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THREE PHENOLIC ACID DERIVATIVES FROM STROMATA OF *EPICHLOE TYPHINA* ON *PHLEUM PRATENSE*

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Key Word Index—*Phleum pratense*; Gramineae; *Epichloe typhina*, Clavicipitaceae; timothy choke disease; 1,3-*O*-di-*trans*-*p*-coumaroylglycerol, 1,2-*O*-di-*trans*-*p*-coumaroylglycerol, chokorin, ^{1}H NMR, ^{13}C NMR.

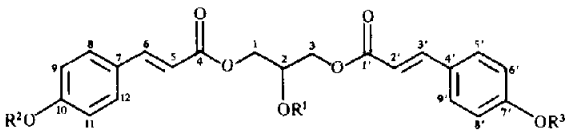
Abstract—Three new phenolic acid derivatives, 1,3-*O*-di-*trans*-*p*-coumaroylglycerol, 1,2-*O*-di-*trans*-*p*-coumaroylglycerol and chokorin were isolated from stromata of *Epichloe typhina* on timothy plants *Phleum pratense*. Their structures were established by spectroscopic and chemical means.

INTRODUCTION

Stroma of *Epichloe typhina* has been called choke and timothy chokes contain many varied classes of fungitoxic compounds In previous studies, fungitoxic cyclopentanoid sesquiterpenes, chokol A, B, C [1] and four C-18 hydroxyunsaturated fatty acids [2] were isolated and identified from timothy chokes infected by *E. typhina*. These compounds seem to be defense substances in the diseased timothy plant *Phleum pratense* against a second invader such as *Cladosporium phlei* [1] This paper deals with the isolation and structure elucidation of three novel but non-fungitoxic phenolic glycerides **1**–**3** together with five known fungitoxic phenolic compounds **4**–**8**.

RESULTS AND DISCUSSION

Compound **1**, mp 194–196°, analysed for $C_{21}H_{20}O_7$ by high resolution EIMS The IR spectrum exhibited the presence of hydroxyl (3340 cm^{-1}), conjugated ester carbonyl (1690 cm^{-1}) and *para*-substituted benzene ring groups (1600 and 830 cm^{-1}) The ^{1}H NMR spectrum (Table 1) showed the presence of two equivalent *p*-coumarate moieties, δ7.55 and 6 89 (J=8.8 Hz) for aromatic rings and δ7 66 and 6.38 (J=15.8 Hz) for *trans* double bonds, which was confirmed by the ^{13}C NMR spectrum (Table 2) and the mass fragmentations, *m/z* 164, 147 (base peak) and 119. Remaining signals δ4 18–4.29 (5H, *m*) in the ^{1}H NMR and δ65.3 (*t*) and 67.6 (*d*) in the ^{13}C NMR spectra suggested the presence of a 1,3-diacyl-



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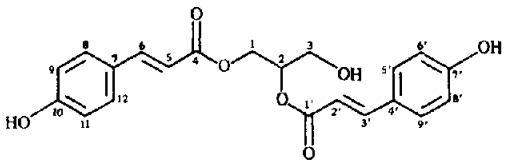

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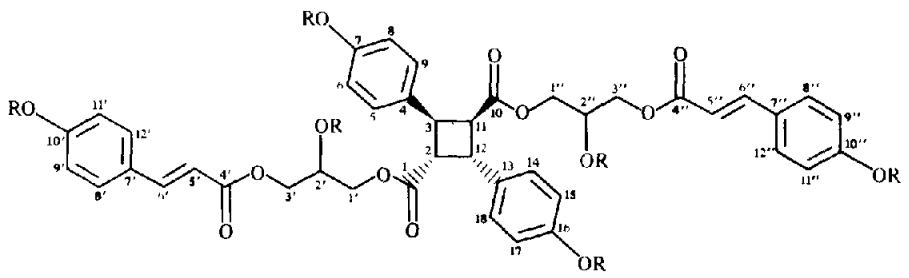

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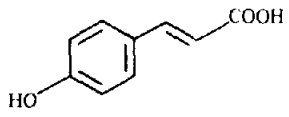
3a R = Ac



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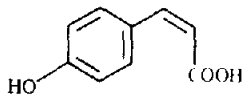

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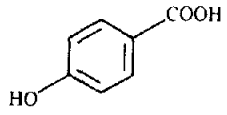

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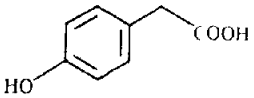

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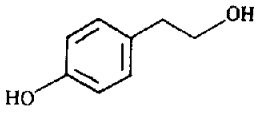

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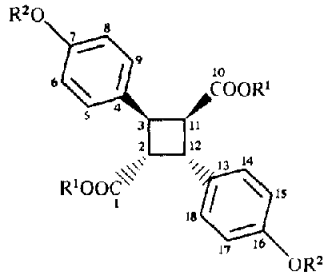
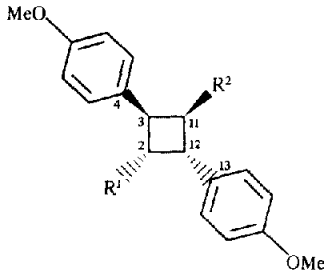


9 $R^1 = R^2 = H$
10 $R^1 = Me$, $R^2 = H$
11 $R^1 = R^2 = Me$



12 $R^1 = COOMe$, $R^2 = CH_2OH$
13 $R^1 = R^2 = CH_2OH$
14 $R^1 = R^2 = CHO$

glycerol moiety. Acetylation of **1** gave the symmetric triacetate **1a** and the asymmetric diacetate **1b**. In the ^1H NMR spectrum of triacetate **1a** the deshielded signal δ5.41 (1H, *m*) was coupled with the protons of two equivalent methylenes, δ4.37 (2H, *dd*, $J = 12.0$ and 6.0 Hz) and 4.48 (2H, *dd*, $J = 12.0$ and 4.0 Hz). These signals were assigned to the protons of a glycerol moiety. The IR, MS and ^1H NMR spectral data of **1a** were identical with the diacetate of lasiocarpin A **1c** [3, 4]. Thus the structure of compound **1** was determined as 1,3-*O*-di-*trans*-*p*-coumaroylglycerol.

Compound **2** had the same molecular formula, $C_{21}H_{20}O_7$, as **1**. The presence of two non-equivalent *p*-coumarate moieties was easily deduced from the ^1H NMR spectrum (Table 1). The ^1H NMR also showed the presence of a 1,2-diacylglycerol moiety. δ5.23 (1H, *m*) for an acylated methine proton, δ4.37 (1H, *dd*, $J = 11.7$ and 6.6 Hz) and 4.49 (1H, *dd*, $J = 11.7$ and 4.0 Hz) for acylated methylene protons and δ3.78–3.82 (2H, *m*) for hydroxymethyl protons. The presence of two methylene groups surrounding the methine group was confirmed by spin decoupling experiments in irradiating the signal at δ5.23. Based on the above spectral data the structure of **2** was determined as 1,2-*O*-di-*trans*-*p*-coumaroylglycerol.

Compound **3**, mp 226–228°, $[\alpha]_D^{24}$ ±0.0 (MeOH, *c* 0.3), which we have named chokorin, had a molecular formula $C_{42}H_{40}O_{14}$, which was deduced from FDMS *m/z* 769 $[M+H]^+$, high resolution FIMS *m/z* 384 $[1/2\ M]^+$ $C_{21}H_{20}O_7$, ^{13}C NMR (Table 2) and ^1H NMR (Table 3). In the ^1H and ^{13}C NMR spectra, the number of signals observed was half that expected, suggesting that **3** had a completely symmetrical structure. The IR spectrum showed hydroxyl (3370 cm^{-1}), ester carbonyl (1710 cm^{-1}) and *para*-substituted benzene ring groups (1600 and 830 cm^{-1}). The ^1H NMR spectrum indicated that **3** possessed two equivalent *p*-coumarate moieties

Table 1. ^{1}H NMR spectral data of compounds **1**, **1a**, **1b** and **2** (270 MHz, TMS as int standard)

H	1*	1a†	1b†	2*
1a		4 48 *dd* (12.0, 4 0)	4.34 4 50 *m*	4 49 *dd* (11 7, 4.0)
1b		4 37 *dd* (12.0, 6 0)		4.37 *dd* (11 7, 6.6)
2	4 18–4 29 *m*	5.41 *m*	5 38 *m*	5 23 *m*
3a		4.48 *dd* (12 0, 4 0)	4.34–4.50 *m*	3.78–3 82 *m*
3b		4 37 *dd* (12.0, 6.0)		
5	6 38 *d* (15 8)	6 41 *d* (16.0)	6 41 *d* (15 8)	6.37 *d* (15 8)
2′			6 29 *d* (16 1)	
6	7.66 *d* (15 8)	7.69 *d* (16 0)	7 68 *d* (15 8)	7 65 *d* (15.8)
3′			7 63 *d* (16 1)	7.63 *d* (15 8)
8,12	7.55 d (8.8)	7.54 *d* (8.8)	7 53 *d* (8.8)	7 56 *d* (8 4)
5′,9′			7 38 *d* (8 8)	7 55 *d* (8 4)
9,11	6 89 *d* (8 8)	7 12 *d* (8 8)	7 11 *d* (8 8)	6 90 *d* (8.4)
6′,8′			6 78 *d* (8 8)	6 89 *d* (8.4)
2-OAc	—	2 12 *s*	2 13 *s*	—
Ar-OAc	—	2 31 *s*	2.32 *s*	—

Coupling constants (J in Hz) are given in parentheses
*Me_2CO-d_6 as solvent
†$CDCl_3$ as solvent

Table 2. ^{13}C NMR spectral data of compounds **1** and **3** (Me_2CO-d_6 solvent, TMS as int standard)

	1*		3†		
C		C		C	
1	65 3 (*t*)	1,10	173 0 (*s*)	1′,1″	66.0 (*t*)
2	67 6 (*d*)	2,11	48.3 (*d*)	2′,2″	68.1 (*d*)
3	65 3 (*t*)	3,12	42 0 (*d*)	3′,3″	66.3 (*t*)
4,1′	166.7 (*s*)	4,13	130 9 (*s*)	4′,4″	168.1 (*s*)
5,2′	114.6 (*d*)	5,9	130 0 (*d*)	5′,5″	115 5 (*d*)
6,3′	145 0 (*d*)	14,18		6′,6″	146 3 (*d*)
7,4′	126 3 (*s*)	6,8	116.4 (*d*)	7′,7″	127 1 (*s*)
8,12,5′9′	130.3 (*d*)	15,17		8′,12′,8″,12″	131 4 (*d*)
9,11,6′,8′	116.0 (*d*)	7,16	157 8 (*s*)	9′,11′,9″,11″	117 1 (*d*)
10,7′	159 9 (*s*)			10′,10″	161.2 (*s*)

Multiplicity are given in parentheses
*25 0 MHz, COM and OFR.
†67 8 MHz, COM and INEPT

δ7.56 and 6.90 (J = 8.8 Hz) for benzene rings and δ7.63 and 6 35 (J = 15.8 Hz) for *trans* double bonds, and two other equivalent *para*-hydroxyl benzene rings δ7.22 and 6.81 (J = 8.8 Hz). These assignments were further supported by the 2D ^{1}H COSY and ^{1}H-^{13}C COSY. In the ^{13}C NMR spectrum the signal at δ173.0 was assigned to a non-conjugated ester carbonyl carbon. The signal at δ68.1 (*d*) whose proton was correlated to δ3.78 by ^{1}H–^{13}C COSY was assigned to a hydroxylated methine carbon from the ^{1}H NMR chemical shift. Two remaining signals at δ66.0 (*t*) and 66.3 (*t*) were attributed to oxygenated methylene carbons whose oxygens must be acylated. To resolve the complicated signals at δ3.75–4.45 in the ^{1}H NMR of **3**, further analyses were carried out with a hexaacetate **3a** obtained by treatment of **3** with acetic anhydride–pyridine. In the ^{1}H NMR spectrum of **3a** in C_6D_6, the signal at δ3.78 of **3** was shifted downfield δ5 16 (*m*, *H*-2′, 2″) and was coupled with four signals at δ4.19 (*dd*, J = 11.9, 4.4 Hz, H-3a′, 3a″), 4.13 (*dd*, J = 11.9, 5.5 Hz, H-3b′, 3b″), 4.07 (*dd*, J = 11.9, 4.6 Hz, H-1a′, 1a″) and 3.75 (*dd*, J = 11.9, 4 9 Hz, H-1b′, 1b″). These coupling data indicated the presence of a 1,3-diacyl-2-acetylglycerol moiety for a partial structure. Remaining methine protons at δ4 53 (2H) and 3.89 (2H) were coupled with each other (J = 10.6, 7 3 Hz) and this evidence suggested that the above methine carbons constituted a 1,2,3,4-tetrasubstituted *cis*, *trans*, *cis*-cyclobutane ring system. Furthermore, each methine carbon of cyclobutane should be substituted by *p*-hydroxyphenyl and ester carbonyl groups alternately [5]. The partial structures mentioned above were corroborated by detailed spin decoupling experiments in benzene and further supported by 2D ^{1}H COSY and spin decoupling experiments in $CDCl_3$ as solvent. Based on the above spectroscopic data the

Table 3 ^{1}H NMR spectral data of chokorin (**3**) and hexaacetate **3a** (270 MHz, TMS as int standard)

H	3*	3a†	3a‡
2,11	3 92 *dd* (10 4, 7 2)	3 98 *dd* (10 6, 7 3)	3 89 *dd* (10 6, 7 3)
3,12	4 38 *dd* (10 4, 7 2)	4 48 *dd* (10 6, 7 3)	4 53 *dd* (10 6 7 3)
5,9,14,18	7 22 *d* (8 8)	7 33 *d* (8 8)	6 99 *d* (8 8)
6,8,15,17	6 81 *d* (8 8)	7 08 *d* (8 8)	6 87 *d* (8 8)
1a′,1a″	3 92 *m*	4 06 *m*	4 07 *dd* (11 9, 4 6)
1b′,1b″	3 78 *m*	3 71 *dd* (11 7, 5 1)	3 75 *dd* (11 9, 4 9)
2′,2″	3 78 *m*	5 02 *m*	5 16 *m*
3a′,3a″	4 03 m	4 06 m	4 19 *dd* (11 9, 4 4)
3b′,3b″			4 13 *dd* (11 9, 5 5)
5′,5″	6 35 *d* (15 8)	6 36 *d* (15 8)	6 32 *d* (16 1)
6′,6″	7 63 *d* (15 8)	7 64 *d* (15 8)	7 73 *d* (16 1)
8′,12′,8′,12″	7 56 *d* (8 8)	7 55 *d* (8 8)	7 05–7 25 *m*
9′,11″,9″,11″	6 90 *d* (8 8)	7 13 *d* (8 8)	
7,16–OH	8 27 *br s*	—	—
2′,2″ OH	4 23 *d* (5 5)	—	—
10′,10″–OH	8 91 *br s*	—	—
7,16–OAc	—	2 22 *s*	1 71 *s*
2′,2″–OAc	—	2 02 *s*	1 69 *s*
10′,10″–OAc		2 31 *s*	1 74 *s*

Coupling constants (*J* in Hz) are given in parentheses
*Me_2CO-d_6 as solvent
†$CDCl_3$ as solvent
‡C_6D_6 as solvent

Table 4. ^{1}H NMR spectral data of compounds **10–14** (270 MHz, TMS as int standard)

H	10*	11†	12*	13*	14†
2	3 86 *dd* (10 3, 7 3)	3 90 *dd* (10 4, 7 1)	3 93 *ddd* (10 3 7 7, 0 7)	3 13 *ddt* (9 3, 7 1, 7 3)	3 81 *ddd* (10 4, 7 1, 1 7)
11			3 12 *m*		
3	4 31 *dd* (10 3, 7 3)	4 38 *dd* (10 4, 7 1)	4 21 *dd* (9 5, 7 7)	3 58 *dd* (9 3, 7 1)	4 60 *dd* (10 4, 7 1)
12			3 79 *dd* (10 3, 5 9)		
5,9	7 17 *d* (8 8)	7 21 *d* (8 8)	7 294 *d* (8 8)	7 32 *d* (8 8)	7 19 *d* (8 2)
14,18			7 286 *d* (8 8)		
6,8	6 79 *d* (8 8)	6 86 *d* (8 8)	6 90 *d* (8 8)	6 88 *d* (8 8)	6 87 *d* (8 2)
15,17			6 87 *d* (8 8)		
COOMe	3 31 *s*	3 33 *s*	3 28 *s*	—	—
Ar OMe	—	3 79 *s*	3 79 *s*	3 78 *s*	3 79 *s*
			3 78 *s*		
O–CH_2	—	—	3 42 *d* (6 6)	3 37 *d* (7 3)	—
CHO	—	—	—	—	9 49 *d* (1 7)

Coupling constants (*J* in Hz) are given in parentheses
*Me_2CO-d_6 as solvent
†$CDCl_3$ as solvent

structure bis-(3-*trans*-*p*-coumaryloxy-2-hydroxy)propyl *cis,trans,cis*-2,4-bis-(4-hydroxy)phenyl-1,3-cyclobutanedicarboxylate was assigned to chokorin (**3**)

Furthermore the ^{1}H NMR studies of compounds **10–14** (Table 4) derived from **9** [6] (see Experimental) confirmed the stereochemistry of the cyclobutane of **3**, and ^{1}H NMR assignments of **3** were determined as follows Firstly, the upfield shifted methylene (δ3.92 and 3 78) of the glycerol moiety in **3** was determined to be adjacent to a carboxyl group of cyclobutane, because the signal of a carbomethoxy methyl of **10** appeared at δ3 31 ppm and this upfield shift was caused by the phenyl group at *cis* position Secondly, the assignments, of cyclobutyl protons of **3** were established by comparison with **12** and **14**, whose assignments were deduced from coupling constants and further confirmed by spin decoupling experiments in the case of **12** Therefore in the ^{1}H NMR spectrum of **3**, the signal at δ4.38 was assigned

to H-3 and H-12, and δ3.92 to H-2 and H-11. On the basis of the ^{1}H NMR assignments of **3**, the ^{13}C NMR assignments were also established by ^{1}H–^{13}C COSY spectrum (Table 2).

Additionally, alkaline hydrolysis of **3** with 5% potassium hydroxide–methanol gave *p*-coumaric acid **4**, glycerol and 4,4′-dihydroxy-α-truxillic acid **9**. The latter was identified by direct comparison with synthetic **9** [6]. These results supported the proposed structure of **3**. Moreover photo-dimerization of **1** in H_2O gave a dimer product which was spectroscopically identical with **3**. This evidence implies that biogenesis of **3** from **1** in sunlight is likely to be by a mode different from the oxidative coupling in lignan formation [7].

Five other phenolic compounds, *trans-p*-coumaric acid **4**, *cis-p*-coumaric acid **5**, *p*-hydroxybenzoic acid **6**, *p*-hydroxyphenylacetic acid **7** and tyrosol **8** were isolated and identified by spectral data and direct comparison with authentic samples. Most of them, **4–8**, inhibited the growth of *Cladosporium herbarium*, demonstrated by means of TLC bioautography [8], but interestingly compounds **1–3** had no activity even though the *trans-p*-coumarate moiety is present in each molecule.

Natural phenolic glycerides have been isolated from several plant sources: Gramineae [9–11], Salicaceae [3, 4, 11], Bromeliaceae [12] and Liliaceae [13]. So the isolated compounds **1–3** may be produced by *Phleum pratense* and not by the choke disease fungus *E. typhina*, although this would be difficult to establish in a complicated system like choke.

EXPERIMENTAL

Extraction and isolation of **1–3**. Timothy chokes (20 kg) was extracted with 70% EtOH (103 l). The extract was evapd and the aq. residue partitioned between *n*-hexane and H_2O. The resulting aq. soln was further partitioned between EtOAc and H_2O. The EtOAc soln was dried on Na_2SO_4, filtered and evapd to dryness and the residue (43 g) chromatographed on silica gel column (1200 g) with $CHCl_3$–MeOH (19:1) and then a silica gel column (300 g) with $CHCl_3$–Me_2CO (7:3). A fraction containing phenolic compounds was cryst. from MeOH and sepd. into the filtrate and the crude crystals. The crude crystals (329 mg) were separated by CC on silica gel (30 g) using $CHCl_3$–MeOH (9:1) and crystallized from the column fractions to give **1** (170 mg) and **3** (16 mg), each as colourless needles. The filtrate was evapd. to dryness (551 mg) and purified by silica gel CC using $CHCl_3$–Me_2CO (4:1) followed by HPLC (μ-BONDAPAK C-18) with H_2O–MeCN (3:2) to give **2** (2 mg) in an amorphous state.

Compound **1**. 1,3-*O*-Di-*trans-p*-coumaroylglycerol. Mp 194–196°; FDMS *m/z* 384 $[M]^+$; EIMS *m/z* (rel. int.) 384 1176 $[M]^+$ (0.6) (calcd. for $C_{21}H_{20}O_7$ 384.1209), 238, (6.7), 207 (6.1), 164 (34.8), 147 (100), 119 (28.2), 91 (23.7), 44 (44.3). IR ν_{max}^{KBr} cm^{-1}: 3340, 1690, 1600, 1250, 1170, 1040, 980, 830. ^{1}H NMR (Table 1). ^{13}C NMR (Table 2).

Acetylation of **1**. Compound **1** (19 mg) was acetylated with Ac_2O (1.5 ml)–pyridine (0.5 ml) at room temp. for 22 hr. After evapn., the residue was purified by silica gel CC (3 g) with Me_2CO–C_6H_6 (7:93) to give the triacetate **1a** (16 mg) and diacetate **1b** (3 mg), each as a colourless viscous oil. **1a**, EIMS *m/z* (rel. int.): 510.1572 $[M]^+$ (0.3) (calcd. for $C_{27}H_{26}O_{10}$, 510.1526), 468 (13.9), 426 (2.5), 322 (5.6), 189 (13.8), 164 (7.0), 147 (100), 119 (12.3), 91 (10.5), 83 (11.4), 81 (10.5), 71 (11.1), 57 (21.4), 55 (21.2), 43 (65.8), 41 (18.8). IR ν_{max}^{film} cm^{-1}: 3020, 2950, 1770, 1720, 1640, 1600, 1500, 1370, 1200, 1010, 910, 760. ^{1}H NMR (Table 1). Diacetate **1b**, EIMS *m/z* (rel. int.) 468.1440 $[M]^+$ (8.9) (calcd. for $C_{25}H_{24}O_9$ 468.1421), 426 (2.3), 262 (3.2), 189 (9.6), 164 (6.9), 147 (100), 119 (14.4), 91 (13.2), 65 (6.7), 43 (43.0). IR ν_{max}^{film} cm^{-1}: 3400, 2940, 1720, 1640, 1610, 1515, 1210, 1170, 1020, 840, 760. ^{1}H NMR (Table 1).

Compound **2**. 1,2-*O*-Di-*trans-p*-coumaroylglycerol. EIMS *m/z* (rel. int.): 384.1227 $[M]^+$ (1.9) (calcd. for $C_{21}H_{20}O_7$ 384.1209), 238 (1.5), 220 (2.0), 207 (1.8), 164 (11.3), 147 (100), 119 (14.1), 91 (9.9), 44 (16.0). IR ν_{max}^{film} cm^{-1}: 3350, 2930, 1700, 1600, 1510, 1270, 1160, 830. $[\alpha]_D^{24}$ ±0.0° (MeOH; *c* 0.12). ^{1}H NMR (Table 1).

Compound **3**. Bis(3-*trans-p*-coumaryloxy-2-hydroxy)propyl *cis,trans,cis*-2,4-bis(4-hydroxy)phenyl-1,3-cyclobutanedicarboxylate. Mp 226–228°, FDMS *m/z* (rel. int.) 807 $[M+K]^+$ (28.9), 791 $[M+Na]^+$ (60.0), 769 $[M+H]^+$ (100), 385 (28.6), EIMS *m/z* (rel. int.) 384.1192 $[1/2\,M]^+$ (1.9) (calcd. for $C_{21}H_{20}O_7$ 384.1209), 292 (1.1), 267 (1.2), 238 (11.1), 223 (1.3), 221 (1.8), 220 (1.4), 207 (1.9), 164 (11.1), 147 (100), 120 (11.1), 119 (21.1), 65 (13.5). IR ν_{max}^{KBr} cm^{-1}: 3370, 1710, 1600, 1510, 1440, 1260, 1170, 830. $[\alpha]_D^{24}$ ±0.0° (MeOH, *c* 0.3). ^{1}H NMR (Table 3). ^{13}C NMR (Table 2).

Acetylation of **3**. Compound **3** (8.0 mg) was acetylated with Ac_2O (0.3 ml)–pyridine (0.3 ml) at room temp. for 18 hr. After the usual work-up, the residue was purified by silica gel CC (5 g) with EtOAc–C_6H_6 (2:3) to give the hexaacetate **3a** (4.4 mg) as a colourless viscous oil. FDMS *m/z* (rel. int.) 1021 $[M+H]^+$ (100), 978 $[M+H-Ac]^+$ (27.1), 507 (33.5); EIMS *m/z* (rel. int.) 468 (2.5), 426 (0.9), 304 (1.9), 280 (1.2), 262 (4.1), 189 (6.7), 164 (38.2), 147 (100), 119 (19.6), 91 (19.0), 43 (81.9). IR ν_{max}^{film} cm^{-1}: 2930, 1760–1730, 1640, 1600, 1505, 1370, 1180, 1020, 915, 840, 755. ^{1}H NMR (Table 3).

Alkaline hydrolysis of **3**. Compound **3** (8 mg) was treated with 5% KOH–MeOH (8 ml) under reflux for 21 hr. The solvent was evaporated and the residue was acidified with cooled 1 N HCl and extracted with EtOAc. The EtOAc layer was dried, concd. and purified by silica gel CC (5 g) with MeOH–$CHCl_3$, HOAc (10:90:1) to give *trans-p*-coumaric acid **4** (3 mg) as a colourless viscous oil and 4,4′-dihydroxy-α-truxillic acid **9** (2 mg) as a white amorphous solid, whose physical and spectral data were identical to those of authentic samples (See below). The aq. layer was neutralized with satd. aq. Na_2CO_3 and evapd. to dryness and the residue extracted with EtOAc. Removal of solvent gave glycerol as a viscous substance (*ca* 0.5 mg), EIMS *m/z*: 93 $[M+H]^+$.

Photo-dimerisation of **1**. Compound **1** (19 mg) was suspended in 1 ml of H_2O and stirred. After 20 hr of irradiation with a 250 W lamp at room temp., solvent was removed and the residue was purified by silica gel CC (10 g) with $CHCl_3$–MeOH (9:1) to give a white solid (8 mg), whose spectral data were identical to those of **3**.

Preparation of 4,4′*-dihydroxy-α-truxillic acid* **9**. **9** was prepared from *trans-p*-coumaric acid **4** according to the procedure previously described [7]. Mp 310° (lit. [7] 340°), EIMS *m/z* (rel. int.) 328.0930 $[M]^+$ (0.1) (calcd. for $C_{18}H_{16}O_6$, 328.0945), 225 (12.3), 164 (32.9), 147 (13.8), 120 (100), 119 (31.3), 91 (54.0), 44 (83.0). ^{1}H NMR (270 MHz, CD_3OD): 7.20 (*d*, *J* = 8.4 Hz, H-5, 9, 14, 18), 6.71 (*d*, *J* = 8.4 Hz, H-6, 8, 15, 17), 4.24 (*br dd*, *J* = 9.2, 6.6 Hz, H-3, 12), 3.77 (*br s*, H-2, 11).

Methylation of **9**. **9** (25 mg) was treated with excess CH_2N_2 in Et_2O–MeOH for 10 hr. After removal of solvent, the reaction mixture was separated by silica gel CC (10 g) with $CHCl_3$–Me_2CO (19:1) to give dimethyl 4,4′-dihydroxy-α-truxillate **10** (2 mg) and dimethyl 4,4′-dimethoxy-α-truxillate **11** (11 mg) each as colourless needles. **10**, mp 174–177°, EIMS *m/z* (rel. int.) 356.1241 $[M]^+$ (0.3) (calcd. for $C_{20}H_{20}O_6$, 356.1257), 236 (6.8), 222 (8.0), 192 (6.7), 179 (15.9), 178 (100), 147 (58.7). ^{1}H NMR (Table 4). **11**, mp 122–124° (lit. [7] 129–130°), EIMS *m/z* (rel. int.) 384.1565 $[M]^+$ (0.2) (calcd. for $C_{22}H_{24}O_6$

384 1573), 206 (12 2), 192 (100), 161 (50 0), 133 (14 3) ^{1}H NMR (Table 4)

Reduction of **11**. To a cooled (−70°) soln of **11** (10 mg) in THF (2 ml) under N_2 was added DIBAH (2 eq) and the soln stirred for 4 5 hr (−70 ~ −40°) The reaction was quenched with half-satd aq NH_4Cl, the soln acidified with 1 N HCl and the products extracted with Et_2O, dried, concd and purified by silica gel prep TLC with $CHCl_3$–Me_2CO (9 1) to give monool **12** (4 mg) and diol **13** (2 mg) each as a viscous oil Monool **12**, EIMS *m/z* (rel int) 356 1664 $[M]^+$ (0 1), (calcd for $C_{21}H_{24}O_5$ 356 1624), 192 (11 5), 164 (100), 161 (21 7), 121 (76 4), 108 (42 8) ^{1}H NMR (Table 4) Diol **13**, EIMS *m/z* (rel int) 328 1685 $[M]^+$ (0 8) (calcd for $C_{20}H_{24}O_4$ 328 1675), 178 (6 2), 164 (100), 121 (90 8), 108 (46 9) ^{1}H NMR (Table 4)

Oxidation of **13** **13** (1 8 mg) was oxidized with PDC in CH_2Cl_2 for 11 hr After addition of satd aq NH_4Cl, the product was extracted with Et_2O, dried evapd and purified by silica gel CC (5 g) with EtOAc–*n*-hexane (3 7) to give 4,4′-dimethoxy-α-truxillaldehyde **14** (1 8 mg) EIMS *m/z* (rel int) 324 1378 $[M]^+$ (51 2) (calcd for $C_{20}H_{20}O_4$ 324 1361), 280 (63 9), 173 (84 4), 121 (100) ^{1}H NMR (Table 4)

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