162. New Chromonocoumarin (= 6*H*,7*H*-[1]Benzopyrano[4,3-*b*][1]benzopyran-6,7-dione) Derivatives from *Polygala fruticosa* BERG.

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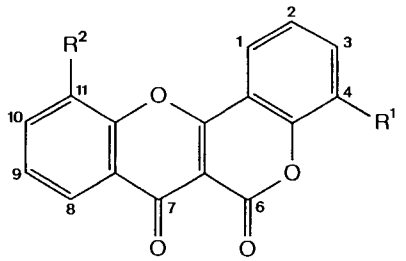
Three chromonocoumarins (= 6*H*,7*H*-[1]benzopyrano[4,3-*b*][1]benzopyran-6,7-diones) **1–3** have been isolated from the leaves and the root bark of *Polygala fruticosa* BERG. (syn. *Polygala oppositifolia* L.; Polygalaceae). The structure of frutinone A (**1**) was established by X-ray diffraction analysis. The structures of the previously undescribed compounds frutinone B (**2**) and C (**3**) were deduced by spectroscopic methods (EI-MS, UV, IR, ^{1}H- and ^{13}C-NMR, including NOE and COSY) in comparison with **1**. Chromonocoumarins **1–3** are the first representatives of a new type of naturally occurring compounds. Frutinone A shows strong fungicidal activity against *Cladosporium cucumerinum*.

Introduction. – The genus *Polygala* (Polygalaceae) comprises *ca.* 500 species distributed over the temperate, subtropical, and tropical regions of all continents, with exception of Australia [1]. *Polygala senega* (vernacular name: snakeroot) is the source of the still officinal drug *Senegae radix*, which is used as an expectorant for its high saponin content. Previous phytochemical investigations of the genus have shown the presence of numerous oleanene-type saponins [2–4], lignans [5] [6], coumarins [7] [8], xanthones [9], hydroxycinnamoyl esters [10], flavonol glycosides [11], and methyl salicylate [12]. Among these, several biologically active compounds have been found, such as saponins which are inhibitors of cAMP phosphodiesterase [3], antitumor lignans [6], a fungicidal coumarin [8], and xanthones with potential inhibitory activity on the monoamino oxidases A and B [13].

Contrary to the European, American, and Asian *Polygala* species, the African representatives of this genus have not been investigated phytochemically. Therefore, as a part of our ongoing search for novel biologically active compounds from African medicinal plants, we undertook a study of *Polygala fruticosa* BERG., a little shrub growing in the Cape Province and Natal (South Africa) [14]. The roots have been used by the Zulus as a remedy against dropsy, scrofula, and to produce profuse perspiration and as an ingredient in a decoction taken for treatment of tuberculosis [15].

In a preliminary screening, the CH_2Cl_2 extract of the leaves of *P. fruticosa* exhibited strong activity against the plant pathogenic fungus *Cladosporium cucumerinum* in a TLC bioassay [16]. The present paper deals with the isolation and structure determination of three chromonocoumarins (= 6*H*,7*H*-[1]benzopyrano[4,3-*b*][1]benzopyran-6,7-diones) **1–3**, the first representatives of a new type of naturally occurring compounds.



1 $R^1 = R^2 = H$
2 $R^1 = CH_3O$, $R^2 = H$
3 $R^1 = H$, $R^2 = OH$
3a $R^1 = H$, $R^2 = CH_3O$

Results. – The leaves and the root bark of *P. fruticosa* were extracted successively with petroleum ether, CH_2Cl_2, and MeOH (see *Exper. Part*). The fungicidal CH_2Cl_2 extract from the leaves was submitted to column chromatography on silica gel with petroleum ether/AcOEt mixtures of increasing polarity. Subsequent recrystallization yielded chromonocoumarins **1** and **2** which we name frutinone A and B, respectively. Column chromatography of the methanolic root extract on silica gel with $CHCl_3/MeOH/H_2O$ mixtures as mobile phase yielded an enriched fraction of frutinone C(**3**) which was purified by filtration on *Sephadex-LH-20* (MeOH).

The structure of frutinone A (**1**) was deduced from UV, IR, ^{1}H- and ^{13}C-NMR, and MS data as being 6*H*,7*H*-[1]benzopyrano[4,3-*b*][1]benzopyran-6,7-dione.

In the EI-MS of **1**, the molecular ion appeared at *m/z* 264 ($C_{16}H_8O_4$). The IR spectrum indicated the presence of lactone C=O (1745 cm^{-1}) and α,β-unsaturated C=O (1640 cm^{-1}) groups. The UV spectrum (MeOH) showed absorption maxima at 229, 261, and 296 and a shoulder at 318 nm. No shift was observed upon addition of NaOMe or $AlCl_3$ indicating the absence of free phenolic OH groups [17]. The ^{1}H-NMR spectrum *(Table 1)* displayed 8

Table 1. *^{1}H-NMR Data of* **1**–**3** *and* **3a**

	1[a])	**2**[b])
H–C(1)	8.20 (*ddd*, *J* = 0.5, 1.7, 8.0)	7.79 (*dd*, *J* = 1.6, 8.0)
H–C(2)	7.46 (*ddd*, *J* = 1.1, 7.4, 8.0)	7.40 (*dd*, *J* = 8.0, 8.2)
H–C(3)	7.75 (*ddd*, *J* = 1.7, 7.4, 8.3)	7.29 (*dd*, *J* = 1.6, 8.2)
H–C(4)	7.38 (*ddd*, *J* = 0.5, 1.1, 8.3)	–
H–C(8)	8.32 (*ddd*, *J* = 0.5, 1.7, 8.0)	8.33 (*ddd*, *J* = 0.5, 1.7, 8.0)
H–C(9)	7.49 (*ddd*, *J* = 1.2, 7.1, 8.0)	7.53 (*ddd*, *J* = 1.2, 7.1, 8.0)
H–C(10)	7.79 (*ddd*, *J* = 1.7, 7.1, 8.3)	7.81 (*ddd*, *J* = 1.7, 7.1, 8.5)
H–C(11)	7.63 (*ddd*, *J* = 0.5, 1.2, 8.3)	7.65 (*ddd*, *J* = 0.5, 1.2, 8.5)
CH_3O–C(4)		4.00 (*s*)
	3[c])	**3a**[a])
H–C(1)	8.29 (*ddd*, *J* = 0.5, 1.7, 7.9)	8.28 (*ddd*, *J* = 0.5, 1.7, 7.9)
H–C(2)	7.59 (*ddd*, *J* = 1.2, 7.4, 7.9)	7.45 (*ddd*, *J* = 1.2, 7.4, 7.9)
H–C(3)	7.89 (*ddd*, *J* = 1.7, 7.4, 8.3)	7.75 (*ddd*, *J* = 1.7, 7.4, 8.3)
H–C(4)	7.52 (*ddd*, *J* = 0.5, 1.2, 8.3)	7.40 (*ddd*, *J* = 0.5, 1.2, 8.3)
H–C(8)	7.87 (*dd*, *J* = 1.6, 7.9)	7.90 (*dd*, *J* = 1.6, 8.0)
H–C(9)	7.50 (*dd*, *J* = 8.0, 8.1)	7.42 (*dd*, *J* = 8.0, 8.1)
H–C(10)	7.83 (*dd*, *J* = 1.6, 8.1)	7.28 (*dd*, *J* = 1.6, 8.1)
CH_3O–C(11)		4.07 (*s*)

[a]) IN $CDCl_3$.
[b]) In $CDCl_3/CD_3OD$ 10:1.
[c]) In (D_6)DMSO.

Table 2. *^{13}C-NMR Data of* **1–3**

	1[a])	**2**[b])	**3**[c])
C(1)	124.2	114.9[d])	124.4[f])
C(2)	124.8	124.7	125.0[f])
C(3)	135.6	116.8[d])	135.8
C(4)	117.4	147.4	116.9
C(4a)	154.2	144.2	153.8
C(6)	156.0	156.0	155.8
C(6a)	105.0	104.5	104.6
C(7)	173.0	173.3	172.6
C(7a)	124.4	124.2	125.1
C(8)	126.8	126.7[e])	119.6
C(9)	126.6	126.6[e])	126.1[g])
C(10)	134.8	135.0	127.1[g])
C(11)	117.8	117.8	146.5
C(11a)	154.3	154.4	142.6
C(12a)	164.9	165.3	164.5
C(12b)	113.2	113.8	113.5
CH_3O		56.3	

[a]) In $CDCl_3$.
[b]) $CDCl_3/CD_3OD$ 10:1.
[c]) In $(D_6)DMSO$.
[d–g]) Values may be interchanged.

aromatic protons in the region 7.38–8.32 ppm. Analysis of the COSY and of a resolution-enhanced ^{1}H-NMR spectrum revealed that the signals were attributable to 2 four-spin systems of *ortho*-disubstituted aromatic rings. The ^{13}C-NMR spectrum *(Table 2)* displayed 16 signals belonging to 2 C=O groups, 3 O-bearing aromatic C-atoms, 3 olefinic or aromatic quaternary C-atoms and 8 protonated aromatic C-atoms. The unsaturated carbonyl group observed in the IR spectrum, the deshielded aromatic proton at 8.32 ppm (*peri* to a C=O), and the ^{13}C-NMR data indicated that one half of the molecule was a γ-chromone moiety. The NMR spectral data were in good agreement with data reported for the chromone moiety of flavone [18]. The structural elements of the other part of the molecule (one *ortho*-disubstituted aromatic ring and one lactone C=O) suggested a coumarin or isocoumarin (4 possible isomeric structures). In a comparison of the observed ^{1}H- and ^{13}C-NMR chemical shifts with values calculated [19] for these structures, formula **1** was found to fit best with the experimental data. Further indication was the presence of a second low-field signal at 8.20 ppm (H–C(1)).

The structure of compound **1** was finally confirmed by X-ray diffraction analysis (see the *Fig.* and *Exper. Part*). In crystalline state, the molecule was found to be planar. To accomplish this, the structure exhibits large deformations in the bond angles involving the two central pyranone rings. The bond distances indicate considerable charge delocalization in the central part of the molecule. The two carbonyl O-atoms are separated by 2.839 Å, little more than the sum of their *van der Waals* radii (2.8 Å). On considering that molecule **1** is made up of a flavonoid and a coumarin moiety, an analysis of these structures in the *Cambridge Structural Data Base* [20] [21] indicates that the bond lengths and angles observed for **1** are normal within experimental error (see *Table 3* in *Exper. Part*).

No ^{1}H- and ^{13}C-NMR data have been previously reported for chromonocoumarins. Unambiguous assignment of the ^{13}C-NMR resonances of **1** was, therefore, essential for the structure elucidation of the chromonocoumarins **2** and **3**. Protonated C-atoms of **1** were first assigned with a 2D one-bond heteronuclear correlation experiment (HETCOR) [22], while the signals of the quaternary C-atoms could be attributed *via* long-range

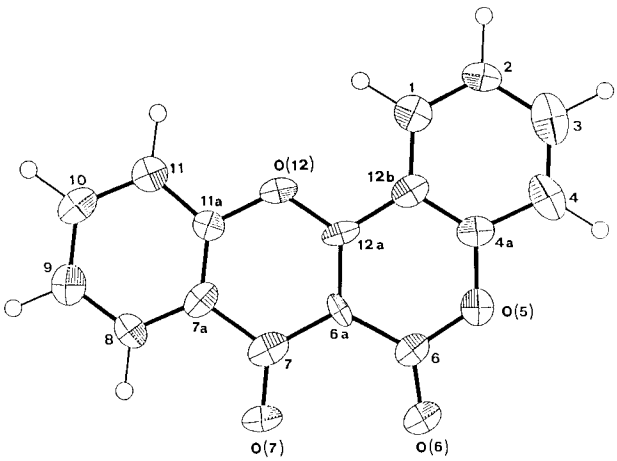


Figure. *View of* **1** *showing the crystallographic atomic numbering scheme and the vibrational ellipsoids* (50% probability level)

connectivities in a HETCOR experiment with delay settings optimized for $J_{CCCH} = 7$ Hz. Cross peaks were observed for C(7) and *H*–C(8), C(7a) and *H*–C(9), C(4a) and *H*–C(3), and C(12b) and *H*–C(2). Additional long-range correlations are listed in the *Exper. Part.*

The structures of frutinone B (**2**) and C (**3**) were deduced from spectroscopic data by comparison with **1** and from data of the monomethyl ether **3a** obtained from **3** by methylation with $(CH_3)_2SO_4$ (see *Exper. Part*). Thus, **2** and **3** are 4-methoxy- and 11-hydroxy-6*H*,7*H*-[1]benzopyrano[4,3-*b*][1]benzopyran-6,7-dione, respectively.

The EI-MS spectrum of **2** exhibited a molecular ion at *m/z* 294 ($C_{17}H_{10}O_5$), 30 amu higher, than that of **1**. The IR spectrum presented also absorption band of 2 C=O groups at 1735 and 1650 cm^{-1}. The UV spectrum (MeOH) showing two major maxima at 247 and 303 nm, remained unchanged upon addition of NaOMe or $AlCl_3$. ^{1}H- and ^{13}C-NMR signals at 4.00 (3H, *s*) and 56.3 ppm, respectively, were indicative of an aromatic MeO group. Its position of attachment at C(4) was readily apparent from the ^{1}H-NMR spectrum *(Table 1)*. While the 4 protons of the γ-chromone moiety were quasi identical with those of **1**, signals for 3 vicinal aromatic protons were present on the aromatic ring of the coumarin part. Compared to **1**, H–C(1) was shifted upfield ($\Delta\delta = -0.41$ ppm) and appeared at 7.79 ppm as a *dd*. The signal attributable to H–C(3) was also shielded ($\Delta\delta = -0.46$ ppm), while H–C(2), *meta* to the substituent, remained almost unchanged. The ^{13}C-NMR spectrum of **2** was in accordance with MeO–C(4) (see *Table 2*). In comparison with **1**, upfield shifts of the signals for C(1) (114.9 ppm; $\Delta\delta = -9.3$ ppm), C(3) (116.8 ppm; $\Delta\delta = -18.8$ ppm), and C(4a) (144.2 ppm; $\Delta\delta = -10.0$ ppm) were observed, C(4) (147.4 ppm) was deshielded by 30 ppm, whereas the signals attributable to C(2), C(12b), and the other C-atoms remained unaffected. Final confirmation was obtained by NOE difference spectroscopy. Irradiation of the MeO signal at 4.00 ppm resulted in an enhancement of the *dd* at 7.29 ppm previously assigned to H–C(3).

The EI-MS of **3**, showed a molecular ion at *m/z* 280 ($C_{16}H_8O_5$), 16 amu higher than that of **1**. In addition to the 2 C=O bands, the IR spectrum indicated the presence of an OH group (3500 cm^{-1}). The UV spectrum (MeOH) displayed a major maximum at 267 nm and a shoulder at 316 nm. Identical UV spectra were obtained upon addition of NaOAc or $AlCl_3$, while bathochromic shifts to 303 and 378 nm were observed in strongly basic solution (MeOH + NaOMe). Consequently, the phenolic group was not attached to C(8) and C(10) [17]. The presence of the aromatic OH group of **3** was confirmed by its methylation yielding the monomethyl ether **3a** ($C_{17}H_{10}O_5$). Compounds **2** and **3a** were different as a comparison of the data (UV, IR, ^{1}H-NMR, and m.p.) and TLC analysis revealed. The attachment of the MeO group of **3a** at C(11) was deduced from the ^{1}H-NMR spectrum *(Table 1)*. When compared to **1**, the chemical shifts of the 4 aromatic protons on the coumarin moiety of **3a** were almost identical. Three vicinal aromatic protons remained on the chromone moiety. While the resonances of the protons

ortho (H–C(10)) and *para* (H–C(8)) to the MeO group appeared upfield ($\Delta\delta = -0.51$ and -0.42 ppm, resp.), H–C(9) was almost unaffected. The substition pattern was corroborated by a NOE difference experiment. An enhancement of H–C(10) (7.28 ppm, *dd*) was observed upon irradiation of the MeO group at 4.07 ppm. The ^{13}C-NMR data of **3** confirmed the substitution at C(11). In accordance with chemical-shift rules [19], the signals of C(8), C(10), and C(11a) appeared at 119.6 ($\Delta\delta = -7.2$ ppm), 127.1 ($\Delta\delta = -7.7$ ppm) and 142.6 ppm ($\Delta\delta = 11.7$ ppm), respectively, while the substituted C(11) was observed at 146.5 ppm ($\Delta\delta = +28.7$ ppm).

Discussion. – Three chromonocoumarins **1–3** have been isolated from *Polygala fruticosa* BERG. Although this type of compounds has been synthesized, the occurrence in nature of chromonocoumarins has not been reported. The frutinones **1–3** bear two *peri* C=O groups on the two central rings, a rarity in natural products. This structural feature explains the large deformations in the bond angles of the two central pyranone rings, as observed by X-ray diffraction analysis of **1**.

The biogenesis of the chromonocoumarins is probably best considered in analogy to the 6-keto dehydrorotenoids, with a 2′-methoxyflavone as precursor instead of a 2′-methoxyisoflavone [23]. After ring closure to the chromanochromanone, oxidation to a 6a-hydroxy compound, followed by a subsequent dehydration and oxidation at C(6) would lead to the 6*H*,7*H*-[1]benzopyrano[4,3-*b*][1]benzopyran-6,7-dione. A particular feature of compounds **1–3** is the lack or uncommon position of substituents on the benzo rings.

No definite answer can be presently given to the question as whether the chromonocoumarins can be considered as genuine compounds or artifacts. For 6-keto dehydrorotenoids, their natural occurrence has not yet been firmly established, as they may be artifacts formed by photo-oxidation of dehydrorotenoids [23]. We are currently pursuing the isolation and structure elucidation of additional phenolic constituents in the search of possible biogenetic precursors.

As mentioned above, molecules containing a chromonocoumarin nucleus have been synthesized [24–27]. Frutinone A (**1**) has been obtained *via* three different synthetic routes [24–26]. The scarcity of spectral data, however, precluded any comparison with the natural compound. Good bacteriostatic activity against *S. aureus*, *B. subtilis*, and *B. coli* has been reported for several halogenated chromonocoumarins [25].

Compounds **1–3** and **3a** were tested against *Cladosporium cucumerinum*, a plant pathogenic fungus, using a TLC bioassay [16]. Frutinone A (**1**) was active, and the mininum quantity required to show antifungal activity in the test was 0.25 µg. Interestingly, the presence of a MeO group in position 4 and substitution by a MeO or an OH moiety at C(11) rendered compounds **2**, **3**, and **3a** inactive. This finding suggests a certain degree of selectivity in the mode of action of **1**. Further biological testing of **1–3** is presently underway.

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Experimental Part

General. TLC: silica gel precoated Al sheets *(Merck)*; *RP-8* precoated glass plates (HPTLC; *Merck*); detection at 254 and 366 nm. Low-pressure liquid chromatography (LPLC): *Lobar Diol* (40–63 µm; 27 × 2.5 cm i.d.; *Merck*, Darmstadt), equipped with *Duramat-80* pump (*Chemie and Filter*, Regensdorf). Purity of compounds **1–3** and **3a** was checked on TLC and HPLC with a *µ-Bondapak C-18* column (10 µm; 30 cm × 3.9 mm i.d.; *Waters*) and a *Spectra Physics 8700* pump (San José, USA); the chromatograms at 210 and 254 nm and the UV/VIS spectra

were recorded with a photodiode array detector *HP 1040A*, an *HP-85B* computer, and an *HP 7470A* plotter *(Hewlett-Packard)*. M.p.: *Mettler FP 80/82* hot stage apparatus; uncorrected. UV (λ_{max} (log ε)): *Varian DMS 100S* spectrophotometer; in MeOH before and after addition of shift reagents according to [17]. IR: *Philips PU 9716* spectrophotometer. ^{1}H- and ^{13}C-NMR: *Varian VXR-200* equipped with a switchable 5-mm probe at 200 and 50.1 MHz, resp.; chemical shifts in δ (ppm) rel. to TMS as internal standard; ^{1}H-NMR with 0.1 Hz digital resolution; accurate $J_{(H,H)}$ were extracted after suitable resolution enhancement. COSY spectra: 128 × 512 K data sets, after zero filling to 512 × 512 K complex data points, pseudo-echo weighting in both dimensions was used. NOE difference spectra: at 30° with a presaturation of 3 s (128 transients). A 1 Hz line broadening function was applied to the difference FID prior to *Fourier* transformation. Multiplicities of the ^{13}C signals were determined by DEPT experiments. 2D HETCOR spectrum of **1**: at 35°, concentration $1.7 \cdot 10^{-1}$ M in $CDCl_3$; spectral width 333 Hz in *F*1 and 5630 Hz in *F*2, data matrix of 64 × 1024 datapoints with 1024 transients per increment; after zero-filling to 128 × 2048 K, pseudo-echo weighting was applied in both dimensions prior to *Fourier* transformation; the long-range HETCOR experiment was performed with delays optimized for $J_{CCCH} = 7$ Hz. EI-MS: *Nermag R 10–10* spectrometer.

Plant Material. Polygala fruticosa BERG. was collected in Silverglen Nature Reserve, Durban, South Africa, in June 1988. A voucher specimen is deposited at the Herbarium, University of Durban-Westville (South Africa).

Extraction and Isolation. Powdered leaves (60 g) and root bark (90 g) of *P. fruticosa* were extracted at r.t. successively with petroleum ether, CH_2Cl_2, and MeOH. A part (3.5 g) of the CH_2Cl_2 extract of the leaves (4.5 g) was fractionated by column chromatography (4.5 × 60 cm) on silica gel *60* (40–63 μm, *Merck*) into 9 fractions *(I-IX)*; using steps-gradient petroleum ether/AcOEt 1:1 →2:3 →2:5, followed by AcOEt. Recrystallisation of *Fraction VI* (298 mg) and *Fraction VII* (728 mg) from CH_2Cl_2/AcOEt 5:1 provided **1** (90 and 311 mg, resp.). Recrystallisation of *Fraction IX* (331 mg) from CH_2Cl_2/MeOH 5:2 gave **2** (29 mg). Further amounts of **1** (19 mg) and **2** (15 mg) were obtained by LPLC of *Fraction VIII* (244 mg) on *Diol* with $CHCl_3$/petroleum ether 1:1.

After elimination of 10.0 g of a white precipitate (sucrose), a portion (17.9 g) of the MeOH extract of the root bark (29.0 g) was submitted to column chromatography (5.0 × 80 cm) on silica gel (40–63 μm, *Merck*) using step-gradient $CHCl_3$/MeOH/H_2O 80:20:2 →60:40:10 (monitoring by TLC) to afford 9 fractions (*I–IX*). Compound **3** (40 mg) was isolated from *Fraction V* (840 mg) by filtration on *Sephadex-LH-20* with MeOH as eluent.

6H,7H-[1]Benzopyrano[4,3-b][1]benzopyran-6,7-dione (= *Frutinone A*; **1**). White prisms from CH_2Cl_2/AcOEt 5:1. M.p. 235–236° ([24]: 233°; [25]: 245°; [26]: 236°). TLC (SiO_2, $CHCl_3$/MeOH 95:5): R_f 0.47, dark fluorescence at 366 nm. HPTLC (*RP-8*, MeOH/H_2O 7:3): R_f 0.49. UV (MeOH): 229 (4.18), 261 (4.28), 296 (4.08), 318 (sh, 3.98; [24]: 231 (4.21), 263 (4.49), 298 (4.11), 320 (4.00)). UV (MeOH + NaOMe): unchanged. UV (MeOH + $AlCl_3$): unchanged. IR (KBr): 3050, 1745, 1640, 1610, 1540, 1410, 1105, 900, 870, 755 ([24]: 1727, 1648, 1620, 1548). ^{1}H-NMR: *Table 1*. ^{13}C-NMR: *Table 2*. Heteronuclear connectivities (long-range HETCOR, $^3J(C,H) = 7$): C(1)/*H*–C(3), C(2)/*H*–C(4), C(3)/*H*–C(1), C(4)/*H*–C(2), C(4a)/*H*–C(3), C(6)/–, C(6a)/–, C(7)/*H*–C(8), C(7a)/*H*–C(9), C(7a)/H–C(11), C(8)/*H*–C(10), C(9)/*H*–C(11), C(10)/*H*–C(8), C(11)/*H*–C(9), C(11a)/*H*–C(10), C(12a)/*H*–C(1), C(12b)/*H*–C(2), C(12b)/*H*–C(4). EI-MS: 264 (100, M^+), 236 (59), 208 (22), 116 (45), 104 (19), 92 (23), 88 (62), 76 (19).

X-Ray Analysis of **1**. Suitable crystals, in the form of transparent plates, were grown from MeCN. Crystal data: $C_{16}H_8O_4$, $M_r = 264.2$, space group *Pnam*, $a = 22.630(9)$, $b = 7.892(1)$, $c = 6.484(1)$ Å, $V = 1158.0$ Å^3, $F(000) = 544$, $Z = 4$, $D_x = 1.516$ gcm^{-3}, Mo$K\alpha$, $\lambda = 0.71073$ Å, $\mu = 0.10$ mm^{-1}. A crystal of dimensions 0.44 × 0.38 × 0.02 mm was used for data collection. Preliminary *Weissenberg* and precession photographs indicated the crystals to be orthorhombic, space group *Pna*2 or *Pnam*. Intensity data, with index limits *h* 0 to 24, *k* 0 to 8, *l* 0 to 6 and $\Theta_{max} = 22.5°$, were measured on a *Stoe Siemens AED2* four-circle diffractometer (graphite-monochromated Mo$K\alpha$ radiation), ω/Θ scan mode, on-line profile fitting [28] [29]. There was a 3% intensity variation for 3 standard reflections measured every h. Of the 649 unique reflections measured, 436 were considered observed ($F_0 > 3\sigma(F_0)$). Cell parameters were from $\pm\omega$ values of 14 reflections and their equivalents in the range $7° < 2\Theta < 31°$. No absorption or extinction corrections were applied. The *E* statistics clearly indicated a centrosymmetric system which was confirmed by the successful least-squares refinement. The structure was solved by direct methods using the program SHELXS-86 [30]. The program SHELX-76 [31] was used for all further calculations. In the final cycles of least-squares refinement the benzene H-atoms were included in idealized positions and treated as 'riding atoms' with an overall isotropic thermal parameter (refined value 0.0823). Weighted anisotropic full-matrix least-squares refinement for 436 reflections converged at $R = 0.073$, $R_w = 0.064$; $w^{-1} = \sigma^2(F_0) + 0.00132(F_0^2)$. Average parameter shift/e.s.d. < 0.008. Heights in final difference map $\rho_{max} = 0.43$, $\rho_{min} = -0.31$ eÅ^{-3}. The rather high *R* factor is probably due to the fact that the crystal did not diffract significantly

Table 3. *Bond Distances* (Å; average error 0.014(3) Å) *and Angles* (°; average error 1.1(2)°) *for* **1**

C(1)–C(2)	1.383	C(7)–O(7)	1.231
C(1)–C(12b)	1.374	C(7)–C(7a)	1.487
C(2)–C(3)	1.391	C(7a)–C(8)	1.385
C(3)–C(4)	1.387	C(7a)–C(11a)	1.340
C(4)–C(4a)	1.392	C(8)–C(9)	1.362
C(4a)–O(5)	1.358	C(9)–C(10)	1.407
C(4a)–C(12b)	1.366	C(10)–C(11)	1.398
O(5)–C(6)	1.394	C(11)–C(11a)	1.393
C(6)–O(6)	1.211	C(11a)–O(12)	1.403
C(6)–C(6a)	1.448	O(12)–C(12a)	1.337
C(6a)–C(7)	1.460	C(12a)–C(12b)	1.442
C(6a)–C(12a)	1.379	O(6)...O(7)	2.839
C(2)–C(1)–C(12b)	120.5	C(7)–C(7a)–C(8)	120.0
C(1)–C(2)–C(3)	119.6	C(7)–C(7a)–C(11a)	120.2
C(2)–C(3)–C(4)	120.5	C(8)–C(7a)–C(11a)	119.8
C(3)–C(4)–C(4a)	118.0	C(7a)–C(8)–C(9)	119.0
C(4)–C(4a)–O(5)	114.8	C(8)–C(9)–C(10)	120.7
C(4)–C(4a)–C(12b)	122.0	C(9)–C(10)–C(11)	120.8
O(5)–C(4a)–C(12b)	123.1	C(10)–C(11)–C(11a)	115.3
C(4a)–O(5)–C(6)	121.9	C(7a)–C(11a)–C(11)	124.5
O(5)–C(6)–C(6a)	117.9	C(7a)–C(11a)–O(12)	122.9
O(5)–C(6)–O(6)	115.0	C(11)–C(11a)–O(12)	112.7
O(6)–C(6)–C(6a)	127.1	C(11a)–O(12)–C(12a)	118.6
C(6)–C(6a)–C(7)	122.4	C(6a)–C(12a)–O(12)	123.9
C(6)–C(6a)–C(12a)	118.0	C(6a)–C(12a)–C(12b)	122.9
C(7)–C(6a)–C(12a)	119.6	O(12)–C(12a)–C(12b)	113.2
C(6a)–C(7)–C(7)	124.2	C(1)–C(12b)–C(4a)	119.4
C(6a)–C(7)–C(7a)	114.8	C(1)–C(12b)–C(12a)	124.5
O(7)–C(7)–C(7a)	121.0	C(4a)–C(12b)–C(12a)	116.1

beyond 40° in 2Θ, hence the reflections/parameters ratio is poor (*ca.* 4). Atomic scattering factors were taken from [32]. Bond distances and angles are given in *Table 3*. The crystallographic numbering scheme is apparent from the *Figure*, prepared using ORTEP-II [33]. Final positional and equivalent isotropic thermal parameters and supplementary material are available from *H. St.-E.* and deposited with the *CCDC*.

*4-Methoxy-6*H,7H-*[1]benzopyrano[4,3-*b*][1]benzopyran-6,7-dione* (= *Frutinone B*; **2**). White needles from CH_2Cl_2/MeOH 5:2. M.p. 279–280°. TLC (SiO_2, $CHCl_3$/MeOH 95:5): R_f 0.43, blue fluorescence at 366 nm. HPTLC (*RP-8*, MeOH/H_2O 8:2): R_f 0.56. UV (MeOH): 247 (4.34), 303 (4.22). UV (MeOH + NaOMe): unchanged. UV (MeOH + $AlCl_3$): unchanged. IR (KBr): 2850–3100, 1755, 1650, 1620, 1555, 1470, 1410, 1280, 890, 770. ^{1}H-NMR: *Table 1*. ^{13}C-NMR: *Table 2*. EI-MS: 294 (88, M^+), 265 (42), 251 (51), 237 (14), 210 (13), 208 (10), 139 (26), 131 (95), 103 (55), 92 (79), 77 (100), 76 (43), 75 (99).

*11-Hydroxy-6*H,7H-*[1]benzopyrano[4,3-*b*][1]benzopyran-6,7-dione* (= *Frutinone C*; **3**). White amorphous solid. M.p. 240–250° (dec.). TLC (SiO_2, $CHCl_3$/MeOH/H_2O 65:35:5): R_f 0.45, yellow fluorescence at 366 nm. UV (MeOH): 267 (4.33), 316 (sh, 4.07). UV (MeOH + NaOMe): 303 (4.03), 378 (3.57). UV (MeOH + NaOAc): unchanged. UV (MeOH + $AlCl_3$): unchanged. IR (KBr): 3500, 1720, 1600, 1410, 1250, 1050, 980, 760, 720. ^{1}H-NMR: *Table 1*. ^{13}C-NMR: *Table 2*. EI-MS: 280 (100, M^+), 265 (5), 224 (8), 145 (16), 139 (16), 121 (18), 116 (19), 107 (13), 88 (24), 56 (27), 41 (18).

*11-Methoxy-6*H,7H-*[1]benzopyrano[4,3-*b*][1]benzopyran-6,7-dione* (**3a**). Methylation was carried out by stirring under reflux for 1 h 10 mg of **3** in 10 ml of dried acetone in the presence of K_2CO_3 (0.7 g) and $(CH_3)_2SO_4$ (0.3 ml). The mixture was filtered and the residue washed several times with acetone. The product was purified by column chromatography on silica gel with $CHCl_3$/MeOH 99:1 and recrystallised from MeCN giving **3a** as white needles. M.p. 259–260°. TLC (SiO_2, $CHCl_3$/MeOH 95:5): R_f 0.45, white fluorescence at 366 nm. UV (MeOH): 273 (4.31), 315 (sh, 3.98). UV (MeOH + NaOMe): unchanged. UV (MeOH + $AlCl_3$): unchanged. IR (KBr): 2800–

3000, 1755, 1610, 1555, 1495, 1420, 1280, 1110, 935, 715. ^{1}H-NMR: *Table 1*. EI-MS: 294 (100, $M^{+\cdot}$), 279 (6), 265 (11), 251 (8), 223 (7), 149 (7), 116 (10), 88 (12), 85 (16), 83 (23), 43 (16).

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