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COMPARISON OF THE FUNGICIDAL ACTIVITIES OF (*E*)-4-HYDROXYLATED STILBENES AND RELATED BIBENZYLS

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Key Word Index—*Gloeophyllum trabeum*; *Poria placenta*; *Coriolus versicolor*; stilbenes; bibenzyls; fungicidal properties; quantitative structure–activity relationship; didecyldimethylammonium chloride; phytoalexins.

Abstract—The fungicidal activities of (*E*)-4-hydroxylated stilbenes and related bibenzyls were measured by the agar plate procedure and selected active compounds by the soil block method. In the agar plate test, stilbenes with 3′-substituents were all active against two brown-rot (*G. trabeum* and *P. placenta*) fungi, with the activity having a parabolic hydrophobic relationship. A highly fungitoxic monomer was used to synthesize a dehydrogenative dimer which showed no brown-rot activity. No stilbene was active against the white-rot fungi *C. versicolor* while three bibenzyls had white-rot activity. Most bibenzyls had moderate brown-rot fungicidal activity. No structural requirement was apparent for bibenzyl brown-rot activity in contrast to the stilbenes. No synergism was observed when various combinations of stilbenes and bibenzyls were tested by the agar plate procedure. Similarities were observed between the agar plate activity and soil block results, although the soil block required higher levels of the stilbene/bibenzyl. No synergism was observed in the soil block results for stilbene and/or bibenzyl combinations. Stilbenes and/or bibenzyls in combination with didecyldimethylammonium chloride, however, showed some synergism.

INTRODUCTION

(*E*)-Hydroxylated stilbenes are formed by woody plants both as constitutive defence agents and as phytoalexins. Thus, stilbenes and related natural compounds have been extensively studied to determine the role they play in disease and decay resistance of plants and lumber products [1–7]. Stilbenes isolated from decay-resistant woods have been shown to be fungitoxic when tested in an agar medium with no wood present. However, these same stilbenes imparted little or no fungicidal properties when impregnated into nondurable wood [1, 2, 8]. Investigators have interpreted these results to suggest that stilbenes act synergistically with the other extractives in decay-resistant wood.

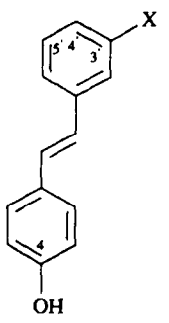
We recently suggested another possible explanation which may act in concert with synergism [9]. Specifically, we proposed that when stilbenes are first formed in plants they are only moderately fungicidal. Intermediates in the stilbene biosynthesis pathway can be altered, or the newly-formed stilbenes can be directly modified *in vivo*, to form derivatives with greater and/or broader bioactivities. Possible biomodifications include oxidative polymerization [3, 10–14], reduction to bibenzyls [3, 15–19], cyclization of stilbenes or bibenzyls to phenanthrenes and 9,10-dihydrophenanthrenes [3, 17–19], and structural modification by aromatic hydroxylation, methylation of phenolic hydroxyls, and *C*-alkylation with isoprenyl groups [1, 3, 20, 21]. For example, while stilbenes are generally reported to be inactive against white-rot fungi [2, 5, 22], a compound bioderived from a stilbene may have fungicidal activity against white-rot fungi.

In a prior study we examined the fungicidal properties of a number of (*E*)-4-hydroxy-3′- and/or -4′-substituted stilbenes and related analogues against one white-rot fungus and two brown-rot fungi using the agar plate technique [9]. 4-Hydroxystilbene, 4-hydroxybibenzyl, and four 4-hydroxy-3′-substituted stilbenes were active against the two brown-rot fungi. The activity was linear in relation to the stilbene's hydrophobicity. Only 4-hydroxybibenzyl was active against the white-rot fungus. None of the three stilbene dehydrogenative dimers synthesized had activity. The dimer results were questionable because two of the three monomeric precursors also had no activity.

We have examined additional (*E*)-4-hydroxy-3′ and/or 4′-substituted stilbene derivatives and in this paper report on: (i) the fungicidal properties of 3′-substituted stilbenes with a wider range of hydrophobicities; (ii) the fungicidal properties of related bibenzyls; (iii) the brown-rot fungicidal activity of a stilbene dimer synthesized using a monomer which was highly active; (iv) soil block tests of selected compounds against *G. trabeum* along with didecyldimethylammonium chloride (DDAC) as a comparison and (v) combinations of selected active stilbenes and/or bibenzyls using both the agar plate and soil block procedures to see if synergism could be observed.

RESULTS AND DISCUSSION

The compounds examined in this study are given in Table 1.



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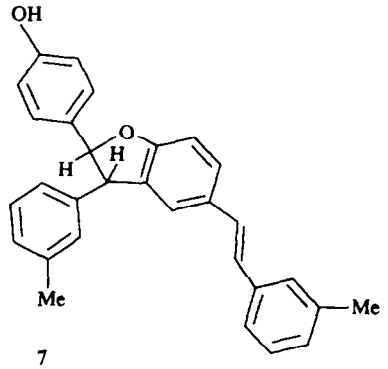

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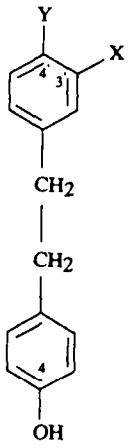

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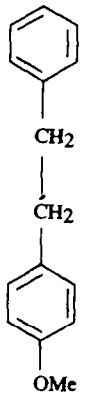

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Table 1. Compounds tested for fungicidal properties

No.	Abbreviation	Name
1	4'-H	(*E*)-4-(2-phenylethenyl)Phenol
2	3'-Me	(*E*)-4-[2-(3-methylphenyl)ethenyl]Phenol
3	3'-OH	(*E*)-4-[2-(3-hydroxyphenyl)ethenyl]Phenol
4	3'-Br	(*E*)-4-[2-(3-bromophenyl)ethenyl]Phenol
5	3'-OPr	(*E*)-4-[2-(3-propoxyphenyl)ethenyl]Phenol
6	3'-OBu	(*E*)-4-[2-(3-butoxyphenyl)ethenyl]Phenol
7	3'Me DIM*	(*E*)-4-[2-(3-methylphenyl)ethenyl]Phenol, dehydrogenative dimer
8	4'-H RED†	4-(2-phenylethyl)Phenol
9	4'-Cl RED	4-[2-(3-chlorophenyl)ethyl]Phenol
10	3'4'-diCl RED	4-[2-(3,4-dichlorophenyl)ethyl]Phenol
11	3'-OMe RED	4-[2-(3-methoxyphenyl)ethyl]Phenol
12	3'-Me RED	4-[2-(3-methylphenyl)ethyl]Phenol
13	4'-OMe RED	4-[2-(4-methoxyphenyl)ethyl]Phenol
14	3'4'-diOMe RED	4-[2-(3,4-dimethoxyphenyl)ethyl]Phenol
15	3'-F RED	4-[2-(3-fluorophenyl)ethyl]Phenol
16	3'-OH RED	4-[2-(3-hydroxyphenyl)ethyl]Phenol
17	3'-Cl RED	4-[2-(3-chlorophenyl)ethyl]Phenol
18	3'-Br RED	4-[2-(3-Bromophenyl)ethyl]Phenol
19	4'-F RED	4-[2-(4-fluorophenyl)ethyl]Phenol
20	4-OMe, 4'-H RED	1-Methoxy-4-(2-phenylethyl)benzene
21	DDAC	Didecyldimethylammonium chloride

*DIM indicates a dimer.

†RED indicates a stilbene which has been reduced to a bibenzyl.

Agar plate test

The concentrations in ppm at which the fungal mycelial growth in agar was inhibited by 50% (IC_{50}) are shown in Table 2. The white-rot fungus continued to be unaffected by any stilbene tested, while all 3'-substituted stilbenes had brown-rot activity. A QSAR examination of various electronic (σ, σ^+), steric (MR, Es) and hydrophobic (π) parameters for the stilbene compounds found hydrophobicity to be the only significant parameter. A hydrophobicity plot, in which the IC_{50} ppm values from Table 2 and a prior study [9] were converted to mM concentrations [23], gave a roughly-shaped parabolic curve for both *G. trabeum* ($r^2 = 75.2\%$) (Fig. 1), and also for *P. placenta* ($r^2 = 60.2\%$) when the 3'-Cl and 3'-Br derivatives were deleted. A linear hydrophobicity plot was reported in our prior study, in which only five samples with a limited hydrophobicity range were plotted [9]. Removal of the 3'-OBu derivative in both the *G. trabeum* and *P. placenta* plots would give essentially linear QSAR plots (Fig. 1). In general, hydrophobicity-QSAR plots are parabolic rather than linear [23]. Difficulty in synthesizing many 3'-substituted stilbenes and the sometimes unpredictable fungicidal behaviour of halogenated derivatives made a QSAR study difficult.

The 3'-Me stilbene dehydrogenative dimer (**7**) had no brown-rot activity despite the monomeric precursor being highly fungitoxic. As reported earlier [9], no synthesized dimer had activity although many natural stilbene dehydrogenative oligomers are reported to be highly bioactive [10–14]. The results obtained in this and our prior [9] study may not be indicative of the fungicidal properties of natural stilbene oligomers because of a number of untested possibilities. For example, the synthesized dimers would be expected to be much more hydrophobic than natural dimers, which may affect the compound's bioactivity.

The bibenzyls also had brown-rot activities although they, in general, were only about half as active as the equivalent stilbene based on the IC_{50} values in Table 2 and a prior study [9]. An exception to this is that all 4'-substituted bibenzyls examined had at least some fungicidal activity against one of the fungi, while the 4'-substituted stilbenes examined previously [9] had no activity except for one dichlorinated derivative. A control bibenzyl, in which the phenolic group was methylated (**20**), had no activity. This is expected of a compound with no free phenolic group [1]. Some halogenated bibenzyls (**10**, **17**, **19**) appeared to have unusually high activity against *P. placenta*, while the 3'-Br and 3'-Cl stilbenes had very low activities against the same fungus. No significant QSAR correlation was found for the bibenzyl brown-rot activities.

A few of the bibenzyls (**9**, **10**, **12**) were fungitoxic against

Table 2. Concentration in parts per million at which the fungus growth is inhibited by 50% relative to the fungus growth in untreated agar

		IC_{50}, ppm		
		White rot fungus	Brown rot fungi	
No.	Compound	*C. versicolor*	*G. trabeum*	*P. placenta*
1	4'-H	>250	31±3*	12±0*
2	3'-Me	(>250)†	(16±1)†	(1±1)†
3	3'-OH	>250	53±4	16±2
4	3'-Br	>250	23±1	46±3*
5	3'-OPr	>250	10±1	<1
6	3'-OBu	>250	83±2*	33±4
7	3'Me DIM‡	—	>90	>90
8	4'-H RED§	224±13*	38±1	20±2*
9	4'-Cl RED	113±7	69±2	17±1
10	3'4'-diCl RED	43±6	69±2	<1
11	3'-OMe RED	>250	87±1	11±1*
12	3'-Me RED	112±7	44±1	13±1
13	4'-OMe RED	>250	>90	15±2
14	3'4'-diOMe RED	>250	>90	21±8
15	3'-F RED‖	>250	77±6	9±4
16	3'-OH RED	>250	>90	39±2
17	3'-Cl RED¶	>250	60±1	<1*
18	3'-Br RED	>250	68±1	27±2
19	4'-F RED	>250	69±3	<1
20	4-OMe, 4'-H RED	>250	>90	>90

*Indicates a sample run several times, with the initial value reported.

†Agar bioactivity data for **2** obtained from an earlier study [9].

‡DIM indicates a dimer.

§RED indicates a stilbene which has been reduced to a bibenzyl.

‖The 3'-F stilbene had IC_{50} values of 16 and 5 ppm for *G. trabeum* and *P. placenta*, respectively [9].

¶The 3'-Cl stilbene had a IC_{50} value of 13 for both *G. trabeum* and *P. placenta* [9].

the white-rot fungi *C. versicolor*. We had earlier reported [9] an IC_{50} of 87 ppm for the 4-hydroxybibenzyl **8**, but in this study we found an IC_{50} value of 224 ppm. Upon repetition, we found an IC_{50} of 218 ppm, suggesting that the higher (less active) value is more accurate. Other selected compounds were also rerun (Table 2), with the results in agreement with this and also the prior study [9] except for the 4-hydroxybibenzyl *C. versicolor* results discussed above. Replicate IC_{50} measurements for compounds **1** and **6** against *G. trabeum* are shown in Fig. 1. No structure/activity correlation was apparent for the three bibenzyls which were active against *C. versicolor*.

Different combinations of several stilbenes and/or bibenzyls were examined using the agar plate test to see if any synergism could be observed (Table 3). No synergism was apparent. Interestingly, the various stilbene/bibenzyl combinations gave remarkably similar fungicidal activity values.

Soil block decay test

Selected bioactive derivatives were examined, both alone and in various stilbene/bibenzyl combinations, against *G. trabeum* using the soil block procedure. As mentioned earlier, stilbenes which were fungitoxic when tested in an agar media were reported to have little or no activity in a soil block test [1, 2, 8]. However, the hydroxylated stilbenes which have been most often studied are resveratrol [(*E*)-4,3',5'-trihydroxystilbene] and 4-hydroxystilbene (**1**). Our agar plate results showed that **1** has only moderate activity while resveratrol, which is very hydrophilic, would be predicted to have minimal or no fungicidal activity based on our QSAR plot (Fig. 1). For a comparison, DDAC (**21**) was also run. The use of acetone as a solvent gave poor results with DDAC when compared to a DDAC/water system during additional control tests. Acetone was necessary, however, because a common solvent was required for both DDAC and the stilbenes/bibenzyls.

The soil block results, as measured by % weight loss (Table 4), followed the same general trend as the agar plate results. As expected, higher concentrations were required for activity in the soil block as compared to the agar plate test. One of the most active stilbenes based on the agar plate method [3'-Me (2)] continued to be more active than 4'-H stilbene (**1**) in the soil block test. In addition, comparison of the 4-hydroxystilbene (**1**) versus 4-hydroxybibenzyl (**8**) showed the bibenzyl to be more effective at higher concentrations. It was previously noted [9] from agar plate tests that 4-hydroxystilbene had a lower IC_{50} value than the related bibenzyl. However, at higher concentrations the bibenzyl **8** totally inhibited the brown-rot fungi while the stilbene **1** still had significant fungal growth on the agar even at the highest concentrations tested.

Various stilbene/bibenzyl combinations showed no synergism, as was also found with the agar plate procedure. This also indicates that the results between the agar plate and soil block tests can be correlated. Interestingly, DDAC-stilbene and/or bibenzyl combinations showed a synergestic effect (Table 4).

The similarities between the agar plate and soil block results, and the advantages of the agar plate procedure (fast, reasonably reproducible, and only milligrams of sample required), suggest that the agar plate technique might be a suitable test for the initial rapid screening of bioactive compounds for wood preservatives.

EXPERIMENTAL

Stilbenes were prepared using previously published methods [9] and were then reduced with 30 psi H_2 over Pd/C to form the corresponding bibenzyl [9, 15]. The stilbenes were recrystallized from HOAc or HOAc–H_2O and the bibenzyls from cyclohexane or cyclohexane–EtOAc. The *n*-propoxy and *n*-butoxy 3'-substi-

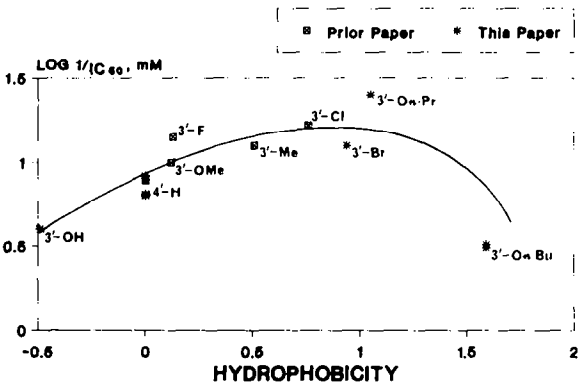

Fig. 1. QSAR hydrophobicity plot for the 3'-substituted stilbenes using *G. trabeum* agar plate results, with some activities obtained from an earlier publication [9].

Table 3. Data for 50% inhibition concentration of selected combinations of stilbenes and bibenzyls in agar

Compound (relative amount)	IC_{50}, ppm*		
	C. versicolor	*G. trabeum*	*P. placenta*
4'-H(1/2):4'-H RED†(1/2)	>250	50±4	31±1
3'-Me(1/2):3'-Me RED(1/2)	>250	42±3	29±2
4'-H(1/2):3'-Me(1/4):3'-Me RED(1/4)	>250	32±1	32±2
4'-H(1/4):3'-Me(1/4):4'-H RED(1/4):3'Me RED(1/4)	>250	50±3	32±1
3'-Me(1/4):4'-H RED(1/4):3'-Me RED(1/2)	>250	50±3	25±2

*The concentration is based on the sum of the individual components.

†RED indicates a stilbene which has been reduced to a bibenzyl.

Table 4. Average soil block results for southern pine blocks exposed to *G. trabeum* for eight weeks

Compound(s) (relative amount)	Retention ($kg\,m^{-3}$)	Weight loss (%)
DDAC* (1)	0.51	19.8 ± 2.5
DDAC (1)	1.04	16.1 ± 2.2
DDAC (1)	1.60	12.6 ± 1.6
DDAC (1)	3.34	7.5 ± 0.7
4′-H (1)	3.79	9.4 ± 1.2
4′-H (1)	5.70	9.0 ± 1.8
4′-H (1)	7.23	10.4 ± 1.4
4′-H RED† (1)	3.60	11.7 ± 3.4
4′-H RED (1)	6.06	6.4 ± 1.2
4′-H RED (1)	7.41	3.4 ± 1.2
3′-Me (1)	3.94	0.9 ± 0.7
3′-Me (1)	5.46	1.3 ± 1.0
3′-Me (1)	7.33	0.1 ± 0.2
DDAC(3/4):4′-H(1/4)	0.50	13.7 ± 1.6
DDAC(3/4):4′-H(1/4)	1.01	8.2 ± 3.0
DDAC(3/4):4′-H(1/4)	1.60	8.8 ± 1.8
DDAC(3/4):4′-H RED†(1/4)	0.51	14.7 ± 3.5
DDAC(3/4):4′-H RED(1/4)	1.07	11.4 ± 2.8
DDAC(3/4):4′-H RED(1/4)	1.73	6.3 ± 2.1
DDAC(3/4):3′-Me(1/4)	0.53	24.4 ± 6.5
DDAC(3/4):3′-Me(1/4)	1.02	12.2 ± 1.9
DDAC(3/4):3′-Me(1/4)	1.60	7.8 ± 1.6
DDAC(3/4):4′-H(1/8):4′-H RED(1/8)	0.50	27.5 ± 2.6
DDAC(3/4):4′-H(1/8):4′-H RED(1/8)	1.06	11.0 ± 2.1
DDAC(3/4):4′-H(1/8):4′-H RED(1/8)	1.62	8.8 ± 2.4
4′-H RED(2/3):3′-Me(1/3)	4.32	19.0 ± 8.3
4′-H RED(2/3):3′-Me(1/3)	6.29	8.0 ± 4.0
4′-H RED(2/3):3′-Me(1/3)	8.88	3.9 ± 1.9
4′-H RED(2/3):4′-H(1/3)	4.22	9.4 ± 3.0
4′-H RED(2/3):4′-H(1/3)	6.35	6.7 ± 1.1
4′-H RED(2/3):4′-H(1/3)	8.22	0.6 ± 0.6
4′-H RED(1/2):4′-H(1/4):3′-Me(1/4)	4.27	18.2 ± 1.5
4′-H RED(1/2):4′-H(1/4):3′-Me(1/4)	6.38	9.7 ± 3.6
4′-H RED(1/2):4′-H(1/4):3′-Me(1/4)	8.02	8.2 ± 1.8
Control	–	27.6 ± 3.7

*Acetone was used as the solvent for all samples. However, control runs showed that DDAC with acetone as the solvent gives poorer results than when water was used as the solvent.

†RED indicates a stilbene which has been reduced to a bibenzyl.

tuted stilbenes were synthesized by reacting 3-hydroxyphenylacetic acid with 1-iodopropane or 1-iodobutane followed by alkaline hydrolysis of the ester to give the alkoxy-substituted phenylacetic acid. The 3′-methyl dehydrogenative dimer was synthesized using a procedure for similar compounds [9, 10] and purified by silica gel followed by reversed-phase chromatography. Mp: uncorr. Elemental analyses were performed by Galbraith Laboratory of Knoxville, TN.

Biological testing using an agar media was performed as reported earlier [9] using the white-rot fungus *Coriolus versicolor* (L.) (Quél.), and the brown-rot fungi *Poria placenta* (Fr.) Cook, and *Gloeophyllum trabeum* (Pres, ex Fires) Murr. Agar plate concentrations for the brown-rot fungi were 3, 6, 15, 30 and 60 ppm, and were 10, 25, 50, 100 and 200 ppm for the white-rot fungus. Five replicates were run on each fungus/compound/concentration combination. The soil block test was run using ASTM method D1413, but with 14-mm cubes of southern yellow pine sapwood used rather than 19-mm cubes. The blocks were treated with Me_2CO solns so that all samples could be examined using one solvent system. Me_2CO, however, gave poor results with DDAC when compared to DDAC–H_2O. Five replicates were run on each concn and these were incubated with *G. trabeum* for eight weeks.

(E)-4-(2-*phenylethenyl*)*Phenol* (1). Mp 187–188° [9].

(E)-4-[2-(3-*methylphenyl*)*ethenyl*]*Phenol* (2). Mp 135–136° [9].

(E)-4-[2-(3-*hydroxyphenyl*)*ethenyl*]*Phenol* (3). Mp 210–211° (lit. [15] no melting point listed). ^1H NMR ($CDCl_3$): δ6.81 to 7.41 (*m*, Ar–OH, Ar–H and –CH=CH–). Found: C, 78.55%; H, 5.60%. $C_{14}H_{12}O_2$ requires: C, 79.22%; H, 5.70%. UV λ_{max}^{MeOH} ($\log \varepsilon_{max}$) 318 nm (4.444) IR ν_{max}^{KBr} cm^{-1}: 1602, 1582 and 1512 (Ar bending), 1253 and 1160 (Ar–O), 968 (*trans* RCH=CHR), 854 and 819 (1,3-disub. Ar). EIMS (probe) 70 eV, *m/z* (rel. int): 212 $[M]^+$ (100), 195 $[M-OH]^+$ (11).

(E)-4-[2-(3-*bromophenyl*)*ethenyl*]*Phenol* (4). Mp 130–133° (lit. [24] 132–134°).

(E)-4-[2-(3-*propoxyphenyl*)*ethenyl*]*Phenol* (5). Mp 103–104°.

^{1}H NMR ($CDCl_3$): δ1.05 (3H, *t*, Me), 1.84 (2H, *q*, Et), 3.96 (2H, *t*, $-OCH_2CH_2$), 6.80–7.41 (11H, *m*, Ar–OH and Ar–CH=CH–Ar). Found: C, 80.23%; H, 7.06%. $C_{17}H_{18}O_2$ requires: C, 80.29%; H, 7.13%. UV λ_{max}^{MeOH} ($\log\varepsilon_{max}$) 303 nm (4.783). IR ν_{max}^{KBr} cm^{-1}: 1594 and 1512 (Ar bending), 1239 (Ar–O), 969 (*trans* RCH=CHR), 844 and 687 (1,3-disub. Ar). EIMS (probe) 70 eV, *m/z* (rel. int.): 254 $[M]^+$ (22), 207 $[M-C_3H_7]^+$ (100).

(E)-4-[2-(3-*butoxyphenyl*)*ethenyl*]*Phenol* (**6**). Mp 96–98°. ^{1}H NMR ($CDCl_3$): δ0.98 (3H, *t*, Me), 1.50 (2H, *q*, Et), 1.78 (2H, *m*, $-CH_2CH_2CH_2-$), 4.00 (2H, *t*, $-OCH_2CH_2-$), 4.95 (Ar–OH), 6.77–7.26 (8H, *m*, Ar–H), 7.38 and 7.40 (2H, *s*, RCH=CHR). Found: C, 80.77%; H, 7.46%. $C_{18}H_{20}O_2$ requires: C, 80.56%; H, 7.51%. UV λ_{max}^{MeOH} ($\log\varepsilon_{max}$) 303 nm (4.763). IR ν_{max}^{KBr} cm^{-1}: 1593 and 1513 (Ar bending), 1244, 1240 and 1172 (Ar–O), 968 (*trans* RCH=CHR), 846 and 686 (1,3-disub. Ar). EIMS (probe) 70 eV, *m/z* (rel. int.): 268 $[M]^+$ (100), 212 $[M-C_4H_7]^+$ (59).

(E)-4-[2-(3-*methylphenyl*)*ethenyl*]*Phenol*, *dehydrogenative dimer* (**7**). Thick golden oil. ^{1}H NMR (Me_2CO-d_6): δ2.33 (*s*, Ar–CH_3), 2.34 (*s*, Ar–Me), 4.51 (*d*, benzyl C–H), 5.50 (*d*, benzyl C–H) 6.80–7.39 (*m*, Ar–H). Found: C, 84.00%, H, 7.59% $C_{30}H_{26}O_2$ requires C, 86.09%; H, 6.26%. [UV λ_{max}^{MeOH} ($\log\varepsilon_{max}$) 305 nm (4.392)]. IR ν_{max}^{KBr} cm^{-1} 1602, 1517, 1489 (Ar), 1448 (Ar–Me), 1236 (Ar–O), 961 *trans* C=C, 812, 777 (Ar–H).

4-(2-*phenylethyl*)*Phenol* (**8**). Mp 99–100° [9].

4-[2-(4-*chlorophenyl*)*ethyl*]*Phenol* (**9**). Mp 114–116° (lit. [25] 107–109°).

4-[2-(3,4-*dichlorophenyl*)*ethyl*]*Phenol* (**10**). Mp 59 60° (after sublimation). ^{1}H NMR ($CDCl_3$): δ2.82 (4H, *s*, $-CH_2CH_2-$), 6.74–7.33 (8H, *m*, Ar–H + Ar–OH). Found: C, 63.68%; H, 4.64%. $C_{14}H_{12}Cl_2O$ requires: C, 62.94%; H, 4.53%. UV λ_{max}^{MeOH} ($\log\varepsilon_{max}$): 279 nm (3.302). IR ν_{max}^{KBr} cm^{-1}: 1590, 1510 and 1473 (Ar bending), 1228 (Ar–O), 830 (1,3,4-trisub. Ar). EIMS (probe) 70 eV, *m/z* (rel. int.): 268 $[M+1]^+$ (2.9), 266 $[M-1]^+$ (4.5), 161 $[(M+1)-107]^+$ (2.6), 159 $[(M-1)-107]^+$ (3.9), 108 $[(M+1)-160]^+$ (9.7), 107 $(M-160)^+$ (100).

4-[2-(3-*methoxyphenyl*)*ethyl*]*Phenol* (**11**). Mp 35°. (lit. [26] bp 145–150°/1 mtorr). ^{1}H NMR ($CDCl_3$): δ2.84 (4H, *s*, $-CH_2CH_2-$), 3.77 (3H, *s*, –OMe), 4.87 (1H, *s*, –OH), 6.71–7.19 (8H, *m*, Ar). Found: C, 78.96%; H, 7.16%. $C_{15}H_{16}O_2$ requires C, 78.92%; H, 7.07%. UV λ_{max}^{MeOH} ($\log\varepsilon_{max}$): 276 nm (3.512). IR ν_{max}^{KBr} cm^{-1}: 1610, 1601, 1584 and 1514 (Ar bending), 1259 (Ar–O), 1049 (Ar–OMe), 827 (1,3-disub. Ar). EIMS (probe) 70 eV, *m/z* (rel. int.): 228 $[M]^+$ (15), 121 $[M-107]^+$ (9.5), 107 $[M-121]^+$ (100).

4-[2-(3-*methylphenyl*)*ethyl*]*Phenol* (**12**). Mp 52–54°. ^{1}H NMR ($CDCl_3$): δ2.32 (3H, *s*, Me), 2.83 (4H, *s*, $-CH_2CH_2-$), 4.71 (1H, *s*, –OH), 6.73–7.16 (8H, *m*, Ar). Found: C, 84.92%; H, 7.63%. $C_{15}H_{16}O$ requires: C, 84.88%; H, 7.60%. UV λ_{max}^{MeOH} ($\log\varepsilon_{max}$): 276 nm (3.225). IR ν_{max}^{KBr} cm^{-1}: 1690, 1515 and 1456 (Ar bending), 1245 (Ar–O), 826 (1,3-disub. Ar). EIMS (probe) 70 eV, *m/z* (rel. int.): 212 $[M]^+$ (20), 107 $[M-105]^+$ (100).

4-[2-(4-*methoxyphenyl*)*ethyl*]*Phenol* (**13**). Mp 123–124° [9].

4-[2-(3,4-*dimethoxyphenyl*)*ethyl*]*Phenol* (**14**). Mp 106–107° (lit. [26] 108–111°).

4-[2-(3-*fluorophenyl*)*ethyl*]*Phenol* (**15**). Mp 65–66°. ^{1}H NMR ($CDCl_3$): δ2.85 (4H, *s*, $-CH_2CH_2-$), 4.66 (1H, *s*, –OH), 6.73–7.25 (8H, *m*, Ar). Found: C, 77.79%; H, 6.08%. $C_{14}H_{13}FO$ requires: C, 77.76%; H, 6.06. UV λ_{max}^{MeOH} ($\log\varepsilon_{max}$): 271 nm (3.310). IR ν_{max}^{KBr} cm^{-1}: 1611, 1587 and 1512 (Ar bending, 1235 (Ar–O), 824 and 795 (1,3-disub. Ar). EIMS (probe) 70 eV, *m/z* (rel. int.): 217 $[M+1]^+$ (2), 216 $[M]^+$ (14.1), 109 $[M-107]^+$ (11.5), 108 $[(M+1)-109]^+$ (10.4), 107 $[M-109]^+$ (100).

4-[2-(3-*hydroxyphenyl*)*ethyl*]*Phenol* (**16**). Mp 106.5–108° (lit. [15] 106–108°).

4-[2-(3-*chlorophenyl*)*ethyl*]*Phenol* (**17**). Bp 146°/5 mtorr. ^{1}H NMR: δ2.82 (4H, *s*, $-CH_2CH_2-$), 5.12 (1H, *s*, –OH), 6.72–7.17 (*m*, 8H, Ar). Found: C, 71.84%; H, 5.66%. $C_{14}H_{13}ClO$ requires: C, 72.26%; H, 5.63%. UV λ_{max}^{MeOH} ($\log\varepsilon_{max}$): 275 nm (3.296). IR ν_{max}^{KBr} cm^{-1}: 1607, 1587 and 1513 (Ar bending), 1228 (Ar–O), 827 (1,3-disub. Ar). EIMS (probe) 70 eV, *m/z* (rel. int.): 232 $[M]^+$ (6), 125 $[M-107]^+$ (5.5), 108 $[M-126]^+$ (8), 107 $[M-125]^+$ (100).

4-[2-(3-*bromophenyl*)*ethyl*]*Phenol* (**18**). Bp 152°/5 mtorr. ^{1}H NMR ($CDCl_3$): δ2.81 (4H, *s*, $-CH_2CH_2-$), 4.99 (1H, *s*, –OH), 6.70–7.32 (8H, *m*, Ar). Found: C, 61.26%; H, 4.36%. $C_{14}H_{13}BrO$ requires: C, 60.67%; H, 4.73%. UV λ_{max}^{MeOH} ($\log\varepsilon_{max}$): 274 nm (3384). IR ν_{max}^{Film} cm^{-1}: 1612, 1596 and 1513 (Ar bending), 1230 (Ar–O), 826 and 785 (1,3-disub. Ar). EIMS (probe) 70 eV, *m/z* (rel. int.): 278 $[M+1]^+$ (21), 277 $[M]^+$ (3), 276 $[M-1]^+$ (22), 171 $[(M+1)-107]^+$ (10), 169 $[(M-1)-107]^+$ (11), 107 $[M-170]^+$ (100).

4-[2-(4-*fluorophenyl*)*ethyl*]*Phenol* (**19**). Mp 104–105°. Yield 86% from corresponding stilbene. ^{1}H NMR ($CDCl_3$): δ2.83 (4H, *s*, CH_2CH_2-), 6.72–7.10 (9H, *m*, Ar–H + Ar–OH). Found: C, 77.79%; H, 6.06%. $C_{14}H_{13}FO$ requires: C, 77.76%; H, 6.06%. UV λ_{max}^{MeOH} ($\log\varepsilon_{max}$): 272 nm (3.342). IR ν_{max}^{KBr} cm^{-1}: 1612, 1598 and 1506 (Ar bending), 1220 (Ar–O), 832 (1,4-disub. Ar). EIMS (probe) 70 eV, *m/z* (rel. int.): 216 $[M]^+$ (8.82), 107 $[M-109]^+$ (100).

1-*Methoxy*-4-(2-*phenylethyl*)*benzene* (**20**). Mp 57–58° (lit. [27] 63°).

Didecyldimethylammonium chloride (**21**). 80% soln. Marketed under trade name Bardac 2280, obtained from Lonza Chemical Co.

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