133. Antifungal Polyphenols from *Cordia goetzei* GÜRKE

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Four highly oxygenated polyphenols, **1**–**4**, have been isolated from the stem bark of *Cordia goetzei* GÜRKE (Boraginaceae) and their structures elucidated by a combination of one- and two-dimensional (including COLOC) NMR spectroscopic techniques, mass spectroscopy, and chemical methods. The first new compound, cordigone (**1**), is a tetrahydrofuran derivative and the second one, cordigol (**2**), a furobenzopyran derivative. The benzofurans **3** and **4** are orange pigments, responsible for the coloration of the stem bark of the tree. All four polyphenols are fungicidal against *Cladosporium cucumerinum*.

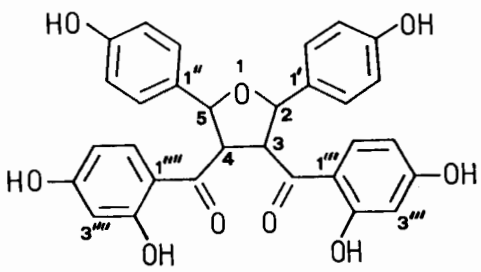
Introduction. – *Cordia goetzei* GÜRKE (Boraginaceae) is a tree found in southern and central Africa, from Tanzania to South Africa. Infusions of the roots are used in traditional medicine for the treatment of malaria and leprosy, while bark extracts help to heal sores [1]. Root extracts and the leaf sap are drunk by patients suffering from abscesses [1].

Some previous work has been carried out on the genus *Cordia* but this has mainly been confined to the Indian medicinal plant *C. obliqua*. Several flavonoid glycosides [2] and lupa-20(29)-ene maltoside have been isolated from this plant [3]. Additionally, a series of terpenoid benzoquinones has been found in the heartwood of *C. alliodora* [4] and other *Cordia* species [5]. Recently, the presence of pyrrolizidine alkaloids in leaves of *C. sinensis* and *C. myxa* has been reported [6].

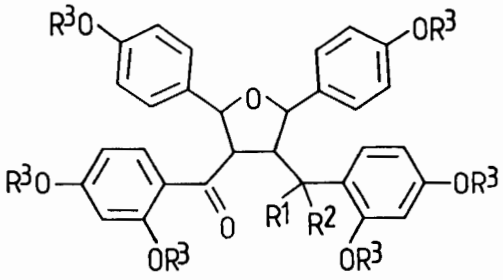
C. goetzei which has as yet not been investigated phytochemically possesses a bright yellow tissue layer between the grey outer stem bark and the reddish heartwood. Extraction of this layer with solvents of increasing polarity gave a MeOH extract with fungicidal activity against spores of the plant pathogenic fungus *Cladosporium cucumerinum* [7]. Bioassay-guided fractionation of the MeOH extract led to the isolation of four antifungal polyphenolics, two of which are previously undescribed compounds.

Results. – The yellow layer of *C. goetzei* stem bark was extracted successively with petroleum ether, $CHCl_3$, and MeOH. Only small quantities of non-fungitoxic petroleum ether and $CHCl_3$ extracts were obtained. The antifungal MeOH extract was fractionated by droplet countercurrent chromatography (DCCC) with the solvent system $CHCl_3$/MeOH/H_2O 43:37:20 in the descending mode. Low-pressure liquid chromatography (LPLC) of the DCCC fractions on *RP-8* led to the isolation of four antifungal compounds, cordigone (**1**), cordigol (**2**), and benzofurans **3** and **4**.

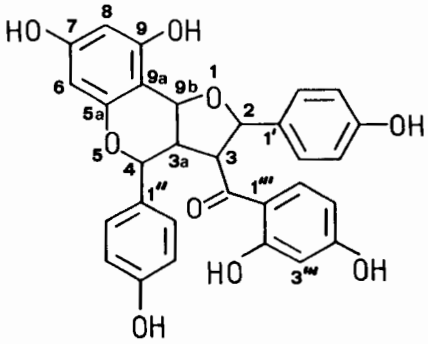
Cordigone (**1**) gave a molecular ion at *m/z* 528 by fast-atom-bombardment (FAB) mass spectrometry. Acetylation of **1** produced a hexaacetate **1a**, indicating the presence of 6 OH groups in **1**. Treatment of **1** with $NaBH_4$ gave **1b**, in which only one of the



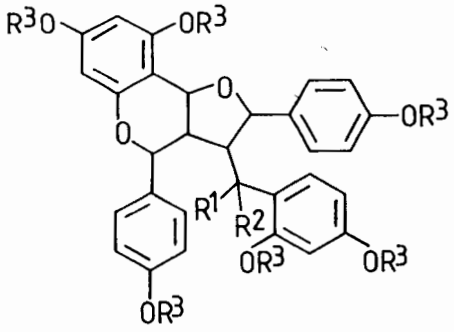
1 Cordigone



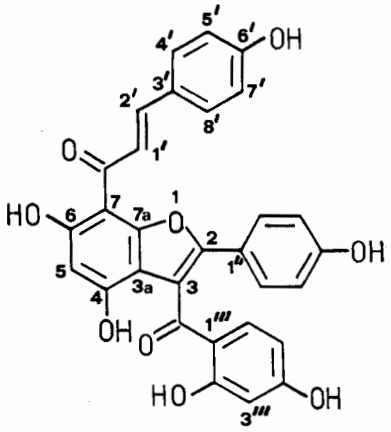
1a $R^1, R^2 = =O, R^3 = CH_3CO$
b $R^1 = R^3 = H, R^2 = OH$



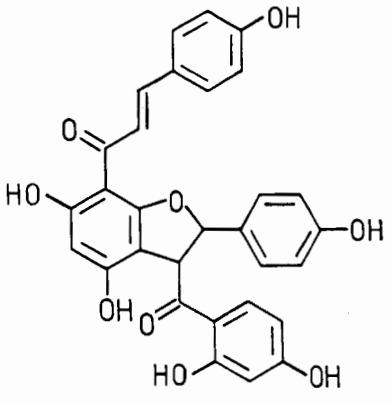
2 Cordigol



2a $R^1, R^2 = =O, R^3 = CH_3CO$
b $R^1 = R^3 = H, R^2 = OH$



3[1])



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[1]) Arbitrary numbering.

Table 1. *^{1}H- and ^{13}C-NMR Spectral Data for Compounds* **1**, **1b**, **2**, *and* **2b**[a])

	1			**1b**
	^{1}H-NMR	^{13}C-NMR	DEPT	^{1}H-NMR
H–C(2)	5.22 (*d*, *J* = 8.6)[b]	78.5[c])	CH	5.04 (*d*, *J* = 7.2)
H–C(3)	4.88 (*m*)	53.2[d])	CH	3.17 (*m*)
H–C(4)		56.6[d])	CH	4.18 (*dd*, *J* = 7.1, 7.3)
H–C(5)	5.54 (*d*, *J* = 8.6)[b])	81.6[c])	CH	4.92 (*d*, *J* = 7.1)
C(1′)		128.4		
H–C(2′)	7.63 (*d*, *J* = 8.8)	130.7	CH	7.11 (*d*, *J* = 8.5)
H–C(3′)	6.71 (*d*, *J* = 8.8)	115.0	CH	6.57 (*d*, *J* = 8.5)
C(4′)		162.2		
H–C(5′)	6.71 (*d*, *J* = 8.8)	115.0	CH	6.57 (*d*, *J* = 8.5)
H–C(6′)	7.63 (*d*, *J* = 8.8)	130.7	CH	7.11 (*d*, *J* = 8.5)
C(1″)		128.9		
H–C(2″)	7.08 (*d*, *J* = 8.7)	128.5	CH	6.92 (*d*, *J* = 8.6)
H–C(3″)	6.50 (*d*, *J* = 8.7)	114.2	CH	6.40 (*d*, *J* = 8.6)
C(4″)		156.5		
H–C(5″)	6.50 (*d*, *J* = 8.7)	114.2	CH	6.40 (*d*, *J* = 8.6)
H–C(6″)	7.08 (*d*, *J* = 8.7)	128.5	CH	6.92 (*d*, *J* = 8.6)
C(1‴)		113.0		
C(2‴)		164.0		
H–C(3‴)	6.01 (*d*, *J* = 2.4)	102.0	CH	5.91 (*d*, *J* = 2.4)
C(4‴)		164.9		
H–C(5‴)	6.24 (*dd*, *J* = 9.1, 2.4)	108.1	CH	6.08 (*dd*, *J* = 9.1, 2.4)
H–C(6‴)	7.72 (*d*, *J* = 9.1)	133.5	CH	7.23 (*d*, *J* = 9.1)
C(1⁗)		115.8		
C(2⁗)		155.8		
H–C(3⁗)	6.15 (*d*, *J* = 2.4)	102.2	CH	6.26 (*d*, *J* = 2.4)
C(4⁗)		157.9		
H–C(5⁗)	6.31 (*dd*, *J* = 8.5, 2.4)	106.6	CH	6.30 (*dd*, *J* = 8.5, 2.4)
H–C(6⁗)	7.44 (*d*, *J* = 8.5)	128.4	CH	7.46 (*d*, *J* = 8.5)
*C*O–C(3)		200.9[e])		
*C*O–C(4)		196.5[e])		
C(1‴)–C*H*–C(3)				4.68 (*d*, *J* = 8.8)
OH–C(4′), OH–C(4″), OH–C(4‴), OH–C(4⁗)	9.24 (br. *s*)			
OH–C(2‴), OH–C(2⁗)	12.15 (*s*)			
OH–C(4′), OH–C(4″), OH–C(2‴), OH–C(4‴), OH–C(4⁗)				8.40 (br. *s*)
OH–C(2⁗)				12.53 (*s*)

	2			2b
	^{1}H-NMR	^{13}C-NMR	DEPT	^{1}H-NMR
H–C(2)	4.90 (*d*, *J* = 6.5)	71.2	CH	4.83 (*d*, *J* = 6.5)
H–C(3)	3.33 (*dd*, *J* = 6.5, 2.0)	55.8	CH	1.92 (*ddd*, *J* = 6.5, 5.0, 2.0)
H–C(3a)	2.71 (*ddd*, *J* = 11.5, 5.0, 2.0)	48.2	CH	2.55(*ddd*, *J* = 11.5, 5.0, 2.0)
H–C(4)	4.91 (*d*, *J* = 5.0)	82.9	CH	4.78 (*d*, *J* = 5.0)
C(5a)		157.5[b])		
H–C(6)	5.75 (*d*, *J* = 2.4)	93.8	CH	5.91 (*d*, *J* = 2.4)
C(7)		156.7		
H–C(8)	5.99 (*d*, *J* = 2.4)	95.6	CH	6.02 (*d*, *J* = 2.4)
C(9)		156.7		
C(9a)		99.4		
H–C(9b)	4.68 (*d*, *J* = 11.5)	77.0	CH	4.48 (*d*, *J* = 11.5)
C(1′)		130.5[c])		
H–C(2′)	7.19 (*d*, *J* = 8.5)	129.4	CH	6.89 (*d*, *J* = 8.5)
H–C(3′)	6.71 (*d*, *J* = 8.5)	115.1	CH	6.60 (*d*, *J* = 8.5)
C(4′)		165.5[d])		
H–C(5′)	6.71 (*d*, *J* = 8.5)	115.1	CH	6.60 (*d*, *J* = 8.5)
H–C(6′)	7.19 (*d*, *J* = 8.5)	129.4	CH	6.89 (*d*, *J* = 8.5)
C(1″)		128.0[c])		
H–C(2″)	7.08 (*d*, *J* = 8.5)	127.5	CH	6.80 (*d*, *J* = 8.5)
H–C(3″)	6.69 (*d*, *J* = 8.5)	115.1	CH	6.51 (*d*, *J* = 8.5)
H–C(4″)		164.8[d])		
H–C(5″)	6.69 (*d*, *J* = 8.5)	115.1	CH	6.51 (*d*, *J* = 8.5)
H–C(6″)	7.08 (*d*, *J* = 8.5)	127.5	CH	6.80 (*d*, *J* = 8.5)
C(1‴)		111.5		
C(2‴)		158.3[b])		
H–C(3‴)	6.10 (*d*, *J* = 2.4)	102.2	CH	5.62 (*d*, *J* = 2.4)
C(4‴)		158.6[b])		
H–C(5‴)	5.77 (*dd*, *J* = 8.6, 2.4)	107.8	CH	6.14 (*dd*, *J* = 8.6, 2.4)
H–C(6‴)	6.04 (*d*, *J* = 8.6)	131.9	CH	6.45 (*d*, *J* = 8.6)
*C*O-C(3)		202.6		
C(1‴)–C*H*–C(3)				5.72 (*d*, *J* = 5.0)
OH–C(7), OH–C(9), OH–C(4′), OH–C(4″), OH–C(4‴)	9.56 (br. *s*)			
OH–C(2‴)	12.70 (*s*)			
OH–C(7), OH–C(9), OH–C(4′), OH–C(4″), OH–C(4‴), OH–C(2‴)				9.05 (br. *s*) 9.45 (br. *s*)

[a]) Chemical shifts in ppm; coupling constants in Hz; solvent (D_6)DMSO.
[b])[c])[d])[e]) May be interchanged, respectively.

carbonyl groups was reduced. The spectra confirmed that cordigone (**1**) is the tetrahydrofuran derivative bis(2,4-dihydroxyphenyl) 2,3,4,5-tetrahydro-2,5-bis(4-hydroxyphenyl)furan-3,4-diyl bisketone.

From the ^{1}H-NMR spectrum of **1** *(Table 1)*, it was ascertained that two of the OH groups were chelated. The ^{1}H-NMR spectrum of **1** also showed 2 *AA'BB'* and 2 *ABX* systems, allowing the identification of two 1,4-disubstituted benzene rings and two 1,2,4-trisubstituted benzene rings. Signals at 4.88, 5.22, and 5.54 ppm were characteristic for a tetrasubstituted furan ring [8]. ^{1}H,^{1}H Connectivities in the benzene and furan rings were confirmed by a COSY 2D chemical shift correlation experiment [9][10]. The ^{13}C-NMR spectrum of **1** established the presence of two carbonyl groups. ^{13}C Assignments were obtained by 2D ^{13}C,^{1}H (HECTOR) [11][12] shift correlation *via* ^1J(C,H), and numbers of attached protons were ascertained by means of a DEPT [13] experiment *(Table 1)*.

Two-dimensional heteronuclear correlation *via* long-range coupling (COLOC) [14] was employed to detect ^3J(H,C) coupling constants in the benzene rings and to aid assignment of the relevant C-atoms of **1**. A pulse sequence was used for quaternary C-atoms giving long-range coupling constants of 10 Hz. In addition, couplings from the non-quaternary C-atoms C(5‴) and C(5⁗) to H–C(3‴) and H–C(3⁗), respectively, were observed *(Figure)*. The COLOC experiment enabled complete assignment of all the non-protonated C-atoms *(Table 2)*.

Table 2. *Long-range ^1H, ^{13}C Couplings in* **1** *from COLOC Data*

H-Atom	H–C(5)	H–C(2′)/H–C(6′)	H–C(2″)/H–C(6″)	H–C(3′)/H–C(5′)
C-Atom	C(2″)/C(6″)	C(4′)	C(4″)	C(1′)
H-Atom	H–C(3″)/H–C(5″)	H–C(3‴)	H–C(3⁗)	
C-Atom	C(1″)	C(1‴)/C(2‴)/C(4‴)/C(5‴)	C(1⁗)/C(2⁗)/C(4⁗)/C(5⁗)	
H-Atom	H–C(5‴)	H–C(5⁗)	H–C(6‴)	H–C(6⁗)
C-Atom	C(1‴)	C(1⁗)	C(2‴)/C(4‴)	C(2⁗)/C(4⁗)

The protons H–C(2), H–C(3), H–C(4), H–C(5), and C(3)–C*H*(OH)–C(1‴) of **1b** could be assigned by a COSY 2D chemical shift correlation experiment. Noticeable was the appearance of a new *d* at 4.68 ppm in the ^{1}H-NMR spectrum, corresponding to C*H*(OH)–C(3) and coupled to the *m* at 3.17 ppm (H–C(3)). Coupling of this *m* to the *d* at 5.04 ppm (H–C(2)) confirmed the 3-substitution of the 2,4-dihydroxybenzoyl moiety.

The coupling constants between H–C(2) and H–C(3) and between H–C(4) and H–C(5) of **1** are both 8.6 Hz. The same coupling constants are also observed for the tetrahydrofuran **5** (J(2,3) = J(4,5) = 8.6 Hz) [15], suggesting that **1** is an all-*trans*-tetrahydrofuran. Further evidence for the configuration comes from the lignan chicanine, in which the *cis*-related H-atoms have a coupling constant J(2,3) = 4.0 Hz and the *trans*-related ones a J(4,5) = 8.5 Hz [16].

FAB-mass spectrometry of cordigol (**2**) showed, as in the case of **1**, a molecular ion at *m/z* 528. Acetylation of **2** gave a hexaacetate **2a**, and reduction with $NaBH_4$ yielded **2b**. The spectra confirmed that cordigol (**2**) is the furobenzopyran derivative 2,4-dihydroxyphenyl 2,3,3a,9b-tetrahydro-7,9-dihydroxy-2,4-bis(4-hydroxyphenyl)-4*H*-furo[3,2-*c*][1]-benzopyran-3-yl ketone.

Similarly to **1**, the ^{1}H-NMR spectrum of **2** *(Table 1)* gave evidence for the presence of 2 *AA'BB'* and 2 *ABX* aromatic systems. The ^{13}C-NMR spectrum *(Table 1)* indicated, however, the presence of only one carbonyl group. Furthermore, analysis of the ^{1}H-NMR spectrum and the COSY 2D correlation experiment allowed the identification of the partial structure –CH–CH(CH)–CH–CH–, which gives a system of 3 *d*, 2 *dd*, and 1 *ddd*. Four of these C-atoms with chemical shifts of 77.0, 71.2, 55.8, and 48.2 ppm were typical of a tetrahydrofuran ring system [8], and further consideration of ^{13}C chemical shifts allowed an analogy to be made with the furobenzopyran ring system found in rotenoid molecules of the type depicted by compound **6** [17]. Chemical shifts of C(4), C(5a), C(6), C(7), C(8), C(9), and C(9a) in the ^{13}C-NMR spectrum of **2** were virtually identical to those of the corresponding C-atoms in the benzopyran moiety of epicatechin [18]. Analysis of the 2D ^{13}C,^{1}H (HETCOR) shift-correlation experiment allowed assignment of the protons to the relevant C-atoms.

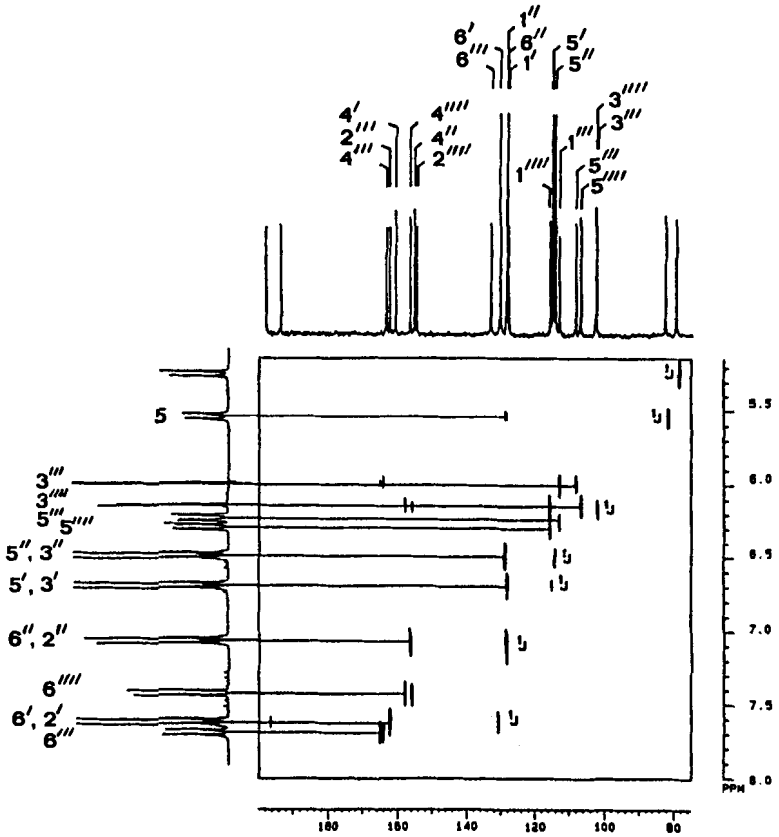
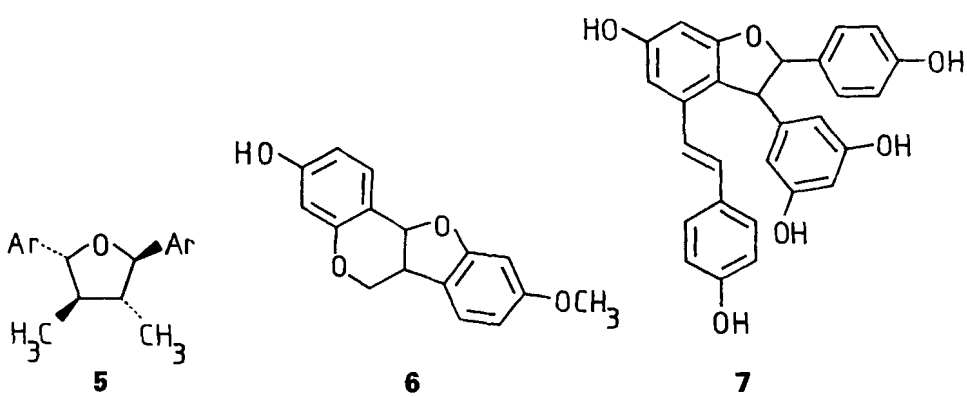


Figure. *250-MHz COLOC spectrum of cordigone* (1)



5 **6** **7**

The derivative **2b** lacked signals for carbonyl groups in the ^{13}C-NMR spectrum. A large upfield shift for H–C(3) was observed in the ^{1}H-NMR spectrum and an additional *d* (J = 5.0 Hz) at 5.72 ppm due to C*H*(OH)–C(3) *(Table 1)*. The resulting –CH–CH(CH)–CH(CH)–CH– skeleton gave the expected system of 4 *d* and 2 *ddd* in the ^{1}H-NMR spectrum. Couplings were again confirmed by a COSY 2D correlation experiment. Substitution at C(3) by the 4-hydroxyphenyl moiety rather than at C(2) would have given 3 *d*, 2 *dd*, and 1 *ddd*.

The value (11.5 Hz) of J(H–C(3a), H–C(9b)) of **2** suggests a *trans* ring junction between rings A and B. This is unlike the situation in the rotenoids, where the fusion of a benzene ring to a furan ring implicates a *cis* junction between the furan and pyran moieties. Additionally, the very weak coupling (J = 2 Hz) between H–C(3) and H–C(3a) indicates a dihedral angle approaching 90° for these two protons [19].

The EI-MS of **3** showed a molecular ion at m/z 524. This was confirmed by the DCI-MS (reactant gas NH_3, positive-ion mode), with quasimolecular ions at m/z 542 ($[M + NH_4]^+$) and m/z 525 ($[M + H]^+$). Comparison with an authentic sample [20][21] (m.p., co-TLC, HPLC) established the structure of **3**.

Two *AA'BB'* systems and an *ABX* system were present in the ^{1}H-NMR spectrum of **3**, representing two 4-substituted benzene rings and one 2,4-substituted benzene ring. In addition, the characteristic *d* at 7.85 and 8.15 ppm (both J = 15.1 Hz) of a chalcone $\alpha\beta$ double bond were conspicuous [22]. The full ^{13}C-NMR spectrum of **3** is presented in *Table 3*.

Table 3. *^{13}C-NMR Spectral Data for Benzopyrans* **3** *and* **4**[a])

C-Atom[b])	**3**[c])	**4**	C-Atom[b])	**3**[c])	**4**
C(2)	150.0	89.6	C(8′)	130.7	130.4
C(3)	112.1	53.2	C(1″)	119.7	130.2
C(3a)	111.2	104.9	C(2″)	127.2	127.4
C(4)	165.6	164.9	C(3″)	116.0	115.7
C(5)	98.4	96.2	C(4″)	158.4	158.0
C(6)	158.4	160.9	C(5″)	116.0	115.7
C(7)	101.0	101.2	C(6″)	127.2	127.4
C(7a)	153.7	162.6	C(1‴)	114.2	112.7
C(1′)	121.6	122.1	C(2‴)	165.6	166.5[d])
C(2′)	144.1	143.5	C(3‴)	102.4	102.7
C(3′)	125.8	126.0	C(4‴)	164.5	165.5[d])
C(4′)	130.7	130.4	C(5‴)	108.8	108.4
C(5′)	116.0	116.1	C(6‴)	135.3	133.3
C(6′)	160.4	160.3	*C*O–C(3)	195.0	201.5
C(7′)	116.0	116.1	*C*O–C(7′)	188.9	190.3

[a]) Chemical shifts in ppm; solvent (D_6)DMSO.
[b]) Numbering non-systematic in order to facilitate comparison with literature values.
[c]) Identity of attached protons established by DEPT experiments.
[d]) May be interchanged.

In the EI-MS of the polyphenol **4**, the molecular ion appeared at m/z 526, indicating a dihydrofuran analogue of **3**. Its structure was confirmed by comparison with **3** [20][21].

The ^{1}H-NMR spectrum of **4** was similar to that of **3**, except for an additional pair of *d* 5.24 and 5.88 ppm (both J = 5.4 Hz). The ^{13}C-NMR spectra of **3** and **4** *(Table 3)* corresponded closely, except for the chemical shifts of C(2), C(3), and C(1″), at or adjacent to sp^3 centres. Thus C(2) and C(3) appeared at 150.0 and 112.2 ppm, respectively, in **3** and at 89.6 and 53.2 ppm, respectively, in **4**.

Discussion. – Four polyphenolic compounds have been isolated from the stem bark of *C. goetzei*, of which **1** and **2** are new natural products. Although cordigone (**1**) bears some resemblance to lignans such as chicanine [16], it represents a new class of furanoid lignans, with two benzoyl substituents on the tetrahydrofuran ring. A benzoylated furan, sylvone, has been isolated from *Piper sylvaticum* [23], but this compound possesses only one benzoyl substituent. Cordigol (**2**) has a furobenzopyran ring system, found, *e.g.*, in the rotenoids. The benzofurans **3** and **4** have been previously described in the stem bark of

Brackenridgea zanguebarica (Ochnaceae) [20][21] and are the major pigments responsible for the yellow colour of the inner bark layer. The structure of **4** is similar to that of ε-viniferin (**7**), a phytoalexin stilbene dimer from the leaves of *Vitis vinifera* (Vitaceae) [24].

All four oxygenated polyphenols are fungitoxic to *Cladosporium cucumerinum*, with the following order of activities in the TLC bioassay [7]: **1** (1 μg), **2** (5 μg), **3** (10 μg), **4** (10 μg). These results compare very favourably with the activity of ε-viniferin in the same bioassay (minimum amount detectable in assay: 2.5 μg) [24]. The function of the polyphenols in the bark of *C. goetzei* is presumably to provide a defence against fungal attack.

From a biogenetic point of view, each of the four compounds can be considered to derive from two chalcone moieties, by their coupling and O-bridge formation. This seems to be the case for the structurally related compound brackenin from *Brackenridgea zanguebarica* (Ochnaceae) [25].

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Experimental Part

General. Acetylations were carried out by stirring the compounds with Ac_2O in pyridine for 24 h at r.t. For reductions, the polyphenol (20 mg) was dissolved in MeOH (5 ml), and $NaBH_4$ was added in 5 10-mg batches. After 24 h, H_2O (20 ml) was added and the mixture acidified to pH 5 with AcOH. Extraction was carried out with H_2O-saturated BuOH (3 × 20 ml); the org. part was washed with H_2O (20 ml) and then evaporated. Droplet countercurrent chromatography (DCCC): *Büchi 670 DCC* chromatograph (294 tubes; i.d. 2.7 mm). Low-pressure liquid chromatography (LPLC): *Lobar RP-8* and *Si-60* columns (40–63 μm; i.d. 2.5 × 27 cm; *Merck*, Darmstadt), equipped with *Duramat-80* pump (*Chemie und Filter*, Regensdorf). TLC: silica gel precoated Al sheets *(Merck)*, lower phase of $CHCl_3$/MeOH/H_2O 43:37:20 (system *1*); *RP-8* precoated glass plates (HPTLC, *Merck*), MeOH/H_2O 7:3 (system *2*). M.p.: *Mettler FP 80/82* hot stage apparatus; uncorrected. UV: *Perkin-Elmer-Lambda-3* spectrophotometer. IR: *Perkin-Elmer-781* spectrophotometer. $[\alpha]_D$: *Perkin-Elmer-241* polarimeter. ^{1}H- and ^{13}C-NMR: *Varian VXR-200* at 200 and 50.1 MHz, resp.; *Bruker WP-250* at 250 and 62.89 MHz, resp.; chemical shifts δ in ppm relative to TMS. All 2D NMR experiments were performed using qaudrature detection in both dimensions, appropriate phase cycling and absolute value mode of display. In general, 256 × 1 K data sets were acquired and processed with sine bell resolution enhancement in both dimensions. The F_1 dimension was zero filled once to yield 512 × 512 K data matrices. EI-MS and DCI-MS (desorption/chemical ionisation): *Nermag R-3010* quadrupole instrument with NH_3 as reactant gas. FAB-MS (fast-atom bombardment): *VG-70-70-EQ* high-resolution mass spectrometer.

Plant Material. C. goetzei was collected near Ifakara (Kilombero District) in Tanzania.

Extraction and Isolation. The yellow inner layer of *C. goetzei* stem bark (69 g) was separated from the grey outer part and ground. Extraction at r.t. with petroleum ether (60–80°) was followed successively by $CHCl_3$ and MeOH. A part (3 g) of the orange MeOH extract (21.9 g) was separated by DCCC with $CHCl_3$/MeOH/H_2O 43:37:20 (descending mode) into 18 fractions *(I-XVIII)*. Crystallisation of *Fraction IV* (68 mg) from AcOEt/hexane provided **3** (55 mg). LPLC of *Fraction VI* (139 mg) on *RP-8* with MeOH/H_2O 6:4 gave **4** (60 mg). Similarly, LPLC of *Fraction XIII* (470 mg) in two batches of 235 mg on *RP-8* with MeOH/H_2O allowed the isolation of **1** (264 mg) and **2** (92 mg).

Cordigone (= Bis(2,4-dihydroxyphenyl) 2,3,4,5-Tetrahydro-2,5-bis(4-hydroxyphenyl)furan-3,4-diyl Bisketone; **1**). Off-white amorphous solid. M.p. 153–155°. TLC (SiO_2, system *1*): R_f 0.19. HPTLC (*RP-8, system 2*): 0.74.

$[\alpha]_D = -96$ ($c = 5$, MeOH). UV (MeOH): 217 (sh), 281, 318 (sh). UV (MeOH + $AlCl_3$): 221 (sh), 285 (sh), 306, 357. IR (KBr): 3380, 1630, 1600, 1515. ^{1}H-NMR: *Table 1.* ^{13}C-NMR: *Table 1.* FAB-MS (thioglycerol, positive-ion mode): 551 ($[M + Na]^+$), 529 ($[M + H]^+$).

Cordigone hexaacetate (**1a**) was purified by LPLC on *Si-60* with $CHCl_3$/MeOH 99:1. ^{1}H-NMR ((D_6)DMSO): 7.96 (*d*, $J = 8.5$, H–C(6‴)); 7.82 (*d*, $J = 8.7$, H–C(2′), H–C(6′)); 7.30 (*m*, H–C(3′), H–C(5′), H–C(2″), H–C(3″), H–C(5″), H–C(6″), H–C(6‴)); 7.93 (*m*, H–C(3‴), H–C(5‴), H–C(3⁗), H–C(5⁗)); 5.51 (*d*, $J = 7.5$, H–C(5)); 5.48 (*d*, $J = 7.5$, H – C(2)); 4.90 (*dd*, $J = 5.6$, 7.5, H–C(4)); 4.63 (*dd*, $J = 5.6$, 7.5, H–C(3)); 2.02, 2.12, 2.22, 2.24, 2.26, 2.27 (6 AcO). DCI-MS (NH_3, negative-ion mode): 780 ($[M]^{-\cdot}$), 738 ($[M - CH_2CO]^-$), 696 ($[M - 2CH_2CO]^-$).

2,4-Dihydroxyphenyl 2,3,4,5-Tetrahydro-2,5-bis(4-hydroxyphenyl)-4-(α,2,4-trihydroxybenzyl)furan-3-yl Ketone (**1b**) was obtained after LPLC on *Si-60* with $CHCl_3$/MeOH/H_2O 60:15:2. ^{1}H-NMR: *Table 1.*

Cordigol (*= 2,4-Dihydroxyphenyl 2,3,3a,9b-Tetrahydro-7,9-dihydroxy-2,4-bis(4-hydroxyphenyl)-4*H*-furo-[3,2-c][1]benzopyran-3-yl Ketone;* **2**). Off-white amorphous solid. M.p. 188–191°. TLC (SiO_2, system *1*): R_f 0.19. HPTLC (*RP-8*, system *2*): R_f 0.68 $[\alpha]_D = +184$ ($c = 5$, MeOH). UV (MeOH): 216 (sh), 280, 321 (sh). UV (MeOH + $AlCl_3$): 216 (sh), 280 (sh), 312, 360. IR (KBr): 3400, 1620, 1515, 835. ^{1}H-NMR: *Table 1.* ^{13}C-NMR: *Table 1.* FAB-MS (thioglycerol, positive-ion mode): 551 ($[M + Na]^+$), 529 ($[M + H]^+$). DCI-MS (NH_3): 546 ($[M + NH_4]^+$), 392, 298, 157, 140. EI-MS: 374 (3), 280 (15), 122 (87), 121 (100).

Cordigol hexaacetate (**2a**) was purified by LPLC on *Si-60* with AcOEt/petroleum ether 1:1. ^{1}H-NMR ($CDCl_3$): 7.27 (*d*, $J = 8.5$, H–C(2′), H–C(6′)); 7.16 (*d*, $J = 8.5$, H–C(2″), H–C(6″)); 7.02 (*d*, $J = 8.5$, H–C(3′), H–C(5′)); 6.97 (*d*, $J = 8.5$, H–C(3″), H–C(5″)); 6.79 (*d*, $J = 2.4$, H–C(3‴)); 6.74 (*dd*, $J = 8.6$, 2.4, H–C(5‴)); 6.64 (*d*, $J = 2.4$, H–C(8)); 6.62 (*d*, $J = 2.4$, H–C(6)); 6.57 (*d*, $J = 8.6$, H–C(6‴)); 5.50 (*d*, $J = 6.5$, H–C(2)); 5.03 (*d*, $J = 5.0$, H–C(4)); 4.68 (*d*, $J = 11.5$, H–C(9b)); 3.42 (*dd*, $J = 6.5$, 2.0, H–C(3)); 2.78 (*ddd*, $J = 11.5$, 5.0, 2.0, H–C(3a)); 2.29 (*m*, 5 AcO); 2.13 (*s*, AcO); assignments were established by a COSY 2D correlation experiment. DCI-MS (NH_3, negative-ion mode): 780 ($[M]^{-\cdot}$), 738 ($[M - CH_2CO]^-$).

*2,3,3a,9b-Tetrahydro-2,4-bis(4-hydroxyphenyl)-3-(α,2,4-trihydroxybenzyl)-4*H*-furo[3,2-c][1]benzopyran-7,9-diol* (**2b**) was obtained after LPLC on *Si-60* with $CHCl_3$/MeOH/H_2O 60:15:2. ^{1}H-NMR: *Table 1.*

3-(2, 4-Dihydroxybenzoyl)-4, 6-dihydroxy-2-(4-hydroxyphenyl)-1-benzofuran-7-yl 2-(4-Hydroxyphenyl)-ethenyl Ketone (**3**). Orange needles from AcOEt/hexane. M.p. 253–254° ([20]: 252–253°). TLC (SiO_2, system *1*): R_f 0.46. HPTLC (*RP-8*, system *2*): R_f 0.14. ^{1}H-NMR ((D_6)DMSO)[1]): 8.15 (*d*, $J = 15.1$, H–C(2′)); 7.85 (*d*, $J = 15.1$, H–C(1′)); 7.69 (*d*, $J = 8.0$, H–C(4′), H–C(8′)); 7.50 (*d*, $J = 8.0$, H–C(2″), H–C(6″)); 7.32 (*d*, $J = 8.8$, H–C(6‴)); 6.89 (*d*, $J = 8.0$, H–C(5′), H–C(7′)); 6.85 (*d*, $J = 8.0$, H–C(3″), H–C(5″)); 6.33 (*d*, $J = 2.4$, H–C(3‴)); 6.26 (*dd*, $J = 8.8$, 2.4, H–C(5‴)); 6.18 (*s*, H–C(5)). ^{13}C-NMR: *Table 3.* DCI-MS (NH_3): 542 ($[M + NH_4]^+$), 525 ($[M + H]^+$). EI-MS: 524 ($M^{+\cdot}$), 508, 404, 388, 294, 268.

3-(2,4-Dihydroxybenzoyl)-2,3-dihydro-4,6-dihydroxy-2-(4-hydroxyphenyl)-1-benzofuran-7-yl 2-(4-Hydroxyphenyl)ethenyl Ketone (**4**). Orange crystals from AcOEt/hexane. M.p. 211–213°. TLC (SiO_2, system *1*): R_f 0.43. HPTLC (*RP-8*, system *2*): R_f 0.37. ^{1}H-NMR ((D_6)DMSO)[1]): 7.96 (*d*, $J = 15.1$, H–C(2′)); 7.77 (*d*, $J = 15.1$, H–C(1′)); 7.59 (*d*, $J = 8.8$, H–C(6‴)); 7.38 (*d*, $J = 8.0$, H–C(2″), H–C(6″)); 7.28 (*d*, $J = 8.0$, H–C(4′), H–C(8′)); 6.87 (*d*, $J = 8.0$, H–C(5′), H–C(7′)); 6.76 (*d*, $J = 8.0$, H–C(3″), H–C(5″)); 6.32 (*d*, $J = 2.4$, H–C(3‴)); 6.28 (*dd*, $J = 8.8$, 2.4, H–C(5‴)); 5.94 (*s*, H–C(5′)); 5.92 (*d*, $J = 5.4$, H–C(2)); 5.23 (*d*, $J = 5.4$, H–C(3)). ^{13}C-NMR: *Table 3.* DCI-MS (NH_3): 544 ($[M+NH_4]^+$), 451, 434. EI-MS: 526 ($M^{+\cdot}$), 508, 416, 390, 296.

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