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NEW NAPHTHOQUINONES FROM *DIOSPYROS**

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Key Word Index—*Diospyros ferrea* var. *buxifolia*; *D. maritima*; Ebenaceae; hydroxyisodiospyrin; maritinone; isoshinanolone; naphthoquinones.

Abstract—7-Methyljuglone (I), isodiospyrin (II), the 2,2′-binaphthyl-1,1′-quinone (III), and a new quinone (IV), hydroxyisodiospyrin, were isolated from the roots of *D. ferrea* var. *buxifolia*. The structure of IV was elucidated as an 8′-hydroxy derivative of isodiospyrin. From the roots of *D. maritima* plumbagin (V), elliptinone (VI), a new quinone maritinone (VII), and a new tetralone isoshinanolone (VIII) were isolated. Maritinone (VII) was shown to be the 8,8′-dimer of plumagin, and (VIII) is *cis*-4,8-dihydroxy-3-methyl-1-tetralone. The naphthoquinones of the genus *Diospyros* are briefly reviewed.

INTRODUCTION

THE GENUS *Diospyros* (Ebenaceae) is a rich source of naphthols and naphthoquinones.[1–5] In previous papers[6–9] we have reported on the constituents of 6 species of the genus. In this paper, further work on the constituents of two of these species is described.

RESULTS AND DISCUSSION

Diospyros ferrea (Willd.) Bakh. var. *buxifolia* (Rottb.) Bakh. (syn. *Maba buxifolia* Pers.) (Japanese name, yaeyamakokutan, kuroki, ryukyukokutan) is a shrub growing in south-east Asia.[10] Although the stem and the leaves have been proved to contain triterpenoids,[11] the naphthoquinones of the plant have not been reported.

The chloroform extract of the dried roots afforded, after chromatographic separation,

* A part of the work has been reported in the preliminary communication [*Chem. Pharm. Bull. Tokyo* **19**, 851 (1971)]. Part V in the series "Naphthoquinone Derivatives from the Ebenaceae". For Part IV see Ref. 9.

[1] R. HEGNAUER, *Chemotaxonomie der Pflanzen*, Band 4, p. 45, Birkhäuser, Basel (1966).
[2] R. H. THOMSON, *Naturally Occurring Quinones*, 2nd Edn, Academic Press, London (1971).
[3] A. L. FALLAS and R. H. THOMSON, *J. Chem. Soc.* C, 2279 (1968); and references therein.
[4] S. H. HARPER, A. D. KEMP and J. TANNOCK, *J. Chem. Soc.* C, 626 (1970).
[5] G. S. SIDHU and K. K. PRASAD, *Tetrahedron Letters* 1739 (1970); and references therein.
[6] K. YOSHIHIRA, M. TEZUKA, P. KANCHANAPEE and S. NATORI, *Chem. Pharm. Bull. Tokyo* **19**, 2271 (1971); K. YOSHIHIRA, S. NATORI and P. KANCHANAPEE, *Tetrahedron Letters* 4857 (1967).
[7] K. YOSHIHIRA, M. TEZUKA and S. NATORI, *Chem. Pharm. Bull. Tokyo* **19**, 2308 (1971); K. YOSHIHIRA, M. TEZUKA and S. NATORI, *Tetrahedron Letters* 7. (1970).
[8] M. KUROYANAGI, K. YOSHIHIRA and S. NATORI, *Chem. Pharm. Bull. Tokyo* **19**, 2314 (1971).
[9] M. TEZUKA, M. KUROYANAGI, K. YOSHIHIRA and S. NATORI, *Chem. Pharm. Bull. Tokyo* **20**, 2029 (1972).
[10] H. HARA, *Enumeratio Spermatophytarum Japonicarum*, Vol. 1, p. 100, Iwanami, Tokyo (1948).
[11] D. S. BHAKUNI, S. SATISH, Y. N. SHUKLA and J. S. TANDON, *Phytochem.* **10**, 2829 (1971).

four naphthoquinones, 7-methyljuglone (I), isodiospyrin (II),[3,5,7] the 2,2'-binaphthyl-1,1'-quinone (III),[9,12] and a new red quinone (IV), m.p. 275–277°, besides crusgallin (sawamilletin, taraxerol 3-methyl ether), betulinic acid and sitosterol. Although crusgallin occurs widely in the grasses,[13] this is the first report of its occurrence in another family; in general, triterpene methyl ethers rarely occur outside the Gramineae.

The new quinone (IV) m.p. 275–277°, $[\alpha]_D^{23}$ −720° (dioxane), showed a characteristic UV ($\lambda_{max}^{CHCl_3}$ 253, 300, 434, 460, 484, 514, 554 nm) (Fig. 1) and IR (ν_{max}^{KBr} 1670 (sh), 1640, 1600 cm^{-1}).

TABLE 1. NMR SPECTRA OF THE NAPHTHOQUINONES*

Compound	2- and 2'-Me or H	3- and 3'-H	5- and 5'-OH or OMe	6- and 6'-H	7- and 7'-Me or H	8- and 8'-H, OH or OMe
7-Methyljuglone (I)	6·98 (1H) *s*	6·98 (1H) *s*	11·91 (1H) *s*	7·14 (1H) *d*, *J* 1·5	2·36 (3H) *s*	7·50 (1H) *d*, *J* 1·5
Isodiospyrin (II)	6·77 (1H)† *d*, *J* 10	6·94 (1H)† *d*, *J* 10	12·12 (1H) *s*	7·35 (1H) *s*	2·05 (3H) *s*	—
Hydroxyisodiospyrin (IV)	6·98 (1H) *s*	6·98 (1H) *s*	12·50 (1H) *s*	—	2·02 (3H) *s*	7·67 (1H) *s*
Hydroxyisodiospyrin trimethyl ether (IV')	6·71 (1H)† *d*, *J* 10	6·90 (1H)† *d*, *J* 10	12·35 (1H)† *s*	‡	2·18 (3H) *s*	—
Plumbagin (V)	1·85 (3H) *s*	—	12·22 (1H)† *s*	‡	‡	12·18 (1H)† *s*
Maritinone (VII)	6·55 (1H)† *d*, *J* 10	6·70 (1H)† *d*, *J* 10	3·99 (3H)† *s*	§	2·21 (3H) *s*	—
Maritinone dimethyl ether (VII')	1·72 (3H) *s*	—	3·94 (3H)† *s*	§	§	3·85 (3H)† *s*
	2·13 (3H) *d*, *J* 1·5	6·66 (1H) *q*, *J* 1·5	11·73 (1H) *s*	7·07 (1H) *dd*	7·39 (1H) *dd*	7·47 (1H) *dd*
	1·99 (6H) *d*, *J* 1·5	6·76 (2H) *q*, *J* 1·5	12·36 (2H) *s*	7·10 (2H)† *d*, *J* 9	7·19 (2H)† *d*, *J* 9	—
	1·91 (6H) *d*, *J* 1·5	6·65 (2H) *q*, *J* 1·5	3·99 (6H) *s*	7·14 (2H)† *d*, *J* 9	7·23 (2H)† *d*, *J* 9	—

* δ in ppm from the internal standard TMS in $CDCl_3$ at 60 MHz. Coupling constant in Hz.
† The alternative assignment might be possible.
‡ δ 7·3 (3H, *m*).
§ δ 7·2 (3H, *m*).

Treatment of the quinone with methyl iodide–silver oxide gave the trimethyl ether (IV'), IR ν_{max}^{KBr} 1650, 1580 cm^{-1}, the MS of which showed the molecular formula $C_{25}H_{20}O_7$ (M^+ 432·115 *m/e*, Calcd. 432·120). NMR spectra of IV and IV' (Table 1) showed the presence of one quinonoid methyl, one aromatic methyl, two quinonoid protons, three aromatic protons, and three hydrogen-bonded hydroxyls in IV.[6–9] Since the UV spectrum of IV is nearly the same as that of 7-methyljuglone (I) superimposed on that of 2-methylnaphthazarin,[14*] a dimeric structure based on two naphthoquinone units became plausible for the new quinone (IV). The two quinonoid protons resonate as an *AB* quartet as observed for 7-methyljuglones with a bulky group at 8-position,[7,9] while the absence of the allylic

* The quinone has been isolated from the roots of *Euclea lanceolata* E. Mey ex Dc. (Ebenaceae) [A. CORREIA ALVES, Á. C. COSTA and M. A. FERREIRA, *Garcia de Orta Lisboa* **17**, 299 (1969)].

[12] O. C. MUSGRAVE and D. SKOYLES, *Chem. Commun.* 1461 (1970).
[13] T. OHMOTO, MI IKUSE and S. NATORI, *Phytochem.* **9**, 2137 (1970).
[14] A. K. MACBETH, J. R. PRICE and F. L. WINZOR, *J. Chem. Soc.* 325 (1935); G. BENDZ and G. LINDBERG, *Acta Chem. Scand.* **22**, 2722 (1968).

coupling in the quinonoid methyl group suggests that 3-position in the other unit is occupied by a substituent (Table 1). Thus structure IV in which the 8-position of 7-methyljuglone is linked to the 3-position of 2-methylnaphthazarin is proposed. Although the NMR spectrum of IV showed that the double bonds in the naphthazarin nucleus are fixed as shown in the structure (IV),[15] the structure corresponds to a tautomer of an 8′-hydroxy derivative of isodiospyrin (II). In order to confirm this structure, hydroxylation of II was attempted using several oxidizing agents; hydrogen peroxide in acetic acid afforded a hydroxyl derivative, in very low yield, identical with the natural product.*

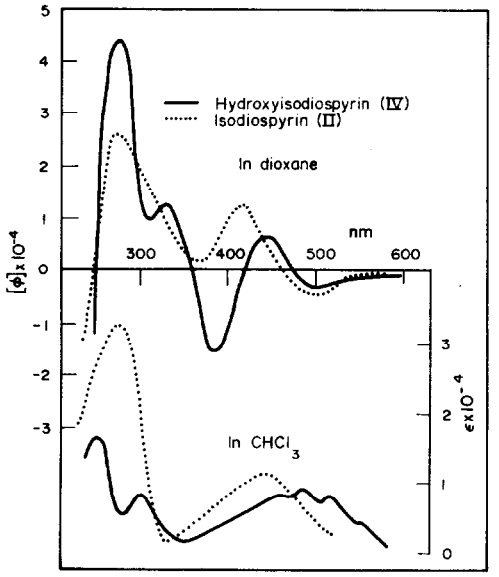


FIG. 1. UV AND ORD CURVES OF ISODIOSPYRIN (II) AND HYDROXYISODIOSPYRIN (IV).

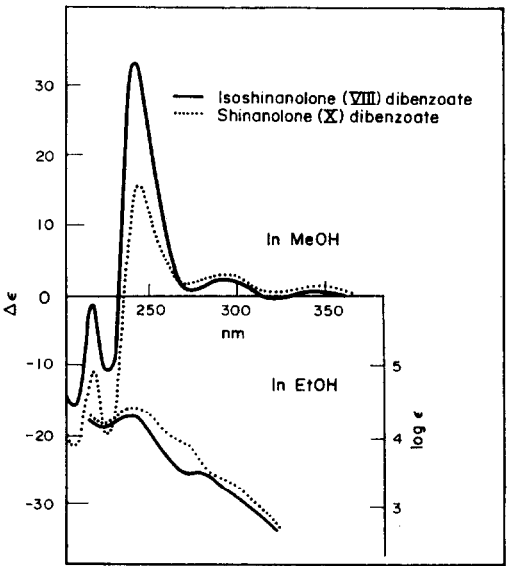


FIG. 2. UV AND CD CURVES OF THE DIBENZOATES OF SHINANOLONE AND ISOSHINANOLONE.

Although present knowledge of the correlation of the ORD curves with absolute configurations of the atropisomers of binaphthyls is limited,[16] the curves shown in Fig. 1 indicate that 8′-hydroxyisodiospyrin (IV) has the same absolute configuration as that of isodiospyrin (II).

Diospyros maritima Blume (Japanese name, kurobo, ryukyugaki) is a shrub growing in south-east Asia. From the bark of the plant the isolation of plumbagin (V) and scopoletin has already been reported.[17] Chromatographic separation of the chloroform extract of the dried roots afforded plumagin (V), elliptinone[3,6] (VI), a new quinone m.p. 193–195° (VII), and a new tetralone (VIII) m.p. 160° (decomp.), $[\alpha]_D^{18}$ −7° ($CHCl_3$), besides scopoletin and three triterpenoids, lupeol, betulin and betulinic acid.

* A quinone, $C_{22}H_{14}O_7$, was isolated from *D. virginiana* and suggested to be a hydroxyisodiospyrin,[3] but the compound has different physical properties from IV.

[15] R. E. MOORE and P. J. SCHEUER, *J. Org. Chem.* **31**, 3272 (1966).
[16] K. MISLOW, M. A. W. GLASS, R. E. O'BRIEN, P. PUTKIN, D. STEINBERG and C. DJERASSI, *J. Am. Chem. Soc.* **82**, 4740 (1960); S. YAMADO and H. ARIMOTO, *Tetrahedron Letters* 3967 (1968).
[17] TH. M. MEYER, *Rec. Trav. Chim.* **66**, 193 (1947).

The new quinone (VII) is orange–red and has a molecular formula of $C_{22}H_{14}O_6$ (M^+ 374·076 *m/e*. Calcd. 374·079). The UV (λ_{max}^{EtOH} 264, 436 nm) and IR (ν_{max}^{KBr} 1647 cm^{-1}) spectra were characteristic for juglone derivatives. It formed a dimethyl ether (VII'). The NMR spectra of VII and VII' (Table 1) suggested that the quinone (VII) is a symmetrical dimer, each half molecule containing a vinyl proton coupled allylically to a methyl group, a hydrogen bonded hydroxyl, and a pair of *o*-coupled aromatic protons. Thus the dimer must be 6,6'- or 8,8'-dimer of 2-methyl- or 3-methyljuglone, since the 6,6'-dimer of 2-methyljuglone (elliptinone) (VI) is excluded on basis of nonidentity. The rather high chemical shifts of the signals of the two aromatic protons indicate their presence at the β-position. Only structures such as 8,8'-dimers of 2-methyl (VII) and 3-methyljuglone (IX) are consistent with these data, the former being favoured by analogy with the congeners. The latter (IX) was eliminated by reduction of the dimer with sodium dithionite,[18] which afforded plumbadin (V). Thus the structure (VII) as an 8,8'-dimer of plumbagin was established. The new quinone was named maritinone, and is the third example of a plumbagin dimer.[3,6,19]

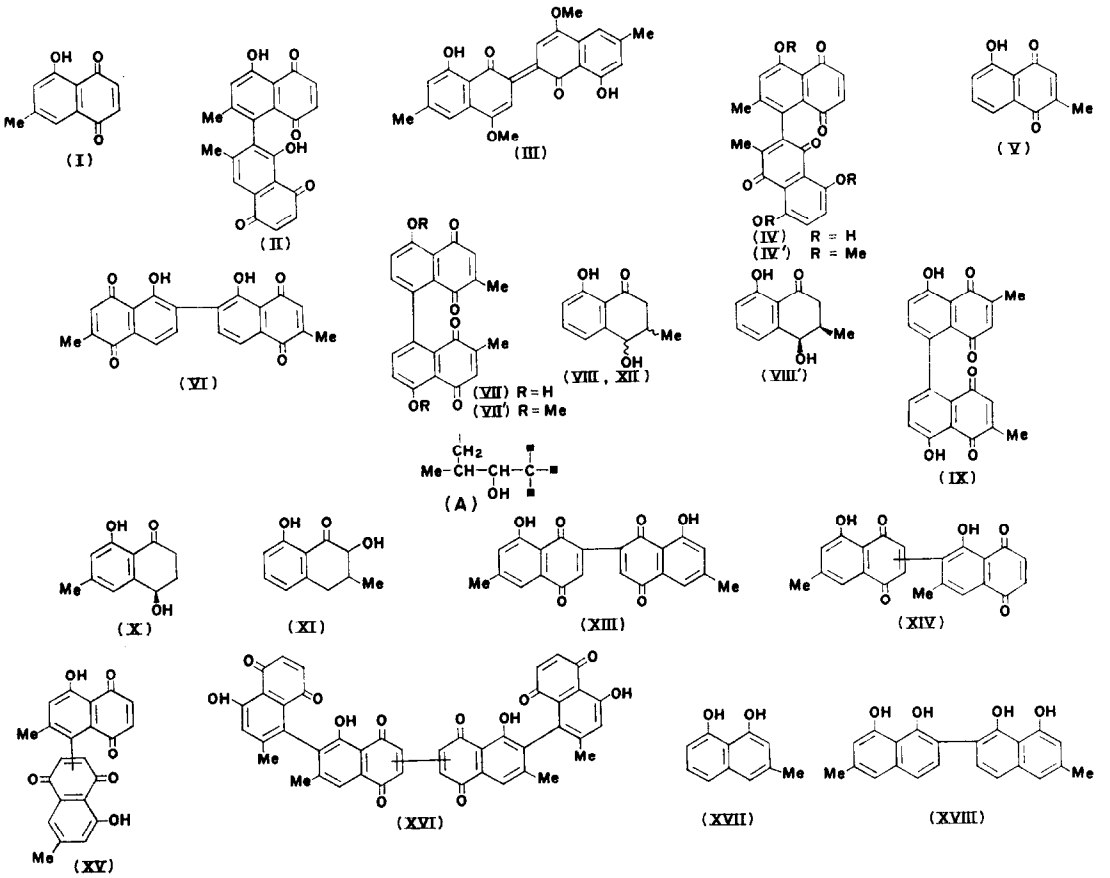
The new tetralone (VIII) is a colorless compound of molecular formula $C_{11}H_{12}O_3$ (M^+ 192·076 *m/e*. Calc. 192·079). The UV spectrum of VIII [λ_{max}^{EtOH} 261·334 nm (log ϵ 3·96, 3·64)] is similar to that of shinanolone (X) isolated from *D. japonica*[8] and *D. kaki* var. *sylvestris*[9] and the presence of the same *o*-hydroxyacylophenone unit in the molecule was further supported by IR ($\nu_{C=O}$ 1643 cm,$^{-1}$ the dibenzoate, $\nu_{C=O}$ 1693 cm^{-1}) and NMR [δ 12·19 (1H, *s*)]. Besides the hydrogen-bonded hydroxyl group, there exists a secondary hydroxyl probably at the benzylic position (ν_{O-H} 3300 cm,$^{-1}$ δ 2·18 (1H, exchangeable with D_2O), δ 4·65 (1H, *d*, *J* 2·5 Hz)) [the dibenzoate, δ 6·27 (1H, *d*)]. The NMR spectrum also suggested the presence of a secondary methyl [δ 1·13 (3H, *d*, *J* 6 Hz)], three methine and methylene protons (δ 2·2–3·2), and three aromatic protons on a 1,2,3-trisubstituted benzene (δ 6·7–7·4). The spin-decoupling experiments performed at the methyl and the methine proton simplified the coupling pattern of the overlapping signals of the three methine and methylene protons, while the both doublet signals of the methyl and the methine proton collapsed to singlets by the irradiation at the methine proton (δ 2·45) thus revealed. These results indicate partial formula (A); only structures VIII and XI are consistent with these findings. The former was assumed to be the more likely on biogenetic grounds. Distinction between the two was performed as follows. Chromium trioxide oxidation of the tetralone afforded plumbagin (V) in a good yield. Thus the structure as 4,8-dihydroxy-3-methyl-1-tetralone (VIII) was established and the compound was named isoshinanolone.

In the case of shinanolone (X), $LiAlH_4$ reduction of 7-methyljuglone (I) afforded the racemate of X but the same treatment of plumbagin (V) afforded the compound assumed to be the racemate of the diastereoisomer (XII) of VIII due to the stereospecific control of the methyl group. In XII the methyl and the hydroxy are expected to be *trans* (the hydroxyl is pseudo-equatorial and the methyl is equatorial).[20] Actually the coupling constant of the carbinyl proton at C-4 of the natural product (VIII) with the methine proton at C-3 is *J* 2·5 Hz, while that of XII 7·5 Hz. The chemical shift of the C-4 proton in VIII (δ 4·65) appears at a lower field than that in XII (δ 4·44), suggesting the existence of the proton in

[18] S. SHIBATA, T. MURAKAMI, I. KITAGAWA and T. KISHI, *Chem. Pharm. Bull. Tokyo* **4**, 111 (1956).
[19] G. S. SIDHU and A. V. B. SANKARAN, *Tetrahedron Letters* 2385 (1971).
[20] E. TOROMANOFF, *Topics in Stereochemistry* (edited by N. ALLINGER and E. L. ELIEL), Vol. II, p. 157. Interscience, New York (1967).

pseudo-equatorial, half-chair conformation. These observations suggest that the methyl and the hydroxyl in VIII are *cis* (the methyl is equatorial and hydroxyl is pseudo-axial).

The conformational dissymmetry rule cannot be safely applied to the phenylalkylcarbinols.[21] In the case of shinanolone (X), application of the aromatic chirality method[22] was attempted for the dibenzoate, though there exist some limitation in the presence of the benzophenone chromophore.[8] As shown in Fig. 2 the CD curves of the dibenzoate of VIII showed strong Cotton effects ($\Delta\epsilon_{240}$ + 33, $\Delta\epsilon_{225}$ − 11) quite similar to the dibenzoate of X, the first positive effect indicating a positive chirality in the dibenzoate as far as the application of the method is tenable. If so, the absolute configuration at C-4 is assigned as *R* and, thence, that at C-3, *R* and the absolute configuration of VIII will be expressed by the formula VIII'.



In the present series of papers, we have studied the naphthoquinones of the genus *Diospyros*[6-9] including dimers such as isodiospyrin (II), elliptinone (VI), maritinone (VII), mamegakinone (XIII),[6,7] diospyrin (XIV),[9] and neodiospyrin (XV)[9] and the tetramer, bisisodiospyrin (XVI).[7] Recent reports concerning the formation of quinone dimers and

[21] J. H. BREWSTER, *Tetrahedron* **13**, 106 (1961).

[22] N. HARADA and K. NAKANISHI, *J. Am. Chem. Soc.* **91**, 3989 (1969); N. HARADA and K. NAKANISHI and S. TATSUOKA, *J. Am. Chem. Soc.* **91**, 5896 (1969); N. HARADA and K. NAKANISHI, *Chem. Commun.* 310 (1970); N. HARADA, H. SATO and K. NAKANISHI, *Chem. Commun.* 1691 (1970); S. MARUMO, N. HARADA, K. NAKANISHI and T. NISHIDA, *Chem. Commun.* 1693 (1970).

cyclic trimers from corresponding monomers in base[23] and in alumina[24] suggested the possibility of the formation of the dimers and the tetramer as artefacts. Indeed, when isodiospyrin (II) was refluxed with silica gel in methanol for 20 hr or was absorbed on alumina and then eluted by methanol or methanolic HCl, formation of the dimer, bisisodiospyrin (XVI), was noticed though in a low yield. Under the same conditions, 7-methyljuglone (I) formed 2-methoxy-[9] and 3-methoxy-7-methyljuglone[9] and mamegakinone (XIII), again in a low yield. However under the conditions employed for the extraction and the separation, such as refluxing in $CHCl_3$ for a long time or leaving in silica gel column for more than 70 days, no sign of dimerization was observed for 7-methyljuglone (I) or for isodiospyrin (II).

For further confirmation the dried roots of *Diospyros lotus*,[7] *D. japonica*,[8] and *D. morrisiana*[7] were reexamined employing benzene, chloroform and methanol for the extraction and the extracts were immediately compared by TLC with all the compounds so far isolated as standards. The results clearly excluded the possibility that the dimers and tetramer were formed in the course of isolation.

TABLE 2. DISTRIBUTION OF NAPHTHOQUINONES IN THE ROOTS OF *Diospyros* SPECIES GROWING IN JAPAN*

Species compound	*D. ferrea* var. *buxifolia*	*D. japonica*[8]	*D. kaki*[9]	*D. kaki* var. *sylvestris*[9]	*D. lotus*[7]	*D. maritima*	*D. morrisiana*[7]
7-Methyljuglone (I)	+	+	+	+	+		
Isodiospyrin (II)	+	+	+	+	+		+
4,4′-Dimethoxy-6,6′-dimethyl-8,8′-dihydroxy-2,2′-binaphthyl-1,1′-quinone (III)	+	±	±	+	±		
Hydroxyisodiospyrin (IV)	+						
Mamegakinone (XIII)		±	+	+	+		
Diospyrin (XIV)			+		±		
Neodiospyrin (XV)			+		±		
Bisisodiospyrin (XVI)		+			+		+
Plumbagin (V)			+			+	
Elliptinone (VI)						+	
Maritinone (VII)						+	
Shinanolone (X)		+	±	+	±		
Isoshinanolone (VIII)						+	

* ± indicates those detected by TLC.

The distributions of naphthoquinones in the roots of Japanese *Diospyros* species are summarized in Table 2. It should be noticed that 7-methyljuglone (I), its dimers (II, III, XIII, XIV, and XV) and the tetramer (XVI) are rather widely distributed accompanying the tetralone (X), except in the case of *D. maritima*, in which plumbagin (V) and its dimer (VI and VII) along with the corresponding tetralone (VIII) occur.*

* The species belongs to section *Patonia* and is morphologically distinct from other species in the genus.

[23] H. BROCKMAN, H. GREVE and K. HOYERMANN, *Tetrahedron Letters* 1493 (1971); H. BROCKMANN, H. GREVE and W. WALDMÜLLER, *Chem. Ber.* **104**, 1436 (1971); K. CHANDRASENAN and R. H. THOMSON, *Tetrahedron* **27**, 2529 (1971).

[24] H. KOJIMA, T. TAKAHASHI, N. KIDA, K. KOKETSU, H. NAWA, T. TSUGE, M. NAIKI and N. KINOMURA, *Nihon Kagaku Zasshi* **92**, 349 (1971).

More than thirty naphthols and naphthoquinones have so far been isolated from more than twenty species of the genus.[1–9] All these compounds have a common feature in their structures and are assumed to be derived from 1,8-dihydroxy-3-methylnaphthalene[25] (XVII) or the biogenetic equivalent. The first step in the modifications from XVII is assumed to be hydroxylation at the 2-, 4-, 5- or 7-position. Dimerization also occurs at 2, 4, 5 or 7 position of XVII,* though there exists no evidence whether this step occurs at the naphthol stage or after oxidation to quinone monomers. Diospyrol[6] (XVIII) isolated from the fresh berries of *D. mollis* is the only example of a naphthol dimer. As far as the formation of optically active unsymmetrical dimers such as isodiospyrin (II) and hydroxyisodiospyrin (IV) is concerned, the step is assumed to be enzymatic.

Since the roots of these plants are faintly colored just after digging and turn yellow while cutting and drying, most of these quinones probably exist in the living plants as naphthols. A typical example is the fruit of *D. mollis*; fresh fruits afford diospyrol (XVIII) exclusively while dried fruits contain mamegakinone (XIII) and elliptinone (VI) instead.[6] Formation of black pigments is also typical phenomenon in the genus but the mechanism of the formation is assumed to be complicated.[6]

Four pathways have been described for the biosynthesis of naphthoquinones in higher plants.[26,27] The structural features of the naphthol and naphthoquinone derivatives of the genus *Diospyros* clearly suggest that they are formed from acetate-polymalonate units and the occurrence of the tetralones (X and VIII) gives further support for this pathway in *Diospyros*.

EXPERIMENT

M.ps were determined in a Yanagimoto apparatus and not corrected. For column chromatography silica gel (Mallinckrodt) was used and for TLC Silicagel G was used unless otherwise specified. For acid treatment of silica gel, 3% oxalic acid solution was used.

Extraction of Diospyros ferrea *var.* buxifolia. The dried roots (3·2 kg) collected at Naze, Kagoshima, in November 1969 were immersed in $CHCl_3$ for 3 months. The extract (17 g) was chromatographed on a column of silica gel (2·0 kg). The graduent elution with benzene–EtOAc afforded the following fractions, each of which was examined by TLC and the column and preparative TLC were repeated until it was pure. In the case of known compounds they were compared with authentic samples by the conventional methods.† (i) Crusgallin (sawamilletin), colorless needles (28 mg) from $CHCl_3$, m.p. 269–270°. IR ν_{max}^{KBr} 2950, 1470, 1390, 1375, 1185, 1110, cm.$^{-1}$ NMR δ (in $CDCl_3$) 0·76–1·06 (24 H), 2·64 (1H, *dd*), 3·32 (3H, *s*), 5·5 (1H, *dd*). (ii) 4,4′-Dimethoxy-6,6′-dimethyl-8,8′-dihydroxy-2,2′-binaphthyl-1,1′-quinone (III), m.p. > 300°, blue needles (51 mg) from $CHCl_3$. (iii) 7-Methyljuglone (I), orange-red needles (49 mg) m.p. 120–121° from hexane. (iv) Sitosterol, m.p. 127–129° (13 mg) from EtOH. (v) 8′-*Hydroxyisodiospyrin* (IV), dark red needles (37 mg) m.p. 275–277° from benzene, $[\alpha]_D^{23}$ −720° (*c*, 0·10, dioxane). UV $\lambda_{max}^{CHCl_3}$ 253, 300, 434, 460, 484, 514, 554 nm (log ϵ 4·24, 3·93, 3·84, 3·92, 3·91, 3·90, 3·66). IR ν_{max}^{KBr} 3400, 1670 (sh), 1640, 1600, 1450, 1285, 1205 cm^{-1}. NMR (Table 1). (vi) Isodiospyrin (II), orange-red needles (1·3 g) m.p. 229–230° from benzene. (vii) Betulinic acid, colorless needles (2·1 g) m.p. > 300° from MeOH.

8′-*Hydroxyisodiospyrin trimethyl ether* (IV′). The $CHCl_3$ solution (5·2 ml) of IV (100 mg) was refluxed with MeI (0·3 ml) and Ag_2O (0·37 g) for 7 hr and the reaction products were separated by preparative TLC (Silicagel H) using $CHCl_3$–Et_2O (3:2). Recrystallization from hexane gave yellow orange powder (20 mg) m.p. 122–123°. UV λ_{max}^{CHCl3} 280, 330, 420 nm (log ϵ 4·10, 3·53, 3·89). IR ν_{max}^{KBr} 1650, 1580, 1470, 1340, 1265, 1250 cm^{-1}. MS (*m/e*) 432·115 (M^+. Calc. for $C_{25}H_{20}O_7$: 432·120), 417 ($C_{24}H_{17}O_7$), 389 ($C_{23}H_{17}O_6$).

Synthesis of 8′-*Hydroxyisodiospyrin* (IV). Isodiospyrin (II) (200 mg) in HOAc (8 ml) was added with

* The linking positions at the quinone portions in XV and XVI have not been established. The evidence for the position in XIV [G. S. SIDHU and M. PARDHASARADHI, *Indian J. Chem.* **8**, 569 (1970)] seems to be insufficient.

† For spectral data of known compounds, see previous papers.[6–9]

[25] S. MONGKOLSUK and C. SDARWONVIVAT, *J. Chem. Soc.* 1533 (1965).
[26] R. DURAND and M. H. ZENK, *Tetrahedron Letters* 3009 (1971).
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H_2O_2 (30%, 1·2 ml) and then, after the addition of further amount of H_2O_2 (1·0 ml), refluxed for 25 min. After the addition of H_2O, the reaction mixture was refluxed again for 15 min. The precipitates were collected after cooling and passed through a column of silica gel in benzene employing benzene–Et_2O (40:1) as the eluent. The first zone afforded the product (IV) (2·4 mg), m.p. 277°, $[\alpha]_D$ −700° (*c*, 0·056, dioxane) from benzene and identified with the natural product by TLC, IR and ORD. From the second band, starting material (II) (106 mg) was recovered. Prolongation of the reaction to 50 min improved the yield, but much longer heating resulted in oxidative cleavage of the quinone ring (monitored by TLC). Attampts to improve the yield, including oxidation with persulfate is alkaline or Fremy's salt or reductive acetylation followed by CrO_3 oxidation, were not successful.

Extraction of D. maritima. The dried roots (3·0 kg) of *D. maritima*, collected at Okinoerabu Is., Kagoshima, in November 1969, were extracted with $CHCl_3$ for 4 months at room temp. The extract (50 g) was refluxed with benzene and the benzene-soluble fraction was chromatographed on a column of silica-gel. The following fractions were obtained by graduent elution with benzene–EtOAc. When necessary, column or preparative TLC was repeated. (i) Plumbagin (V), orange needles (8 mg) m.p. 73° from hexane. (ii) Lupeol, colorless needles (0·85 g) m.p. 215–216°. (iii) Sitosterol, colorless needles (8 mg) m.p. 132–133° from MeOH–$CHCl_3$. (iv) Elliptinone (VI), orange–red needles (0·35 g) m.p. 300–305° (decomp.) from $CHCl_3$. (v) *Maritinone* (VII), red needles (40 mg) from hexane–benzene, m.p. 193–195°. UV λ_{max}^{EtOH} 264, 436 nm (log ϵ 4·42, 3·87). IR ν_{max}^{KBr} 1656 (sh), 1647, 1614, 1455, 1360, 1320, 1216, 1026, 900, 782 cm^{-1}. NMR (Table 1). MS (*m/e*) 374·076 (M^+. Calcd. for $C_{22}H_{14}O_6$: 374·079), 346 ($C_{21}H_{14}O_5$), 331 ($C_{20}H_{11}O_5$), 317 ($C_{20}H_{13}O_4$), 303 ($C_{19}H_{11}O_4$), 287 ($C_{17}H_{10}O_4$), 250 ($C_{16}H_{10}O_3$). (vi) *Isoshinanolone* (VIII), colorless crystals (46 mg), decomp. at 160°, sublime at 230° and melt completely at 255°, $[\alpha]_D^{18}$ −7° (*c*, 0·078, $CHCl_3$). UV λ_{max}^{EtOH} 261, 334 nm (log ϵ 3·96, 3·64). IR ν_{max}^{KBr} 3300, 2930, 1643, 1623, 1453, 1345, 1242, 1151, 1040, 1024, 980, 815, 796, 745 cm^{-1}. NMR δ (in $CDCl_3$) 1·13 (3H, *d*, *J* 6 Hz), 2·18 (1H, *s*, exchangeable with D_2O), 2·2–3·2 (3H, *m*), 4·65 (1H, *d*, *J* 2·5 Hz), 6·80 (2H, *dd*), 7·36 (1H, *dd*) (1,2,3-trisubstituted benzene), 12·19 (1H, *s*). MS (*m/e*): 192·076 (M^+. Calcd. for $C_{11}H_{12}O_3$: 192·079), 177 ($C_{10}H_9O_3$), 174 ($C_{11}H_{10}O_2$), 163 ($C_9H_7O_3$), 159 ($C_{10}H_7O_2$), 121 ($C_7H_5O_2$). (vii) Betulin, (viii) betulinic acid, and (ix) scopoletin were further purified with those obtained from the benzeneisoluble fraction (*vide infra*). The benzene-insoluble part of the $CHCl_3$ extract was refluxed with MeOH and the precipitates (420 mg) formed after cooling were filtered off. A part of the precipitate (30 mg) was treated with ethereal CH_2N_2 and the reaction mixture was separated by preparative TLC using benzene. The upper zone afforded methyl betulinate, needles (14 mg) m.p. 226–227°. The lower zone gave betulin, needles (8 mg) m.p. 256–257°. The methanolic mother liquor was evaporated and the residue was washed with boiling benzene and recrystallized from $CHCl_3$ to give scopoletin, pale yellow–green needles (540 mg) m.p. 199–200°.

Maritinone dimethyl ether (VII'). Maritinone (VII) (18 mg) in $CHCl_3$ (10 ml) was refluxed for 2 hr with Me I (1 ml) and Ag_2O (50 mg). After filtration and evaporation, the residue was purified by preparative TLC and recrystallization from benzene gave orange crystals (11 mg) of m.p. 272–274°. IR ν_{max}^{KBr} 2730, 1660, 1551, 1465, 1275, 1250, 1224, 1183, 1051, 959 cm^{-1}. NMR (Table 1). MS (*m/e*): 402·107 (M^+. Calcd. for $C_{24}H_{18}O_6$: 402·110).

Reductive cleavage of VII. To maritinone (VII) (5 mg) in 2 N Na_2CO_3 (2 ml) on a boiling H_2O bath was added $Na_2S_2O_4$ (20 mg). After 10 min the reaction mixture was cooled, acidified, and extracted with Et_2O. The ethereal residue was applied for TLC and, besides the recovery of the starting material (4 mg), formation of plumbagin (V) was confirmed by cochromatography.

Isoshinanolone dibenzoate. Isoshinanolone (VIII) (20 mg) in $CHCl_3$ (2 ml)-pyridine (1 ml) was treated with benzoyl chloride (1 ml). The reaction product separated by preparative TLC as a colorless viscous oil (28 mg) $[\alpha]_D^{17}$ +12·2° (*c*, 0·41, $CHCl_3$). UV λ_{max}^{EtOH} 233, 275, 283, 296 nm (log ϵ 4·40, 3·36, 3·38, 3·24). IR ν_{max}^{KBr} 2925, 1745, 1721, 1693, 1605, 1452, 1315, 1263, 1222, 1176, 1100, 1080, 1065, 1021, 703 cm^{-1}. NMR δ (in $CDCl_3$) 1·15 (3H, *d*), 1·64 (1H, *m*), 2·72 (2H, *m*), 6·27 (1H, *m*), 7·0–8·2 (13H). MS (*m/e*): 400·129 (M^+. Calcd. for $C_{25}H_{20}O_5$: 400·131).

Chromium trioxide oxidation of isoshinanolone (VIII). Isoshinanolone (VIII) (15 mg) in pyridine (1 ml) was added to CrO_3 (20 mg) in pyridine (2 ml) under stirring and, after keeping at room temp. for 20 hr, the reaction mixture was treated with H_2O, extracted with Et_2O, washed, and purified by preparative TLC. Plumbagin (V) (7 mg) was obtained and identified with the authentic sample. The starting material (5 mg) was recovered.

Lithium aluminium hydride reduction of plumbagin (V). Plumbagin (V) (100 mg) in ether was added to the suspension of $LiAlH_4$ (10 mg) in Et_2O (anh). After 6 hr excess $LiAlH_4$ was decomposed and the product was eventually obtained from hexane as colorless crystals (XII) (5 mg) of m.p. 90°. UV λ_{max}^{EtOH} 260, 334 nm (log ϵ 4·03, 3·56). IR ν_{max}^{Nujol} 3200, 1633, 1455, 1341, 1247, 810, 786, 758 cm^{-1}. NMR δ (in $CDCl_3$) 1·17 (3H, *d*, *J* 6 Hz), 1·95 (1H, *s*), 2·2–3·0 (3H), 4·44 (1H, *d*, *J* 7·5 Hz), 6·79, 7·02, 7·35 (each 1H, *dd*, 1,2,3-trisubstituted benzene), 12·19 (1H, *s*). CrO_3 oxidation of XII (10 mg) as in the case of VIII afforded plumbagin (V) (6 mg).

Reaction of juglone, 7-methyljuglone (I) *and isodiospyrin* (II) *with silica gel and alumina.* (i) II was refluxed in $CHCl_3$ or benzene for 25 hr or kept standing in silica gel column in benzene for 75 days. No detectable dimerization or other reaction product was observed. (ii) II (240 mg) in MeOH was refluxed with silica gel

for 20 hr. The solution was separated by preparative TLC. Besides the recovery of the starting material (II, 220 mg) six spots were observed and one of them was identified as bisisodiospyrin (XIII) (4 mg). (iii) Juglone (14 mg) in MeOH was absorbed on a column of alumina (Woelm, acidified with 0·5 N HCl, washed with water, and activated at 460–500°) and kept standing for 5 days. Elution with 0·05% MeOH–HCl and separation by preparative TLC showed the formation of four products, the major of which was isolated as yellow crystals (6 mg) of m.p. 213–215° (lit.[28] m.p. 222–222·5°) and identified as 3-methoxyjuglone. (iv) 7-Methyljuglone (50 mg) was treated as in (iii) and 2-methoxy-[9] (3 mg) and 3-methoxy-7-methyljuglone[9] (9 mg) and mamegakinone[6,7] (XIII) (0·5 mg) were obtained besides the starting material (25 mg). (v) Isodiospyrin (II) (400 mg) was treated as in (iii) and eluted with MeOH. The eluate showed five spots and besides the starting material (56 mg) and an unidentified black substance (14 mg), bisisodiospyrin (XVI) (1 mg), m.p. >300°, $[\alpha]_D^{18}$ −247° (*c* 0·15, $CHCl_3$ (lit.[7] $[\alpha]_D$ −678° ($CHCl_3$) was obtained and identified.* Isodiospyrin (II) (100 mg) in MeOH was treated as the same way with alumina (Wako, acidified as before). Elution with 0·05% HCl–MeOH gave dark-violet crystals (12 mg), the starting material (II, 8 mg), bisisodiospyrin (1 mg), and a black substance (6 mg). Besides these, three yellow spots were observed on TLC.

Reexamination of the extracts of D. lotus,[7] D. japonica,[8] *and* D. morrisiana[7] *by TLC.* The dried root barks of the three plants (*ca.* 100–300 g) were extracted with benzene, $CHCl_3$ and MeOH for 10 days at room temp. The extracts from each solvent were immediately examined by TLC employing benzene and the spots were compared and identified with the compounds so far isolated.

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* The smaller rotation value is assumed to be due to a partial racemization in the course of the reaction.

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