 35 *br s* | 5.35 *br s* | 5 37 | | 5 34 | 5 38 | | 5 36 | *d* |
| 7 | 3 69 *dddd* | 3 74 *dddd* | 3 59 | | 3 54 | 3 61 | | 3 56 | *br s* |
| 8 | 4 78 *dd* | 4 85 *dd* | 5 50 | | 5.40 | 5 49 | | 5 40 | *br s* |
| 9 | 4 97 *dd* | 5 06 *dd* | 4 71 | | 4.66 | 4 72 | | 4 65 | *br d* |
| 10 | 2 53 *ddq* | 2 55 *ddq* | | 2 44 | | | 2 43 | | *dq* |
| 13 | 6 50 *d* | 6 50 *d* | | 6 79 | | | 6 79 | | *br s* |
| 13′ | 6 25 *d* | 6 29 *d* | | 6 09 | | | 6 10 | | *br s* |
| 14 | 1 24 *d* | 1 26 *d* | | 1 44 | | | 1 43 | | *d* |
| 15 | 1 03 *s* | 1 03 *s* | 1 08 | | 1.07 | 1 08 | | 1 07 *s* | |
| 6-OCOR | 4 70 *br s* | 6 51 *q* | | 4 74 *d* | | 6 51 *q* | | 6 51 *q* | |
| | 6 23 *br s* | 2 09 *d* | | 4 69 *d* | | 2 10 *d* | | 2 10 *d* | |
| | 5 89 *br s* | 4 60 *d* | | 6 28 *br s* | | 4 59 *br s* | | 4.59 *br s* | |
| | | 4 55 *d* | | 5 89 *br s* | | | | | |
| 8-OCOR | 2 64 *qq* | 6 19 *qq* | 6 18 *qq* | | 2 17 *d* | 6 17 *qq* | | 2 17 *d* | |
| | 1 19 *d* | 2 03 *dq* | 1 91 *dq* | | 2 07 *m* | 1 91 *dq* | | 2 05 *m* | |
| | 1 18 *d* | 1 93 *dq* | 1 82 *dq* | | 0.91 *d* | 1 82 *dq* | | 0 91 *d* | |
| OAc | 2 08 *s* | 2 05 *s* | 2.08 *s* | | 2.07 *s* | 2 02 *s* | | 2 01 *s* | |

*J* [Hz] Compounds **1a** and **8a**, see Table 1 Compounds **12a**–**15a** 1,2 = 1 5, 1,3 = 3, 1,10 = 12; 2,3 = 6, 6,7 = 3 5, 7,8 = 1 5, 7,13 = 7,9 = 8,9 = 9,10 ~ 1, 10,14 = 7, OCOR, see Table 1.

Table 3 $^1$H NMR spectral data of compounds **19**–**25** ( 400 MHz, $CDCl_3$, $\delta$-values)

| H | **19** | | **20** | **21*** | | **22†** | **23‡** | **24** | | **25** |
|---|---|---|---|---|---|---|---|---|---|---|
| 2 | | 7 04 *d* | | 7 06 *d* | | 7 05 *d* | 7 06 *d* | | 6.82 *d* | |
| 6 | | | | | | | | | 6 87 *dd* | |
| 3 | | 7 26 *d* | | | 7 28 *d* | | 7 28 *d* | | — | |
| 5 | | | | | | | | | 6 98 *d* | |
| 7 | | 3 58 *d* | | | 3 81 *d* | | 3 81 *d* | | 3 57 *d* | |
| 8 | | 3 00 *dq* | | | 3 22 *ddd* | | 3 23 *ddd* | | 2 99 *dq* | |
| 9 | | 1.44 *d* | | 4 47 *dd* | | 4 48 *dd* | 4 47 *dd* | | 1 44 *d* | |
| 9′ | | | | | 4 11 *dd* | | 4 11 *dd* | | | |
| OCOR | 2 55 *dd* | | 2 42 *d* | 2 55 *dd* | | 2 43 *d* | 2 43 *d* | 2 57 *dd* | | 2.44 *d* |
| | 2 34 *dd* | | 2 23 *tqq* | 2.34 *dd* | | 2.24 *tqq* | 2.24 *tqq* | 2 35 *dd* | | 2 25 *tqq* |
| | 2 02 *ddt* | | 1 05 *d* | 2 03 *ddt* | | 1 04 *d* | 1 06 *d* | 2 04 *ddt* | | 1 06 *d* |
| | 1 31 *dq* | | | 1 33 *dq* | | | | 1 32 *dq* | | |
| | 0 95 *t* | | | 0 93 *t* | | | | 0 95 *t* | | |
| | 1 03 *d* | | | 1 05 *d* | | | | 1 04 *d* | | |

*9-OCOR 2.26 *d*, 2 13 *m*, 0 97 *d*, † 9-OCOR 2 45 *dd*, 2 24 *dd*, 1 90 *ddt*, 1 30 *m*, 0 92 *t*, 1 05 *d*, ‡9-OCOR 2 26 *d*, 2 13 *m*, 0 98 *d*; *J* [Hz]. 2,3 = 5,6 = 8; 2,6 = 1.7; 7,8 = 2; 8,9 = 5 (compounds **21**–**23** 8,9 = 4; 8,9′ = 6, 9,9′ = 12); $OCOCH_2CHMeEt$ 2,2′ = 15, 2,3 = 6; 2′,3 = 8, 3,4 = 4,5 = 3,6 = 7, O*i*Val 2,3 = 3,4 = 3,5 = 7

acetylated ($Ac_2O$, 1 hr, 70°) and separated by TLC (T1 ×2) affording 2 mg **8a** ($R_f$ 0.60) and three mixtures (1/1–1/3) HPLC of 1/1 gave 3 mg **11a** ($R_t$ 4 7 min), 2 mg **9a** ($R_t$ 5 5 min) and 1 mg **10a** (containing **9a**, $R_t$ 5 4 min). HPLC of 1/2 afforded 3 mg **1a** ($R_t$ 2 7 min) and 3 mg **14a** and **15a** (*ca* 2·1) ($R_t$ 5.8 min). HPLC of 1/3 gave 2 mg **1a** and 5 mg **12a** and **13a** (*ca* 2·1) ($R_t$ 5.2 min)

TLC of fraction 2 (T1) gave 6 mg **8** ($R_f$ 0.40), 3 mg **6** ($R_f$ 0.52), 2 mg of a mixture of **6** and **7** ($R_f$ 0.50) and a mixture which gave by TLC (T2, 5×) 25 mg **4** ($R_f$ 0.65) and 35 mg **5** ($R_f$ 0.60) Fraction 3 was acetylated (see above). TLC (T2) gave 10 mg **18a** ($R_f$ 0 35). TLC of fraction 4 (T1) gave 10 mg **2** ($R_f$ 0 60) and 10 mg **3** ($R_f$ 0 52). The extract of 35 g of roots gave by CC two non-polar fractions ($Et_2O$–petrol, 1 9 and 1 3) TLC of fraction 1 (T4, ×2) gave 20 mg **19** ($R_f$ 0 48) and 5 mg **20** ($R_f$ 0 44). TLC of the second fraction (T3) gave 6 mg **21**/**22** (*ca* 1.1) ($R_f$ 0 60), 15 mg **23** ($R_f$ 0.51) and 4 mg **24**/**25** (*ca* 1 1) ($R_f$ 0 42).

*9β-Isobutyryloxyhelenalin-[4-hydroxymethacrylate]* (**1**) Colourless glass, IR $\nu_{\max}^{\mathrm{CHCl_3}}$ cm$^{-1}$ 3505 (OH), 1770 (γ-lactone), 1720 ($CO_2R$), MS *m/z* (rel int ) 330 147 $[M - R^1CO_2H]^+$ (3) (calc for $C_{19}H_{22}O_5$ 330 147), 260 $[330 - O{=}C{=}CMe_2]^+$ (40), 242 $[330 - RCO_2H]^+$ (39), 85 $[R^1CO]^+$ (68), 71 $[R^2CO]^+$ (100), $[\alpha]_D^{24}$ $-21$ ($CHCl_3$, *c* 6 38) Acetylation afforded **1a**, colourless gum, MS *m/z* (rel int ) 474 189 $[M]^+$ (0 1) (calc for $C_{25}H_{30}O_9$ 474 189), 386 $[M - R^1CO_2H]^+$ (0 8), 330 $[M - R^2CO_2H]^+$ (1), 242 $[330 - R^1CO_2H]^+$ (25), 127 $[R^1CO]^+$ (100), 71 $[R^2CO]^+$ (42)

*9β-Angeloyloxyhelenalin angelate* (**2**) Colourless gum, IR $\nu_{\max}^{\mathrm{CCl_4}}$ cm$^{-1}$ 1780 (γ-lactone), 1725, 1640 ($C{=}CCO_2R$), MS *m/z* (rel int ) 442 199 $[M]^+$ (1) (calc for $C_{25}H_{30}O_7$ 442 199), 342 $[M - RCO_2H]^+$ (2), 314 $[342 - CO]^+$ (1 7), 242 $[342 - RCO_2H]^+$ (14), 83 $[RCO]^+$ (100)

*9β-Angeloyloxyhelenalin methacrylate* (**3**) Colourless gum, IR $\nu_{\max}^{\mathrm{CCl_4}}$ cm$^{-1}$ 1780 (γ-lactone), 1725, 1640 ($C{=}CCO_2R^1$), MS *m/z* (rel int ) 428 184 $[M]^+$ (0 5) (calc for $C_{24}H_{28}O_7$ 428 184), 342 $[M - R^1CO_2H]^+$ (1 3) 260 $[342 - O{=}C{=}C{=}(Me)CH{=}CH_2]^+$ (3 5), 242 $(342 - R^1CO_2H]^+$ (18) 83 $[R^1CO]^+$ (66), 69 $[R^2CO]^+$ (100)

*9β-Isobutyryloxyhelenalin methacrylate* (**4**) Colourless gum, IR $\nu_{\max}^{\mathrm{CCl_4}}$ cm$^{-1}$ 1780 (γ-lactone), 1730 ($CO_2R^1$), MS *m/z* (rel int ) 416 184 $[M]^+$ (0 1) (calc for $C_{23}H_{28}O_7$ 416 184), 330 $[M - MeacrOH]^+$ (0 8), 328 $[M - i\mathrm{BuOH}]^+$ (0 2), 300 $[328 - CO]^+$ (3), 260 $[330 - O{=}C{=}CMe_2]^+$ (12), 242 $[330 - i\mathrm{BuOH}]^+$ (14), 71 $[R^1CO]^+$ (18), 69 $[R^2CO]^+$ (100)

*9β-Methacryloyloxyhelenalin methacrylate* (**5**) Colourless gum, IR $\nu_{\max}^{\mathrm{CCl_4}}$ cm$^{-1}$ 1780 (γ-lactone), 1725, 1640 ($C{=}CCO_2R$), MS *m/z* (rel int ) 328 131 $[M - RCO_2H]^+$ (0 3) (calc for $C_{19}H_{20}O_5$ 328 131), 242 $[328 - RCO_2H]^+$ (1 8), 86 $[RCO_2H]^+$ (100); $[\alpha]_D^{24}$ $-15$ ($CHCl_3$, *c* 3 26)

*9β-Angeloyloxyhelenalin-[2,3-epoxyisobutyrate]* (**6**) Colourless oil, IR $\nu_{\max}^{\mathrm{CCl_4}}$ cm$^{-1}$ 1785 (γ-lactone), 1740 ($CO_2R^1$), 1725 ($C{=}CCO_2R^1$), MS *m/z* (rel int ) 444 178 $[M]^+$ (0 7) (calc for $C_{24}H_{28}O_8$ 444 178), 344 $[M - AngOH]^+$ (1 7), 342 $[M - R^1CO_2H]^+$ (2 4), 242 $[M - 2 \times R^1CO_2H]^+$ (50), 85 $[R^1CO]^+$ (37), 83 $[R^2CO]^+$ (100)

*9β-Isovaleryloxyhelenalin-[2,3-epoxyisobutyrate]* (**7**) Colourless oil, not free from **6**, IR $\nu_{\max}^{\mathrm{CCl_4}}$ cm$^{-1}$ 1780 (γ-lactone), 1740 ($CO_2R$), MS *m/z* (rel int ) 446 194 $[M]^+$ (0 5), 344 $[M - RCO_2H]^+$ (3), 242 $[344 - RCO_2H]^+$ (42), 85 $[RCO]^+$ (52), 57 $[85 - CO]^+$ (100)

*9β-Angeloyloxyhelenalin-[5-hydroxyangelate]* (**8**) Colourless gum, IR $\nu_{\max}^{\mathrm{CCl_4}}$ cm$^{-1}$ 3500 (OH), 1780 (γ-lactone), 1725 ($C{=}CCO_2R^1$), MS *m/z* (rel int ) 458 194 $[M]^+$ (0 3) (calc for $C_{25}H_{30}O_8$ 458 194), 440 $[M - H_2O]^+$ (0 3), 360 $[M - O{=}C{=}C(CH_2OH)CH{=}CH_2]^+$ (28), 342 $[M - R^1CO_2H]^+$ (8), 260 $[360 - R^1CO_2H]^+$ (37), 242 $[342 - R^1CO_2H]^+$ (100) Acetylation afforded **8a**, colourless gum, IR $\nu_{\max}^{\mathrm{CCl_4}}$ cm$^{-1}$ 1780 (γ-lactone), 1730 ($CO_2R^1$), MS *m/z* (rel int ) 500 205 $[M]^+$ (0 2) (calc for $C_{27}H_{32}O_9$ 500 205), 400 $[M - R^1CO_2H]^+$ (1 3), 342 $[M - R^2CO_2H]^+$ (2), 242 $[342 - R^1CO_2H]^+$ (61), 141 $[R^2CO]^+$ (98), 83 $[R^1CO]^+$ (100), 81 $[141 - HOAc]^+$ (99)

*9β-Angeloyloxyhelenalin-[4-hydroxymethacrylate]* (**9**) Isolated as its acetate **9a**, colourless gum, IR $\nu_{\max}^{\mathrm{CCl_4}}$ cm$^{-1}$ 1780 (γ-lactone), 1730 ($CO_2R$), MS *m/z* (rel int ) 486 189 $[M]^+$ (0 5) (calc for $C_{26}H_{30}O_9$ 486 189), 342 $[M - RCO_2H]^+$ (0 2), 242 $[342 - RCO_2H]^+$ (5), 127 $[RCO]^+$ (20), 83 $[RCO]^+$ (100)

*9β-Isovaleryloxyhelenalin-[4-hydroxymethacrylate]* (**10**) Isolated as its acetate **10a**, not free from **9a**, IR $\nu_{\max}^{\mathrm{CCl_4}}$ cm$^{-1}$ 1780 (γ-lactone), 1730 ($CO_2R$), MS *m/z* (rel int ) 488 205 $[M]^+$ (0 1), 242 $[M - 2 \times RCO_2H]^+$ (16), 127 $[RCO]^+$ (82), 85 $[RCO]^+$ (100)

*9β-Isobutyryloxyhelenalin-[5-hydroxyangelate]* (**11**) Isolated as its acetate **11a**, colourless gum, IR $\nu_{\max}^{\mathrm{CCl_4}}$ cm$^{-1}$ 1780 (γ-lactone), 1740, 1245 (OAc), 1725 ($C{=}CO_2R$), MS *m/z* (rel int ) 488 205 $[M]^+$ (0 1), 400 $[M - RCO_2H]^+$ (1), 340 $[400 - HOAc]^+$ (5), 242 $[300 - RCO_2H]^+$ (31), 141 $[RCO]^+$ (100), 81 $[141 - HOAc]^+$ (76), 71 $[RCO]^+$ (51)

*6α-[hydroxymethacryloyloxy]-6-Desacyloxy-linearifolin B angelate and isovalerate* (**12** and **13**) Isolated as their acetates **12a** and **13a**, IR $\nu_{\max}^{\mathrm{CCl_4}}$ cm$^{-1}$ 1750 (OAc, δ-lactone, $CO_2R$), MS *m/z* (rel int ) 502 221 and 500 205 $[M]^+$ (0 2 and 0 6) (calc for $C_{27}H_{34}O_9$ 502 221 and for $C_{27}H_{32}O_9$ 500 205), 400 $[M \; R^1CO_2H]^+$ (4), 344 and 342 $[M - R^2CO_2H]^+$ (2 and 3), 242 $[400 - R^2CO_2H]^+$ (20), 141 $[R^1CO]^+$ (100), 85 $[C_4H_9CO]^+$ (21), 83 $[C_4H_7CO]^+$ (80), 81 $[141 - HOAc]^+$ (73)

*6α-[4-hydroxymethacryloyloxy]-6-Desaycyloxy-linearifolin B angelate and isovalerate* (**14** and **15**) Isolated as their acetates **14a** and **15a**, colourless gum, IR $\nu_{\max}^{\mathrm{CCl_4}}$ cm$^{-1}$ 1740 (OAc, δ-lactone, $CO_2R$), MS *m/z* (rel int ) 488 205 and 486 189 $[M]^+$ (0 4 and 0 6) (calc for $C_{26}H_{32}O_9$ 488 205 and for $C_{26}H_{30}O_9$ 486 189), 127 $[RCO]^+$ (100), 85 $[C_4H_9CO]^+$ (21), 83 $[C_4H_7CO]^+$ (8)

*1,2-Dihydroxy-11,15-epoxyphyt-3(20)-ene* (**18**) Isolated as its diacetate **18a**, colourless gum, IR $\nu_{\max}^{\mathrm{CCl_4}}$ cm$^{-1}$ 1745 (OAc), MS *m/z* (rel int ) 395 280 $[M - Me]^+$ (2 5) (calc for $C_{23}H_{39}O_5$ 395 280), 352 $[M - HOAc]^+$ (1) 335 $[395 - HOAc]^+$ (22), 267 (52), 225 (22), 127 $[X]^+$ (100), 109 $[127 - H_2O]^+$ (95), 81 (52), 69 (81), $^1H$ NMR (400 MHz, $CDCl_3$) δ4 10 and 4 26 (*dd*, H-1), 5 37 (*dd*, H-2), 2 03 (*t*, H-4), 1 44 and 1 30 (*m*, $CH_2$), 1 22 (*s*, H-16, H-17), 1 17 (*s*, H-18), 0 87 (*d*, H-19), 5 08 and 4 97 (*br s*, H-20), *J* [Hz] 1,2 = 3, 1′,2 = 8, 1,1′ = 12, 4,5 = 7, 19 = 7, $^{13}C$ NMR ($CDCl_3$, 67 9 MHz, C-1 – C-20) δ64 6 *t*, 73 8 *d*, 144 6 *s*, 33 2 *t*, 25 0 *t*, 37 5 *t*, 32 6 *d*, 36 5 *t*, 21 3 *t*, 42 3 *t* 72 8 *s*, 42 3 *t*, 18 7 *t*, 44 4 *t*, 71 0 *s*, 26 9 *q*, 29 3 *q*, 29 3 *q*, 19 6 *q*, 112 4 *t*, OAc 170 8 *s*, 170 1 *s*, 20 8 *q*, 21 1 *q* (some signals may be interchangeable)

trans-7,8-*Epoxyanol-[3-methylvalerate]* (**19**) Colourless oil, IR $\nu_{\max}^{\mathrm{CCl_4}}$ cm$^{-1}$ 1760 (PhOCOR), MS *m/z* (rel int ) 248 141 $[M]^+$ (9) (calc for $C_{15}H_{20}O_3$ 248 141), 150 $[M - O{=}C{=}CHCHMeFt]^+$ (100) 107 $[150 - COMe]^+$ (44), 106 $[C_7H_6O]^+$ (73), 99 $[RCO]^+$ (42), 71 $[99 - CO]^+$ (57), $[\alpha]_D^{24}$ $-21°$ ($CHCl_3$, *c* 1 01)

trans-7,8-*Epoxyanol isovalerate* (**20**) Colourless oil, IR $\nu_{\max}^{\mathrm{CCl_4}}$ cm$^{-1}$ 1760 (PhOCOR), MS *m/z* (rel int ) 234 126 $[M]^+$ (7) (calc for $C_{14}H_{18}O_3$ 234 126), 150 $[M - O{=}C{=}CHCHMe_2]^+$ (100), 107 (61), 106 (73), 85 (20), 57 $[85 - CO]^+$ (64)

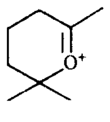
*9-Isovaleryloxy*-trans-7,8-*epoxyanol-[3-methylvalerate] and 9-[3-methylvaleryloxy]*-trans-7,8-*epoxyanol isovalerate* (**21** and **22**) Colourless oil which could not be separated, IR $\nu_{\max}^{\mathrm{CCl_4}}$ cm$^{-1}$ 1760 (PhOCOR), 1740 ($CO_2R$), MS *m/z* (rel int ) 348 194 $[M]^+$ (0 1) (calc for $C_{20}H_{28}O_5$ 348 194), 264 $[M - O{=}C{=}CHCHMe_2]^+$ (0 5), 250 $[M - O{=}C{=}CHCHMeEt]^+$ (2), 166 $[250 - O{=}C{=}CHCHMe_2]^+$ (4), 99 $[RCO]^+$ (17), 85 $[RCO]^+$ (64), 57 $[85 - CO]^+$ (100)

*9-Isovaleroyloxy*-trans-7,8-*epoxyanol isovalerate* (**23**) Colourless oil, IR $\nu_{\max}^{\mathrm{CCl_4}}$ cm$^{-1}$ 1760 (PhOCOR), 1740 ($CO_2R$), MS *m/z* (rel int ) 334 178 $[M]^+$ (calc for $C_{19}H_{26}O_5$ 334 178), 250 $[M - O{=}C{=}CHCHMe_2]^+$ (2 5), 85 $[RCO]^+$ (69), 57 $[85 - CO]^+$ (100), $[\alpha]_D^{24}$ $-19°$ ($CHCl_3$, *c* 1 49)

trans-7,8-*Epoxyisoeugenol-[3-methylvalerate]-and isovalerate* (**24** and **25**) Colourless oil which could not be separated, IR $\nu_{\max}^{\mathrm{CCl_4}}$ cm$^{-1}$ 1760 (PhOCOR), 1740 ($CO_2R$), MS *m/z* (rel int ) 278 152 and 264 136 $[M]^+$ (1 3 and 1 9) (calc for $C_{16}H_{22}O_4$ 278 152 and for $C_{15}H_{20}O_4$ 264 136), 180 $[M - RCH{=}C{=}O]^+$

---

X =



(84), 137 (56), 136 (67), 99 $[RCO]^+$ (10), 85 $[RCO]^+$ (25), 71 $[99 - CO]^+$ (40), 57 $[85 - CO]^+$ (100).

The aerial parts (200 g) of *Antiphiona fragrans* (voucher 88/115, collected at the Brandberg, Namibia) gave by CC and TLC 3 g **26**, 3 g naringenin, 20 mg **27** (TLC, $CHCl_3$–$C_6H_6$–$Et_2O$, 9.9:2, $R_f$ 0 65) and 10 mg **33**; colourless crystals, mp 128°; $[\alpha]_D^{24°} + 43°$ ($CHCl_3$, *c* 0.24), $^{13}C$ NMR ($CDCl_3$, 67 8 MHz, C-1–C-15)· δ46 0, 26 3, 26 3, 26.4, 53 4, 33 6, 44.4, 78.1, 39.0, 50.2, 44 4, 180.3, 15 2, 20 9, 18 5

*Thymohydroquinone*-5-O-3-*phenyl propionate* (**27**). Colourless oil, IR $\nu_{max}^{CCl_4}$ $cm^{-1}$ 3600 (OH), 1750 (PhOCOR); MS *m/z* (rel. int )· 298 157 $[M]^+$ (5.5) (calc for $C_{19}H_{22}O_3$ 298.157), 166 $[M - O{=}C{=}CHCH_2Ph]^+$ (100), 151 $[166 - Me]^+$ (35), 133 $[RCO]^+$ (7), 105 $[133 - CO]^+$ (23), 91 $[C_7H_7]^+$ (22), $^1H$ NMR ($CDCl_3$, 400 MHz) δ6 67 (*s*, H-3), 6.65 (*s*, H-6), 2.16 (*s*, H-7), 2 72 (*qq*, H-8, $J = 7, 7$ Hz), 1 09 (*d*, H-9, H-10, $J = 7$), $PhCH_2CHCO_2R$ 7 35–7 19 (*m*), 3 09 (*br t*, $J = 7$), 2 90 (*t*, $J = 7$)

The aerial parts (180 g) of *Antiphiona pinnatisecta* (voucher 88/86, collected near Tsumeb, Namibia) gave by CC and TLC 20 mg γ-humulene, 50 mg lavandulol, 10 mg taraxasterylacetate, 1 5 g naringenin, 3 mg **28** (HPLC, MeOH–$H_2O$, 7·3, $R_t$ 3.3 min), 400 mg **29** (HPLC, MeOH–$H_2O$, 13:7, $R_t$ 2 5 min), 200 mg **30** (dito, $R_t$ 4 7 min), 5 mg **32** and 40 mg **31**, yellow crystals, mp 174°

*Thymohydroquinone*-6-O-*acetate* (**28**) Colourless oil, IR $\nu_{max}^{CCl_4}$ $cm^{-1}$ 3600 (OH), 1760 (PhOAc), MS *m/z* (rel int ) 208 110 $[M]^+$ (12) (calc for $C_{12}H_{16}O_3$· 208.110), 166 $[M - \text{ketene}]^+$ (92), 151 $[166 - Me]^+$ (100), $^1H$ NMR ($CDCl_3$, 400 MHz) δ6 79 (*s*, H-3), 6 58 (*s*, H-6), 2 08 (*s*, H-7), 3 13 (*qq*, H-8, $J = 7, 7$ Hz), 1 22 (*d*, H-9, H-10), 2 30 (*s*, OAc)

2-*Acetoxy*-5-*hydroxythymol* (**29**) Colourless oil, IR $\nu_{max}^{CCl_4}$ $cm^{-1}$. 3600 (OH), 1760 (PhOAc); MS *m/z* (rel int.) 224.105 $[M]^+$ (16) (calc for $C_{12}H_{16}O_4$ 224.105), 182 $[M - \text{ketene}]^+$ (84), 167 $[182 - Me]^+$ (100); $^1H$ NMR ($CDCl_3$, 400 MHz) δ6 15 (*s*, H-6), 2.03 (*s*, H-7), 3 42 (*qq*, H-8, $J = 7, 7$ Hz), 1 33 (*d*, H-9, H-10, $J = 7$), 2.33 (*s*, OAc)

5-*Acetoxy*-2-*hydroxythymol* (**30**) Colourless oil, IR $\nu_{max}^{CCl_4}$ $cm^{-1}$ 3600 (OH), 1760 (PhOAc); MS *m/z* (rel int ). 224 105 $[M]^+$ (17) (calc for $C_{12}H_{16}O_4$ 224 105), 182 $[M - \text{ketene}]^+$ (77), 167 $[182 - Me]^+$ (100), $^1H$ NMR ($CDCl_3$, 400 MHz)· δ6 27 (*s*, H-6), 2 08 (*s*, H-7), 3.11 (*qq*, H-8), 1.29 (*d*, H-9, H-10), 2 31 (*s*, OAc)

*Acknowledgements*—We thank Dr M Muller and Miss H. Kolberg (Southwest African Herbarium, Windhoek, Namibia) for identification of the plant material and their help during plant collection

## REFERENCES

1 Merxmüller, H, Leins, P and Roessler, H (1977) *The Biology and Chemistry of the Compositae* (Heywood, V. H., Harborne, J B and Turner, B L., eds), p 590 Academic Press, London
2 Bohlmann, F., Zdero, C and Ahmed, M (1982) *Phytochemistry* **21**, 1679.
3 Bohlmann, F, Wallmeyer, M, Jakupovic, J., Gerke, T., King, R M and Robinson, H (1985) *Phytochemistry* **24**, 505.
4. Hoffmann, O in Engler, A and Prantl, K (1889) Volume IV, 5, p 210 Leipzig
5. Bohlmann, F., Singh, P and Jakupovic, J (1982) *Phytochemistry* **21**, 2122
6. Pettit, G., Herald, C L., Gust, D., Herald, D L and Vanall, L D (1978) *J Org Chem.* **43**, 1092.
7 Dominguez, X. A, Franco, R., Bohlmann, F and Bohlmann, R. (1980) *Phytochemistry* **19**, 2204
8. Bohlmann, F and Zdero, C (1969) *Chem Ber* **102**, 1691.
9 Bohlmann, F and Zdero, C. (1968) *Chem. Ber* **101**, 3243.
10. Bohlmann, F., Zdero, C and Ahmed, M (1982) *Phytochemistry* **21**, 1679
11 Seaman, F C (1982) *Bot. Rev.* **48**, 205
12. Bohlmann, F, Jakupovic, J and Ahmed, M (1982) *Phytochemistry* **21**, 2027
13 Bohlmann, F, Zdero, C, King, R. M and Robinson, H (1984) *Phytochemistry* **23**, 1979.