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THE SESQUITERPENE LACTONE CHEMISTRY OF THE GENUS *PARTHENIUM* (COMPOSITAE)

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Abstract—The sesquiterpene lactone chemistry is summarized for seventeen taxa of *Parthenium* including new detailed data for four species and new preliminary results for *P. fruticosum*, *P. confertum*, *P. hispidum* and *P. rollinsianum*. In connection with the former four species for which detailed data are given, six pseudoguaianolides were isolated from three populations of *P. bipinnatifidum* including bipinnatin (V) a new natural product, and three known substances, ambrosin (VI), damsin (IV) and hysterin (XVI). In addition, neoambrosin (VII), and hysterin acetate (XVII) were tentatively identified. Ten populations of *P. hysterophorus* yielded the known pseudoguaianolide parthenin (I) as the major sesquiterpene lactone. *P. tomentosum* afforded incanin (XVIII), a C_{14}-oxygenated pseudoguaianolide previously obtained from *P. incanum*. *P. ligulatum* also yielded incanin along with the previously described C_{14}-oxygenated pseudoguaianolide tetraneurin-B (XI). The structure elucidations of both incanin (XVIII) and bipinnatin (V) are described.

INTRODUCTION

IN CONNECTION with our chemosystematic investigations of several genera of the Compositae, we wish to summarize here the sesquiterpene lactone chemistry of the genus *Parthenium*. We and others previously investigated *P. hysterophorus*,[1,2] *P. incanum*,[3,4] *P. argentatum*,[5,6] *P. alpinum* var. *tetraneuris*,[7] *P. confertum* var. *lyratum*,[8] *P. confertum*[9] cf. var. *microcephalum*,* *P. integrifolium*,[8] *P. fruticosum* var. *trilobatum*[10] and *P. lozanianum*[10] for their sesquiterpene lactone constituents (see Table 1). We now report the sesquiterpene lactone chemistry for *P. bipinnatifidum* (Ortega) Rollins, *P. hysterophorus* L., *P. tomentosum* L. and *P. ligulatum* (Jones) Barneby and, in addition, include preliminary results for *P. fruticosum* L., *P. confertum* Gray, *P. hispidum* Raf. and *P. rollinsianum* Rzedowski. Finally, we describe the structure elucidation of two new pseudoguaianolides, incanin (XVIII) and bipinnatin (V).

* In our previous report[9] of the sesquiterpene lactone chemistry of this taxon, no varietal nomenclature was employed; however, morphologically, the taxon appears to correspond to var. *microcephalum*.

[1] W. HERZ, H. WATANABE, N. MIYAZAKI and Y. KISHIDA, *J. Am. Chem. Soc.* **83**, 2601 (1962).
[2] A. ROMO DE VIVAR, E. A. BRATOEFF and T. RIOS, *J. Org. Chem.* **31**, 673 (1966).
[3] W. HERZ and G. HÖGENAUER, *J. Org. Chem.* **26**, 5011 (1961).
[4] A. ROMO DE VIVAR, C. GUERRERO and G. WITTGREEN, *Rev. Latinoamerica Quim.* **1**, 39 (1970).
[5a] H. J. HAAGEN-SMIT and C. T. O. FONG, *J. Am. Chem. Soc.* **40**, 2075 (1948).
[b] J. B. HENDRICKSON and R. REES, *Chem. & Ind.* 1424 (1962).
[6] L. RODRIGUEZ-HAHN, A. ROMO DE VIVAR, A. ORTEGA, M. AGUILAR and J. ROMO, *Rev. Latinoamericana Quim.* **1**, 24 (1970).
[7] H. RÜESCH and T. J. MABRY, *Tetrahedron* **25**, 805 (1969).
[8] H. YOSHIOKA, E. RODRIGUEZ and T. J. MABRY. *J. Org. Chem.* **35**, 2888 (1970).
[9] A. ROMO DE VIVAR, H. AGUILAR, H. YOSHIOKA, A. HIGO, E. RODRIGUEZ, J. MEARS and T. J. MABRY, *Tetrahedron* **26**, 2775 (1970).
[10] H. YOSHIOKA, H. RÜESCH, E. RODRIGUEZ, J. A. MEARS, T. J. MABRY, J. G. CALZADA ALAN and X. A. DOMINGUEZ, *Tetrahedron* **26**, 2167 (1970).

TABLE 1. SESQUITERPENE LACTONES FROM THE GENUS *Parthenium**†

SPECIES	Typical pseudoguaianolides							C_{14} and C_{15} oxygenated pseudoguaianolides															Others	
Collection Site and Number‡	Parthenin (I)	Hymenin (II)	Coronopilin (III)	Damsin (IV)	Bipinnatin (V)	Ambrosin (VI)	Neoambrosin (VII)	Conchosin-A (VIII)	Conchosin-B (IX)	Tetraneurin-A (X)	Tetraneurin-B (XI)	Tetraneurin-C (XII)	Tetraneurin-D (XIII)	Tetraneurin-E (XIV)	Tetraneurin-F (XV)	Hysterin (XVI)	Hysterin acetate (XVII)	Incanin (XVIII)	Oaxacin (XIX)§	Chiapin-A (XX)§	Chiapin-B (XXI)§	Tomentosin (XXII)§‖	Fruticosin‖
I. SECT.: ARGYROCHAETA																							
P. hysterophorus¶																							
10 populations from locations in Texas, Mexico and Jamaica	+																						
P. bipinnatifidum																							
(1) Dr. Arroyo, N. L., Mexico (JM-3290)				+	+	+	+									+	+						
(2) Pablillo, N. L. Mexico (ER-65)						+										+							
(3) Santa Ana Pozos, S.L.P., Mexico (JM-3314)				+	+	+										+							
P. confertum																							
San Saba, Texas (DS-1489); Llano, Texas (DS-1548); 15·8 miles S of Linares, Tamulipas, Mexico (DS-1350)		+																					
P. confertum cf. var. *microcephalum***																							
(1) 15·8 miles S of Linares, Tamaulipas, Mexico (DS-1351)		+						+															
(2) Cierro de la Silla, N.L., Mexico (JM-3233)								+															
P. confertum var. *lyratum*																							
Pearsall, Texas, (DS-1278); N. Laredo, Tamaulipas, Mexico (DS-1289); La Ascension, N.L., Mexico (JM-3283)										+				+	+								
II. SECT.: BOLOPHYTUM																							
P. alpinum var. *tetraneuris*																							
Fremont Co., Colorado (JM-2738)											+	+	+										
P. alpinum																							
Alcova, Wyoming (JM-3013)												+											

P. ligulatum												
10·6 miles SE of Rainbow Mine, Utah (JM-2930)			+				+					
III. SECT.: PARTHENIASTRUM												
P. integrifolium												
Cisco City, Piatt Co., Illinois (AJ-s.n.)				+		+						
P. hispidum												
Van Buren, Carter County, Missouri (JM-3393)				+		+						
IV. SECT.: PARTHENICHAETA												
P. tomentosum												
31 miles N of Oaxaca, Oaxaca, Mexico (ER-48)							+	+			+	
P. fruticosum												
19 miles S of Tuxtla Gutierrez, Chiapas, Mexico (ER-51)		+							+	+		
P. fruticosum var. *trilobatum*												
17·6 miles SE of Linares, N.L., Mexico (ER-38); 18 miles E of El Barretal, Tamaulipas, Mexico (ER-32)				+	+	+						+
P. lozanianum												
Cerro de la Silla, N.L., Mexico (XD-s.n.)				+	+	+						+
P. incanum												
La Encantada, Coahuila, Mexico (JM-3241a)	+											
P. argentatum												
Saltillo, Coahuila, Mexico (ER-9)		No sesquiterpene lactones detected										
P. rollinsianum												
Santa Ana Pozos, S.L.P., Mexico (ER-39)		No sesquiterpene lactones detected										

* Remaining taxa to be investigated in the near future: *P. tomentosum* var. *stramonium*, *P. schottii*, *P. glomeratum*, *P. cineraceum* and *P. densipilum*. The species are grouped in sections according to Rollin's interpretation of the genus.[15]

† All sesquiterpene lactones presented in this Table were isolated in crystalline form with the exception of tomentosin (XXII) and oaxacin (XIX).

‡ All vouchers have been deposited in the University of Texas Herbarium. We wish to express our thanks to a number of individuals who made plant collections in connection with the present investigation. The collection numbers are given in parentheses: ER, Eloy Rodriguez; JM, James Mears; WR, Walter Renold; DS, David Seigler; AJ, Almut Jones; TM Tom Mabry, XD, Xorge Dominguez.

§ Structures tentatively assigned from NMR and i.r. spectral data.

|| Spectral data indicate that these two compounds belong to the xanthanolide class of sesquiterpene lactones. Spectral data for fruticosin (with no structural assignment) were given in a previous paper.[10]

¶ Austin, Texas (ER-la); Edinburg, Texas (ER-12); Monterrey, N.L., Mexico (ER-2); 17·6 miles SE of Linares, Tamaulipas, Mexico (ER-37); Santa Ana Pozos, S.L.P., Mexico (JM-s.n.); Ixmiquilpan, Hidalgo, Mexico (ER-7); Ciudad Valles, S.L.P., Mexico (ER-6); 20 miles N of Guatemalan Border, Chiapas, Mexico (ER-52); 34 miles S of Los Mochis, Nayarit, Mexico (WR-54); and Mona, St. Andrew, Jamaica (TM-s.n.).

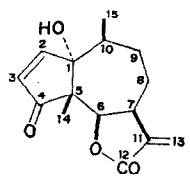
** Two other pseudoguaianolides (which have not been fully characterized) were isolated as a mixture from this taxon; they were designated Conchosin-C and -D.[9]

The data presented here establish that species belonging to all four sections of the genus *Parthenium* are characterized by their ability to elaborate a unique series of C_{14} and C_{15} oxygenated pseudoguaianolides. The detailed systematic implications of these data and a comparative chemical analysis of South American taxa of *Parthenium* will be described elsewhere.

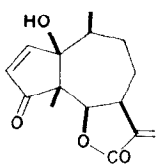
RESULTS

Sesquiterpene Lactones from P. hysterophorus

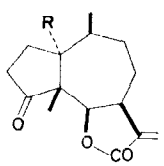
Previously, the pseudoguaianolides hysterin (XVI) and ambrosin (VI) were reported from *P. hysterophorus*;[2] however, Herz has pointed out that the species actually examined was probably *P. bipinnatifidum*.[11] Our results for both species support the latter view. The



Parthenin (I)



Hymenin (II)

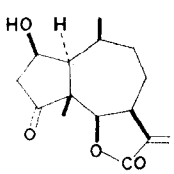


Coronopilin (III), R = OH
Damsin (IV), R = H

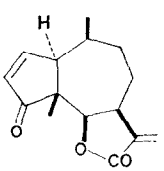
present investigation of ten widely distributed populations of *P. hysterophorus* (Table 1) always yielded parthenin (I) as the major sesquiterpene lactone.

Sesquiterpene Lactones from P. bipinnatifidum

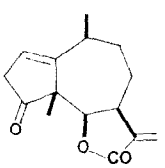
Our investigation of three populations (Table 1) of *P. bipinnatifidum* resulted in the isolation of not only hysterin (XVI) and ambrosin (VI) (which supports the view mentioned above that the previous report for *P. hysterophorus* was in fact for *P. bipinnatifidum*), but



Bipinnatin (V)



Ambrosin (VI)



Neoambrosin (VII)

also a new pseudoguaianolide, bipinnatin (V). In addition, *P. bipinnatifidum* yielded damsin (IV) and a small amount of a 3:2 mixture of two substances which were tentatively identified as neoambrosin (VII) and hysterin acetate (XVII). The latter two substances could not be separated by TLC on silica gel using several solvent systems or on silica gel impregnated with $AgNO_3$. However, the NMR spectral properties of the mixture as well as the TLC results were identical with those observed for an authentic 3:2 mixture of neoambrosin and hysterin acetate (the latter substance was prepared from hysterin).[2]

[11] W. HERZ, in *Recent Advances in Phytochemistry* (edited by T. J. MABRY) Appleton-Century-Crofts, New York (1968).

TABLE 2. NMR DATA FOR *Parthenium* SESQUITERPENE LACTONES*

Compound	H_2	H_3	H_6	H_7	C_{11}=CH_2	C_5-Me	C_{10}-Me	C_5-CH_2-OR	C_{10}-CH_2-OR	Acetyl-Me	Miscellaneous
V†	4·6c		4·53d (J = 8·0)	3·45m	5·67d (J = 3·0) 6·17d (J = 3·3)	1·32	1·38d (J = 7·0)				4·2 (C_2-OH)
XVIII			4·6d (J = 8·0)	3·35m	5·60d (J = 3·0) 6·30d (J = 3·0)		1·03d (J = 7·0)	4·35		2·01	
XXIII	6·20 brd. tr. (J = 1·5)	3·05 brd. tr. (J = 2)	4·67d (J = 9·0)	3·42m	5·68d (J = 3·0) 6·35d (J = 3·0)		1·12d (J = 7·0)	4·40		1·98	
XXIV			4·67c				0·98 (J = 6·0)	4·0d 4·2d (J=12 ea)		1·98	1·83c (C_{11}-Me)
XXV	6·15d‡ (J = 2·0)	5·95d‡ (J = 2·0)	4·2d (J = 9·0)	3·0-3·5m	5·55d (J = 3·0) 6·25d (J = 3·5)	1·20	1·2d (J = 7·0)			2·25	
XIX	7·68dd (J = 2 and 6)	6·25dd (J = 3 and 6)	4·84d (J = 8·0)	3·55m	5·64d (J = 3·0) 6·33d (J = 3·0)		1·02d (J = 7·0)	4·47d 4·22d (J = 12 ea)		1·99	3·20c (C_1-H)
XX			4·60d (J = 8·5)	3·40m	5·65d (J = 3·0) 6·30d (J = 3·0)	1·03			4·07–4·56c		1·17d (J = 6) methyls of isobutyrate
XXI			4·95d (J = 8·0)	3·42m	5·67d (J = 2·5) 6·30d (J = 2·5)	1·07			4·10–4·60c		1·17d (J = 6) methyls of isobutyrate
XXII				3·32m	5·55d (J = 3·0) 6·27d (J = 3·0)	1·14d (J = 6)					5·32–5·50c (C_5-H) 4·7m (C_8-H) 2·16 (C_4-methyl)

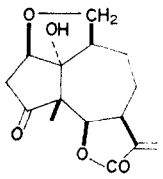
* Spectra were recorded in $CDCl_3$ on a Varian A-60 spectrometer. Values are given in ppm (δ-scale) relative to TMS as an internal standard. Numbers in parentheses denote coupling constants in c/s. Signals are singlets unless otherwise stated: d(doublet), dd(double doublet), tr(triplet), m(multiplet), brd(broad) and c(complex).

† Spectrum recorded in acetone.

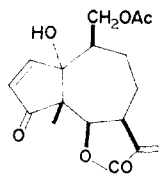
‡ The assignments for the C_1 and C_2 protons may be reversed.

Bipinnatin (V)

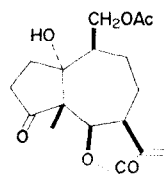
Bipinnatin (V), $C_{15}H_{20}O_4$, m.p. 196–198°, $[\alpha]_D^{25}$ −9·4°, was readily characterized as a C_2-hydroxyl derivative of damsin (IV) since even mild treatment of bipinnatin with acetic anhydride* and pyridine readily afforded ambrosin (VI).† The presence of a C_2 hydroxyl



Conchosin — A (VIII)



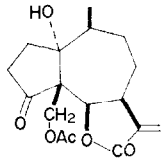
Conchosin — B (IX)



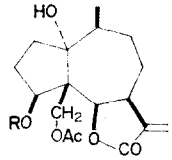
Tetraneurin — A (X)

group in V was confirmed by the presence of an i.r. band at 3500 cm^{-1} and an NMR signal at 4·60‡ for the C_2 proton; spin-decoupling analysis of the signal observed for H-2 clearly indicated the presence of at least three neighboring protons (see Table 2).

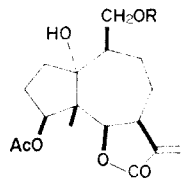
The only remaining question with regard to the structure of bipinnatin concerned the stereochemistry at C_2. Unfortunately the acetyl derivative of bipinnatin could not be prepared; otherwise, it could have been compared directly with 4-dehydrosalsolin (XXVI), whose C_2-acetoxyl function has been previously assigned an α-configuration.[12] However, during the course of our investigation, the structure of a new pseudoguaianolide ivoxanthin



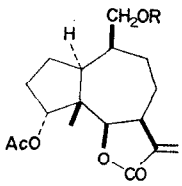
Tetraneurin — B (XI)



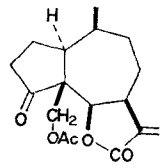
Tetraneurin — C (XII), R=Ac
Tetraneurin — D (XIII), R=H



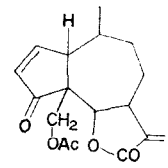
Tetraneurin — E (XIV), R = H
Tetraneurin — F (XV), R = Ac



Hysterin (XVI), R=H
Hysterin Acetate (XVII), R=Ac



Incanin (XVIII)



Oaxacin (XIX)§

* An attempt to acetylate bipinnatin (V) with *p*-toluene sulfonic acid and acetic anhydride resulted in the formation of the enol acetate XXV obtained directly from ambrosin.

†The previous investigators of *P. bipinnatifidum* (see comments above with regard to *P. hysterophorus*) did not encounter bipinnatin; however, the detection of ambrosin and the easy conversion of bipinnatin to ambrosin may account for this discrepancy.

‡ All signals are given in ppm, δ-scale.

§ Tentative structure.

[12] F. P. TORIBIO and T. A. GEISSMAN, *Phytochem.* **6**, 1563 (1967).

(XXVII) from *Iva xanthifolia* came to our attention;* ivoxanthin was reported to be C_2-α-hydroxydamsin; the assignment of the stereochemistry of the C_2-hydroxyl group being based upon spectroscopic evidence.[13] Since the NMR spectral properties of ivoxanthin were different from those observed for bipinnatin, bipinnatin must be C_2-β-hydroxydamsin (V).† The chemical shifts for the C_{14} and C_{15} methyl groups of both bipinnatin and ivoxanthin supported these assignments: the C_2-β-hydroxyl group of bipinnatin would be expected to deshield the β-C_{14} and β-C_{15} methyl groups whereas the C_2-α-hydroxyl group of ivoxanthin should have little or no effect on them; thus, the two methyl groups of ivoxanthin should appear at chemical shifts similar to those observed for damsin (IV). The observed values are in complete accord with these expectations:

	C_{14}-Me	C_{15}-Me
Bipinnatin	1·34	1·35
Ivoxanthin	1·11	1·06
Damsin	1·08	1·06

The dehydration of bipinnatin to ambrosin combined with the above spectral findings established structure V for bipinnatin.

Sesquiterpene Lactones from P. tomentosum *and* P. ligulatum

P. tomentosum (See Table 1) afforded three new sesquiterpene lactones, oaxacin (XIX), tomentosin (XXII) and incanin (XVIII); *P. ligulatum* also yielded incanin along with the previously described tetraneurin-B (XI).[7,9] Tomentosin and oaxacin are presently under further investigation, the structural assignments made here being based primarily on NMR data.

Incanin.‡ The u.v., i.r. and NMR data for incanin (XVIII) indicated that it had certain structural features similar to those of the known C_{14}-oxygenated pseudoguaianolide tetraneurin-B; however, the i.r. spectrum for incanin did not display a band for a hydroxyl group, thus suggesting that incanin might correspond to dehydroxytetraneurin-B. This assumption was confirmed by the conversion of tetraneurin-B (XI) to iso-incanin (XXIV). Treatment of tetraneurin-B (XI) with thionyl chloride and pyridine afforded an anhydro product which could be assigned structure (XXIII) on the basis of its NMR spectrum. Hydrogenation of XXIII with PtO_2 as catalyst afforded material identical by m.p., mixed

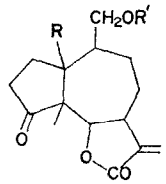
* We thank Dr. Z. Samek for a copy of the manuscript on ivoxanthin prior to publication and for an NMR spectrum af ivoxanthin.

† The NMR spectra of both bipinnatin and ivoxanthin were recorded on a Varian HA-100 spectrometer in $CDCl_3$.

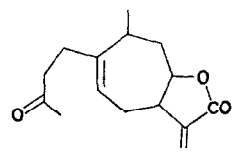
‡ After we had completed a detailed structure analysis of a substance which we called ligulatin-B, we found that other workers[6] had reported the isolation of what appeared to be the same substance from *P. incanum* and introduced the name incanin. These investigators recognized the correct skeletal features for incanin from spectral evidence. Although no sample was available for direct comparison, our material was identical by NMR and i.r. with incanin; therefore, we retain the name incanin. We thank Dr. A. Romo de Vivar for copies of the NMR and i.r. spectra of his material.

[13] A. Samek, M. Holub, V. J. Novikov, J. N. Forostjan and D. P. Dopa, *Coll. Czech. Chem. Commun.* in press (1970).

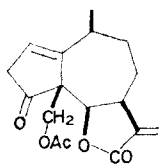
[14] M. Suchý, V. Herout and F. Šorm, *Coll. Czech. Chem. Commun.* **28**, 2257 (1963).



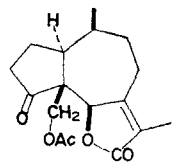
Chiapin—A (XX), R = H, R' = $COCH(CH_3)_2$†
Chiapin—B (XXI), R = OH, R' = $COCH(CH_3)_2$†



Tomentosin (XXII)†



(XXIII)

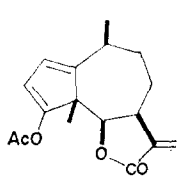


(XXIV)

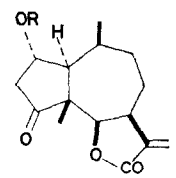
m.p, NMR and i.r. with iso-incanin (XXIV). The latter substance was obtained by treating incanin under hydrogenation conditions using Pd-C as catalyst. The proton at C_1 in incanin must be α since the formation of iso-incanin from tetraneurin-B involves catalytic hydrogenation which for steric reasons (C_5,C_6,C_7 and C_{10} β-substituents) should afford a product with an α-proton at C_1. The CD data of incanin at the $n-\pi^*$ transition of the cyclopentanone function was similar to those obtained for damsin (IV) and thus support a C_1–C_5 *trans* orientation for incanin. The configuration at C_7 for incanin is assigned on the basis of a biogenetic analogy since all other sesquiterpene lactones from *Parthenium* have a C_7-β-substituent.

Preliminary Investigations for Sesquiterpene Lactones in P. fruticosum, P. rollinsianum, P. hispidum *and* P. confertum

In order to summarize as completely as possible the sesquiterpene lactone chemistry of *Parthenium*, we report investigations of *P. fruticosum*, *P. hispidum*, *P. confertum* and *P. rollinsianum*. No sesquiterpene lactones were detected in the latter species and hymenin (II) was the only member of this class of compounds detected in certain populations (see Table 1 for collection sites) of *P. confertum*.‡ *P. hispidum* yielded the two known pseudoguaianolides, tetraneurin-C (XII)[7,8] and tetraneurin-E (XIV).[8,10]



(XXV)



(XXVI), R = Ac
(XXVII), R = H

† The *P. confertum* which afforded hymenin may correspond to the *P. confertum* types described by Rollins;[15] it should be mentioned that these newly examined populations appear to be morphologically distinct from those which yielded conchosin-A (VIII) and -B (IX) along with small amounts of hymenin.[9] A biochemical systematic investigation of the entire *P. confertum* complex is presently underway.

‡ Tentative structures.

[15] R. C. ROLLINS, *Contrib. Gray Herbarium*, Harvard University No. 172 (1950).

P. fruticosum yielded two new pseudoguaianolides, chiapin-A (XX) $C_{19}H_{26}O_5$, m.p. 120–121°, chiapin-B (XXI) $C_{19}H_{26}O_6$, m.p. 156–157°, and the known pseudoguaianolide tetraneurin-A (X).[7,8] For the most part, the tentative structure assignments for both chiapin-A and-B, as well as the previously mentioned oaxacin and tomentosin are based upon NMR and i.r. data (Table 2).

EXPERIMENTAL*

Bipinnatin (V), Ambrosin (VI), Damsin (IV), Neoambrosin, Hysterin acetate (XVII) and Hysterin (XVI) from Parthenium bipinnatifidum.

Air-dried, ground material (303 g) of *Parthenium bipinnatifidum* (collected 0·9 miles south of Dr. Arroyo on highway 61, N.L., Mexico; see Table 1, collection No. Mears 3290) was extracted once with $CHCl_3$ and worked up in the usual way,[16] yield: 3·7 g of crude syrup. When the syrup was left overnight in a minimum of EtOAc crude crystals formed (300 mg), and from NMR analysis the material appeared to be a 3:1 ratio of hysterin (XVI) and bipinnatin (V). Two recrystallizations of the crude crystals from EtOAc yielded a total of 120 mg of hysterin (XVI) and 67 mg of pure bipinnatin (V), m.p. 196–198°. TLC of the original filtrate showed four spots with hysterin (XVI) and bipinnatin (V) having the same R_f values (0·25) (benzene–acetone, 4:1). The crude syrup (1·3 g) was chromatographed over a column of silica gel (65 g, packed in benzene). The column was eluted with benzene–acetone (6:1) and 24 fractions (25 ml each) were collected, then 21 fractions (25 ml each) of benzene–acetone (4:1) were collected; finally, the column was eluted with acetone.

All fractions were monitored by TLC; fractions 2–9 yielded 15 mg of an oil which consisted of a 3:2 ratio of neoambrosin (VII) and hysterin acetate (XVII) (by NMR). The substances could not be separated by TLC. An authentic 3:2 mixture of neoambrosin and hysterin acetate (prepared by acetylation of hysterin) gave an indentical NMR spectrum and TLC results. Fractions 10–12 yielded 40 mg of damsin (IV); fractions 13–21 yielded 62 mg of ambrosin (VI) and fractions 25–45 yielded 106 mg of hysterin (XVI) and bipinnatin (V). Recrystallization of the crude crystals from EtOAc yielded 42 mg of pure bipinnatin. The combined total yield of pure bipinnatin (V) was 107 mg; m.p. 196–198° (from acetone): $[\alpha]_D^{25}$ −9·1° (MeOH: C, 0·53); λ_{max} MeOH 212 nm (ϵ 8200), i.r. bands (nujol): 3500 (hydroxyl) and 1725 (carbonyl) cm^{-1}. (Found: C, 68·09; H, 7·75; O, 24·39. Calc. for $C_{15}H_{20}O_4$: C, 68·15; H, 7.58; O, 24·22.)

A mixture containing 35 mg of bipinnatin (V) and 20 mg of *p*-toluene sulfonic acid in 1 ml Ac_2O was allowed to stand at room temp. for 24 hr. The solution was evaporated *in vacuo* and the resultant oil was chromatographed on TLC plates (silica gel G; benzene–acetone, 4:1). A band (R_f, 0·62) afforded XXV as an oil; yield 15 mg; i.r. bands ($CHCl_3$): 1750 (carbonyl) and 1225 (acetate) cm^{-1}.

Isolation of Incanin (VIII), Tomentosin and Oaxacin from Parthenium tomentosum

Air-dried, ground material (100 g) of *P. tomentosum* (collected 25 December 1969, 31 miles north of the city of Oaxaca, Oaxaca, Mexico; see Table 1, collection No. Rodriguez and Whiffin 48) was extracted once with $CHCl_3$ and worked up in the usual way,[16] yield: 2·5 g of crude syrup. The syrup was chromatographed over silica gel (75 g, packed in benzene). Elution of the column with benzene and acetone (4:1) and collecting 25 ml fractions gave from fractions 2–10 310 mg of an oil which from NMR and i.r. was tentatively assigned structure XXII and named "tomentosin", i.r. bands ($CHCl_3$): 1750, 1712 (carbonyls) and 1232 (acetate) cm^{-1}.

Fractions 12–22 yielded 240 mg of crude crystals which corresponded (by NMR) to incanin (XVIII). Recrystallization of the crude material from $CHCl_3$–isopropyl ether yielded 200 mg of pure incanin (XVIII), m.p. 167–168°: $[\alpha]_D^{25}$ −52·1° (MeOH: C, 0·60); λ_{max} (MeOH): 212 nm (ϵ 5600); i.r. bands ($CHCl_3$): 1750 (carbonyl) and 1235 (acetate) cm^{-1}. (Found: C, 66·42; H, 7·17; O, 26·33. Calc. for $C_{17}H_{22}O_5$ requires C, 66·75; H, 7·19; O, 26·18.)

The final fractions yielded 40 mg of oaxacin which was tentatively assigned structure XIX on the basis of NMR data.

Incanin (XVIII) and Tetraneurin-B (XI) from Parthenium ligulatum

Air-dried, ground material (60 g) of *P. ligulatum* (collected 10·6 miles south east of Rainbow Mine, Uintah Co., Utah, U.S.A.; see Table 1, collection No. Mears 2930) was extracted in the usual way;[16] yield: 1·1 g of crude syrup. Column chromatography (70 g silica gel packed in benzene) yielded incanin (XVIII) and tetraneurin-B (XI) as the main components.

* M.ps are uncorrected. Analyses were determined by Dr. Alfred Bernhardt, Mikroanalytisches Laboratorium, Elbach über Engelskirchen, West Germany.

[16] T. J. Mabry, H. E. Miller, H. B. Kagan and W. Renold, *Tetrahedron* **22**, 1139 (1966).

Formation of $\Delta^{1(2)}$-Anhydrotetraneurin-B (XXIII) from Tetraneurin-B (XI)

A solution of tetraneurin-B (XI) (200 mg) in 4 ml of anhydrous pyridine was treated under cooling with 2 ml $SOCl_2$. After a few min the solution was evaporated *in vacuo* and the resultant residue was dissolved in 10 ml $CHCl_3$. Work-up of the solution yielded a crude oil (100 mg) whose TLC and NMR properties were consistent with compound structure XXIII. Purification of the oil over TLC (silica gel; benzene–acetone, 4:1) afforded, after trituration with ether, pure $\Delta^{1(2)}$-anhydrotetraneurin-B (XXIII), yield: 60 mg; m.p. 161–163°, i.r. bands ($CHCl_3$): 1750 (carbonyl), 1240 (acetate), and 812 (trisubstituted double bond) cm^{-1}. (Found: C, 66·87; H, 6·38. Calc. for $C_{17}H_{20}O_5$: C, 67·10; H, 6·57.)

Hydrogenation of $\Delta^{1(2)}$-Anhydrotetraneurin-B (XXIII) with PtO_2 as Catalyst

$\Delta^{1(2)}$-Anhydrotetraneurin-B (50 mg) in 15 ml of MeOH was hydrogenated for 11 hr in the presence of PtO_2 (20 mg), which had been prehydrogenated for 15 min. NMR analysis of the product indicated a mixture of the iso- and tetrahydrocompounds (1:1 ratio). The product was separated from the tetrahydro-derivatives by thick-layer silica gel G chromatography using ether as the developing solvent: yield of iso-incanin, 22 mg. Recrystallization of material from $CHCl_3$–isopropyl ether yielded 15 mg of pure iso-incanin (XXIV), m.p. 201–202°; i.r. bands ($CHCl_3$): 1750, 1625 (carbonyls) and 1235 (acetate) cm^{-1}. (Found: C, 66·54; H, 7·07. Calc. for $C_{17}H_{22}O_5$: C, 66·66; H, 7·18.)

Hydrogenation of Incanin (XVIII) with Pd-C as Catalyst

Incanin (50 mg) in 15 ml of MeOH was hydrogenated for 12 hr in the presence of 35 mg of Pd-C (not prehydrogenated). NMR analysis of the residue obtained from the reaction solution indicated that the major component was iso-incanin (XXIV). The residue was crystallized from $CHCl_3$–isopropyl ether; yield 40 mg of iso-incanin which was identical by NMR, i.r., m.p. and mixed m.p. with the iso-product from $\Delta^{1(2)}$-anhydrotetraneurin-B (XXIII).

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