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SYNTHESIS OF SOME 1,3,6-TRIOXYGENATED ISOPENTENYLATED XANTHONES

CONSTITUTION OF GARCINONE A

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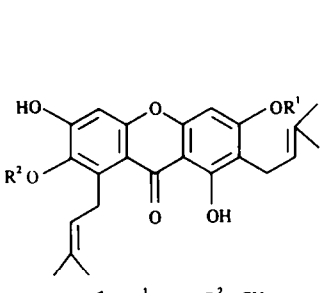
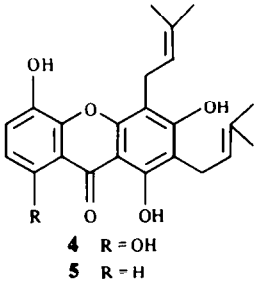
Abstract—The reaction of 1,3-dihydroxy-6-methoxy- and 1,3,6-trihydroxy-xanthone with 1-bromo-3-methylbut-2-ene in presence of methanolic sodium methoxide, to give corresponding 3-methylbut-2-enylated xanthones, is described. Synthesis of 1,3,6-trihydroxy-2,4-bis(3-methylbut-2-enyl)-9H-xanthen-9-one, designated as garcinone A and reported as a natural product from the fruit-hulls of *Garcinia mangostana* (Guttiferae), has also been achieved. However synthetic xanthone is found to be different from natural garcinone A, therefore its constitution needs reinvestigation.

AMONG naturally occurring isopentenylated xanthones, the C_5 unit is generally present as either 3-methylbut-2-enyl or condensed 2,2-dimethylchromene moiety.[1,2] The C_5 unit can also be present as a 1,1-dimethylallyl group.[1] The occurrence of xanthones with two C_5 units of the same or different type is common in tropical plants[3] (Guttiferae and Moraceae species). However, xanthones with two 3-methylbut-2-enyl substituents are few, viz. mangostin[4] (**1**), β-mangostin[5] (**2**), γ-mangostin[6] (**3**), gartanin[7] (**4**) and 8-desoxygartanin[7] (**5**) [*Garcinia mangostana* (Guttiferae)] and toxyloxanthone D[8] (**6**) [Maclura pomifera (Moraceae)].

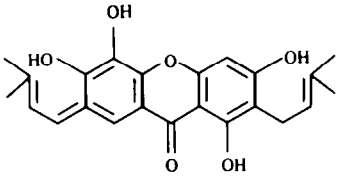
Thus 1,3-dihydroxy-6-methoxyxanthone[10] on reaction with 1-bromo-3-methylbut-2-ene in the presence of methanolic sodium methoxide gave a mixture of three products A, B and C in the ratio 20:1:20 (overall yield 66%), which were separated by column chromatography over silica gel. Compound A gave deep green colour with alcoholic $FeCl_3$ solution,



1 $R^1 = H$, $R^2 = CH_3$
2 $R^1 = R^2 = CH_3$
3 $R^1 = R^2 = H$



4 R = OH
5 R = H



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Scheme 1.

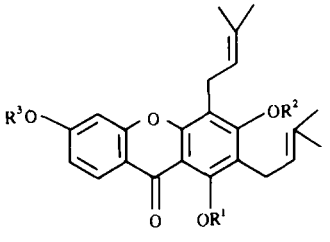
Banerji *et al.*[9] recently reported the isolation of garcinone A, along with garcinone B and C from the fruit-hulls of *Garcinia mangostana* (Guttiferae). Garcinone A was given the constitution 1,3,6 - trihydroxy - 2,4 - bis(3 - methylbut - 2 - enyl) - 9H-xanthen - 9 - one (**7**) and this assignment was made purely on the basis of spectral studies. In order to confirm the proposed structure, it was considered of interest to study nuclear 3-methylbut-2-enylation of the parent hydroxyxanthones (1,3-dihydroxy-6-methoxy- and 1,3,6-trihydroxy - xanthone).

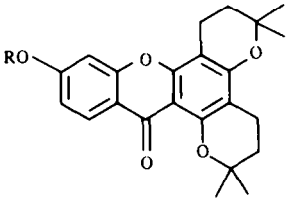
formed a diacetate (δ2.41 and 2.54; each 3H, each s) and its elemental analysis showed the introduction of two prenyl units. The presence of two 3-methylbut-2-enyl groups was indicated by the NMR spectrum of A, which showed the presence of

two gem-dimethyl groups (δ1.75 and 1.86, each 6H, each s), two benzylic methylene groups [δ3.44, 4H, t (J = 7 Hz)], two olefinic protons (δ5.27, 2H, m), two OH groups (δ6.34, and 13.50, each 1H, each s, exchanged with D_2O) and one proton doublet (δ8.03, J = 9 Hz), which was readily assigned to 8-H and since the proton showed a normal ortho coupling, the 7-position was also unsubstituted. The two proton multiplet at δ6.70–6.88 was assigned to 5-H and 7-H of the same B-ring. Thus, two 3-methylbut-2-enyl substituents were in 2- and 4-positions of xanthone. Compound A was therefore, identified as 1,3 - dihydroxy - 6 - methoxy - 2,4 - bis(3 - methylbut - 2 - enyl) - 9H - xanthen - 9 - one (**8**) and its diacetate assigned the structure **9**. The assigned structure **8** was supported in two ways: (i) **8** on partial methylation with one mole of dimethyl sulphate, gave the monomethyl ether **10**; (ii) cyclization of **8** with formic acid yielded 11 - methoxy - 3,4,7,8 - tetrahydro - 2,2,6,6, - tetramethyl - 2H,6H,14H - dipyrano [2,3-a: 2′,3′-c] xanthen-14-one (**11**). The NMR spectra of **10** and **11** agreed with the assigned structure (Experimental).

Compound B, on the basis of analytical data, showed the introduction of one prenyl group. It formed a monoacetate (δ2.41, 3H, s). The presence of a chelated OH group (1-OH) was shown by a positive ferric reaction and a sharp low-field singlet at δ13.06 (1H, exchanged with D_2O) in its NMR spectrum, which also showed the presence of gem-dimethyl group [δ1.74, 6H, d (J = 4.5 Hz)], methyleneoxy group [δ4.40, 2H, d (J = 7 Hz)] and olefinic proton [δ5.41, 1H, m] besides other signals. Thus the prenyl group was involved in ether formation with 3-OH. Compound B was therefore identified as 1 - hydroxy - 6 - methoxy - 3 - (3 - methylbut - 2 - enyloxy) - 9H - xanthen - 9 - one (**12**) and its monoacetate assigned the structure **13**.

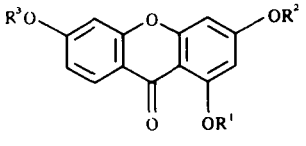
Compound C was identified as 1,3 - dihydroxy - 6-methoxy - 2 - (3 - methylbut - 2 - enyl) - 9H - xanthen - 9 - one (**14**) as follows: It gave positive ferric chloride reaction and formed a diacetate **15** (δ2.45, 6H, s) indicating that both the hydroxyls (1- and 3-OH) are free. Elemental analysis and the NMR spectrum of 14 showed the presence of one 3-methylbut-2-enyl group which could be at the 2- or 4- position; proton signals of three aromatic protons of B-ring were intact and one proton singlet at δ6.36 could be assigned to one aromatic proton of A-ring. Compound **14** on partial methylation with one mole of dimethyl sulphate gave the monomethyl ether (**16**), which on treatment with formic acid afforded 5,9 - dimethoxy - 3,4 - dihydro - 2,2 - dimethyl - 2H,12H-pyrano[2,3 - a]xanthen - 12 - one (**17**); its structure was in agreement with its NMR spectral data (Experimental). It clearly indicated the involvement of the OH in cyclization with the 3-methylbut-2-enyl group present at the 2-position. Therefore 3-methylbut-2-enyl group in **16** and hence in compound C could only be present at 2-position. This confirms beyond any doubt the structure **14** for compound C.

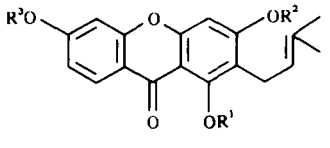




7 $R^1 = R^2 = R^3 = H$
8 $R^1 = R^2 = H$, $R^3 = CH_3$
9 $R^1 = R^2 = COCH_3$, $R^3 = CH_3$
10 $R^1 = H$, $R^2 = R^3 = CH_3$
20 $R^1 = R^2 = R^3 = COCH_3$

11 $R = CH_3$
21 $R = H$

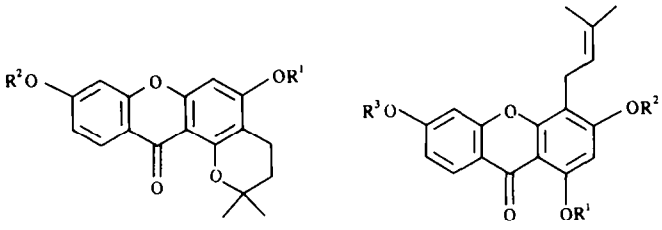




12 $R^1 = H$, $R^2 = CH_2CH = (CH_3)_2$, $R^3 = CH_3$
13 $R^1 = COCH_3$, $R^2 = CH_2CH = (CH_3)_2$, $R^3 = CH_3$
18 $R^1 = H$, $R^2 = R^3 = CH_2CH = (CH_3)_2$
19 $R^1 = COCH_3$, $R^2 = R^3 = CH_2CH = (CH_3)_2$

14 $R^1 = R^2 = H$, $R^3 = CH_3$
15 $R^1 = R^2 = COCH_3$, $R^3 = CH_3$
16 $R^1 = H$, $R^2 = R^3 = CH_3$
22 $R^1 = R^2 = R^3 = H$
36 $R^1 = R^2 = R^3 = COCH_3$

Scheme 2.



17 $R^1 = R^2 = CH_3$
27 $R^1 = H$, $R^2 = CH_3$
29 $R^1 = R^2 = H$

23 $R^1 = R^2 = R^3 = H$
24 $R^1 = H$, $R^2 = R^3 = CH_3$
37 $R^1 = R^2 = R^3 = COCH_3$

Scheme 3.

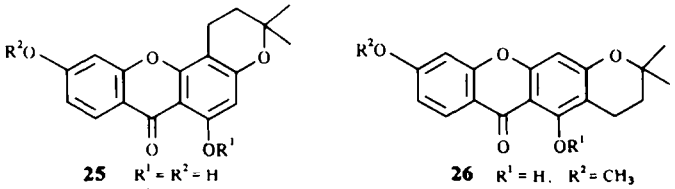
1,3,6-Trihydroxyxanthone[10] on similar reaction with 1-bromo-3-methylbut-2-ene gave a mixture of four products D, E, F and G in the ratio of 1:20:20:30 (overall yield 73%), which were separated by column chromatography over silica gel. Compound D gave a positive ferric reaction and formed a monoacetate (δ2.42, 3H, s). The NMR spectrum of D showed the presence of two 3-methylbut-2-enyloxy unit and a low-field singlet at δ13.20 (1H, exchanged with D_2O), besides other signals. Thus only 1-OH was free, 3- and 6- were involved in ether formation with prenyl groups. Compound D was therefore identified as 1-hydroxy-3,6 - bis(3 - methylbut - 2 - enyloxy) - 9H - xanthen - 9 - one (**18**) and its monoacetate assigned the structure **19**.

Compound E was found to be isomeric to compound D on elemental analysis but formed a triacetate (δ2.33 and 2.48, 6H and 3H resp. ■, each s). The NMR spectrum of E and its triacetate showed the presence of two 3-methylbut-2-enyl units at the 2- and 4-positions of the A- ring (Experimental). Compound E was, therefore, identified as 1,3,6 - trihydroxy - 2,4 - bis(3 - methylbut - 2 - enyl) - 9H - xanthen - 9 - one (**7**) and its triacetate assigned the structure **20**. These assignments were further supported as follows: (i) **7** on partial methylation with two moles of dimethyl sulphate gave a dimethyl ether identical (m.p., m.m.p. and co-IR) with 10, prepared by partial methylation (one mole) of **8**; and (ii) treatment of **7** with formic acid afforded 11 - hydroxy - 3,4,7,8 - tetrahydro - 2,2,6,6, - tetramethyl-2H, 6H, 14H - dipyrano[2,3 - a:2′,3′ - c]xanthen - 14 - one (**21**), which on methylation gave a methyl ether identical (m.p., m.m.p. and co-IR) with **11** (acid cyclized product of **8**). **7** was found to be different in m.p. and spectral data (UV, IR, NMR and MS) with natural garcinone A[9] (Table 1). However, a direct comparison could not be made due to non-availability of the natural sample. The constitution of garcinone A, therefore, needs reinvestigation.

Both the compounds F and G were found to be isomeric mono 3-methylbut-2-enylated xanthones from their elemental analysis and NMR spectral data (Experimental). Either of the compound F and G could be assigned the structure, 1,3,6 - trihydroxy - 2 - (3 - methylbut - 2 - enyl) - 9H - xanthen - 9 - one (**22**) or 1,3,6 - trihydroxy - 4 - (3 - methylbut - 2 - enyl) - 9H - xanthen - 9 - one (**23**). The structures of compounds F and G were established as **22** and **23** respectively by preparing their dimethyl ethers. The dimethyl ether of compound F was found to be identical (m.p., m.m.p. and co-IR) with **16** (monomethyl ether of **14**). Compound G gave a dimethyl ether (**24**), which did not undergo any change on formic acid treatment, confirming thereby the presence of the 3-methylbut-2-enyl group at 4-position in **24** and hence in compound G.

Formic acid treatment of **23** afforded 6,10- dihydroxy - 1,2 - dihydro - 3,3 - dimethyl - 3H, 7H - pyrano[2,3-c]xanthen - 7 - one (**25**). However **14** and **22** on similar acid cyclization gave a mixture of dihydropyranoxanthones **26** and **27**; **28** and **29** respectively. Compounds **25** and **28** on partial methylation gave **30** and **26** respectively. Methylation of either **27** or **29** gave **17**. Similarly **26** and **30** on methylation gave **31** and **32** respectively. The structure of the above formed dihydro-pyranoxanthones were in agreement with their NMR spectral data (Experimental). Further, a singlet due to one aromatic proton (δ6.18) in **32** resonated 0.3 ppm upfield compared to that of **31**. This was in agreement with our earlier observation.[11] The formation of dihydropyranoxanthones (**25**, **26**, **27**, **28** and **29**) by formic acid cyclization further supported structures **14**, **22** and **23** assigned to compounds C, F and G respectively.

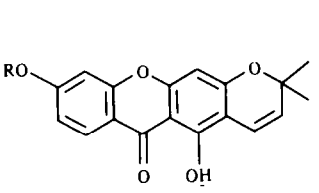
Compound **22** on reaction with 2,3-dichloro-5,6-dicyano-p-benzoquinone (DDQ) in refluxing benzene, gave a product (60%), which was assigned the structure 5,9 - dihydroxy - 2,2 - dimethyl - 2H, 6H - pyrano[3,2 - b]xanthen - 6 - one (**33**) on the basis of its NMR spectral data, which showed characteristic pair of doublets (J = 10 Hz) at δ5.48 and 6.49. Similar oxidative cyclization of **14** and **23**, with DDQ gave pyranoxanthones (**34** and **35**) respectively.



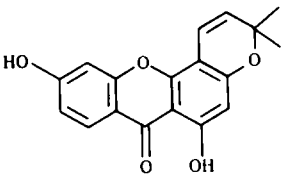
25 $R^1 = R^2 = H$
30 $R^1 = H$, $R^2 = CH_3$
32 $R^1 = R^2 = CH_3$

26 $R^1 = H$, $R^2 = CH_3$
28 $R^1 = R^2 = H$
31 $R^1 = R^2 = CH_3$

Scheme 4.



33 R=H
34 R=CH_3



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Scheme 4. (*Contd*)

Table 1.

Compound	Garcinone A[9] (Natural)	1,3,6-Trihydroxy-2,4-bis(3-methylbut-2-enyl)-9H-xanthen-9-one) (7) (Synthetic)
m.p. (°C)	224-225	178-179
UV (λ_{max}^{EtOH}, nm)	245,260,289,323 and 370	220,236,262,269 and 310 nm
IR υ_{max}^{nujol}	3380 and 1635	2910,1660,1450,1250 and 860
NMR* (90 MHz, δ)		(DMSO-d_6): 1.35-1.75 [12H, m, 2 x $C(CH_3)_2$], 2.73 and 2.93(each 2H, each d, J=7 Hz, 2 x CH_2), 4.63 and 4.95(each 1H, each m, 2 x CH), 6.85-7.05(2H, m, 5- and 7-H) and 7.90(1H, d, J=9 Hz, 8-H).
	(triacetate, $CDCl_3$): 1.60 (3H, s), 1.66(3H, s), 1.75 (3H, s), 1.99(3H, s), 3.31 (4H, d, J=6 Hz), 5.06(2H, t, J=6 Hz), 7.25-7.45(2H, m) and 8.15(1H, dd, J=9, 1Hz)	(triacetate, $CDCl_3$): 1.65-1.90[12H, m, 2 x $C(CH_3)_2$], 2.33 and 2.48(6H and 3H resp., each s, 1-, 3- and 6- $OCOCH_3$), 3.23 and 3.48 (each 2H, each d, J=7 Hz, 2 x CH_2), 4.82-5.10(2H, m, 2 x CH), 6.89-7.20(2H, m, 5- and 7-H) and 8.07 (1H, d, J=9 Hz, 8-H).
Mass** (m/z, rel. int.)	380[M^+] (25), 337(5), 324(7), 323(5), 311(63) 295(17), 283(5), 269(16) and 257(100)	380[M^+](79), 365(12), 363(20), 337(42), 325(58), 324(34), 309(73), 281(66), and 269(100).

* In the NMR spectrum of triacetate of natural garcinone A; signals of three acetate groups were not described and two gem-dimethyl groups appeared as four singlets of three proton each at δ 1.60, 1.66, 1.75 and 1.99, which is unusual[7] for xanthones with two 3-methylbut-2-enyl substituents at 2- and 4-position.

Table 1. (*Contd*)

** Unlike mass spectrum of natural garcinone **A**, 7 showed major fragments at m/e 337 ($M^+-C_3H_7$), 325($M^+-C_4H_7$), 324($M^+-C_4H_8$), 281(m/e 337-C_4H_8) and 269(m/e 325-C_4H_8), which were in agreement[7,13] with the presence of two 3-methylbut-2-enyl substituents directly attached to aromatic ring. In the mass spectrum of natural garcinone **A**, though m/e 337, 324 and 269 were present but only as minor fragments, the major fragments were m/e 311($M-C_5H_9$) and 257. The former fragment indeed result from the loss of entire pentenyl side chain thereby suggesting[13] its attachment to the aromatic ring through oxygen. The base peak (m/e 257) could then result from the loss of C_4H_6 from 311.

Table 2.

Compound	Yield[a] [%]	M.p. [°C]	Molecular formula	Found(Calcd.) C [%]	H [%]	NMR(δ, J in Hz)
7[b]	20.5[f]	***	$C_{23}H_{24}O_5$	72.5 (72.6)	6.6 (6.4)	***
8[c]	32.7[g]	163-164	$C_{24}H_{26}O_5$	73.2 (73.0)	6.7 (6.6)	1.75 and 1.86 [each 6H, each s, 2 x $C(CH_3)_2$], 3.44(4H, t, J=7 Hz, 2 x CH_2), 3.84(3H, s, 6-OCH_3), 5.27(2H, m, 2 x CH), 6.34(1H, s, exchanged with D_2O, 3-OH), 6.70-6.88(2H, m, 5- and 7-H), 8.03(1H, d, J=9 Hz, 8-H), and 13.50(1H, s, exchanged with D_2O, 1-OH).
9	74.0[h]	170-171	$C_{28}H_{30}O_7$	70.2 (70.3)	6.4 (6.3)	1.79 and 1.94 [each 6H, each s, 2 x $C(CH_3)_2$], 2.41 and 2.54(each 3H, each s, 1- and 3-$OCOCH_3$), 3.30 and 3.55(each 2H, each d, J=7 Hz, 2 x CH_2), 3.92(3H, s, 6-OCH_3), 5.00-5.30(2H, m, 2 x CH), 6.75-7.00(2H, m, 5- and 7-H) and 8.10(1H, d, J = 9 Hz, 8-H)
10	87.0[h]	125-126	$C_{25}H_{28}O_5$	73.3 (73.5)	7.1 (6.9)	1.71-1.89 [12H, m, 2 x $C(CH_3)_2$], 3.43(4H, t, J=7 Hz, 2 x CH_2), 3.79 and 3.89(each 3H, each s, 3- and 6-OCH_3), 5.24(2H, m, 2 x CH), 6.69-6.89(2H, m, 5- and 7-H), 8.04(1H, d, J=9 Hz, 8-H), and 13.22(1H, s, exchanged with D_2O, 1-OH).
11	70.0[h]	193-194	$C_{24}H_{26}O_5$	73.1 (73.0)	6.8 (6.6)	1.35 and 1.40 [each 6H, each s, 2 x $C(CH_3)_2$], 1.67-1.90(4H, m, 3- and 7-H), 2.58 and 2.82(each 2H, each t, J=7 Hz, 4- and 8-H), 3.82(3H, s, 11-OCH_3), 6.65-6.83(2H, m, 10- and 12-H) and 8.05(1H, d, J=9 Hz, 13-H).
12[c]	1.6[h]	114-115 (110-112)[12]	$C_{19}H_{18}O_5$	69.9 (70.0)	5.6 (5.5)	1.74 [6H, d, J=4.5 Hz, $C(CH_3)_2$], 3.74(3H, s, 6-OCH_3), 4.40(2H, d, J=7 Hz, CH_2), 5.41(1H, m, CH), 6.18(2H, s, 2- and 4-H), 6.55-6.80 (2H, m, 5- and 7-H), 7.91(1H, d, J=9 Hz, 8-H), and 13.06(1H, s, exchanged with D_2O, 1-OH).

Table 2. (*Contd*)

Compound	Yield (%)	m.p. (°C)	Molecular formula	Found (Calcd.) C (%)	H (%)	NMR (δ, J in Hz)
13	71.0[h]	116-117	$C_{21}H_{20}O_6$	68.3 (68.5)	5.6 (5.4)	1.71 and 1.75[each 3H, each s, $C(CH_3)_2$], 2.41(3H, s, 1-$OCOCH_3$), 3.78(3H, s, 6-OCH_3), 4.50(2H, d, J=7 Hz, CH_2), 5.40(1H, m, CH), 6.44-6.80(4H, m, 2-, 4-, 5- and 7-H) and 7.95(1H, d, J=9 Hz, 8-H).
14[c]	31.7[i]	195-196	$C_{19}H_{18}O_5$	69.9 (70.0)	5.7 (5.5)	1.65 and 1.76 [each 3H, each s, $C(CH_3)_2$], 3.22(2H, d, J=7 Hz, CH_2), 3.85(3H, s, 6-OCH_3), 5.17(1H, m, CH), 6.36(1H, s, 4-H), 6.79-6.89(2H, m, 5- and 7-H) and 7.92(1H, d, J=9 Hz, 8-H)[j].
15	67.0[h]	238-239	$C_{23}H_{22}O_7$	67.2 (67.3)	5.5 (5.4)	1.68 and 1.78 [each 3H, each s, $C(CH_3)_2$], 2.45(6H, s, 1- and 3-$OCOCH_3$), 3.27(2H, d, J=7 Hz, CH_2), 3.86(3H, s, 6-OCH_3), 5.17(1H, m, CH), 6.77-6.95(3H, m, 4-, 5- and 7-H), and 7.90(1H, d, J=9 Hz, 8-H).
16	91.0[h]	153-154	$C_{20}H_{20}O_5$	70.5 (70.6)	6.0 (5.9)	1.67 and 1.78 [each 3H, each s, $C(CH_3)_2$], 3.28(2H, d, J=7 Hz, CH_2), 3.85 (6H, s, 3- and 6-OCH_3), 5.15(1H, m, CH), 6.24(1H, s, 4-H), 6.59-6.85(2H, m, 5- and 7-H), 7.97(1H, d, J=9 Hz, 8-H) and 13.10(1H, s, exchanged with D_2O, 1-OH).
17	80.0[h]	194-195 (192-193)[14]	$C_{20}H_{20}O_5$	70.4 (70.6)	6.1 (5.9)	1.43 [6H, s, $C(CH_3)_2$], 1.78 and 2.58(each 2H, each t, J=7 Hz, 3- and 4-H), 3.78(6H, s, 5- and 9-OCH_3), 6.29(1H, s, 6-H), 6.60-6.85(2H, m, 8- and 10-H) and 8.10(1H, d, J=9 Hz, 11-H).
18[b]	1.0[h]	135-136	$C_{23}H_{24}O_5$	72.5 (72.6)	6.5 (6.4)	1.76 [12H, s, 2 x $C(CH_3)_2$], 4.48(4H, m, 2 x CH_2), 5.44(2H, m, 2 x CH), 6.22(2H, s, 2- and 4-H), 6.60-6.85(2H, m, 5- and 7-H), 7.94(1H, d, J=9 Hz, 8-H) and 13.20(1H, s, exchanged with D_2O, 1-OH).
19	72.0[h]	95-96	$C_{25}H_{26}O_6$	71.0 (71.1)	6.4 (6.2)	1.75 [12H, d, J=4.5 Hz, 2 x $C(CH_3)_2$], 2.42(3H, s, 1-$OCOCH_3$), 4.48(4H, d, J=7 Hz, 2 x CH_2), 5.41(2H, m, 2 x CH), 6.46(2H, d, J=2 Hz, 2- and 4-H), 6.60-6.86(2H, m, 5- and 7-H) and 8.01(1H, d, J=9 Hz, 8-H).
20	67.6[h]	180-181	$C_{29}H_{30}O_8$	68.6 (68.8)	6.1 (5.9)	***
21	80.0[f]	267-268	$C_{23}H_{24}O_5$	72.4 (72.6)	6.6 (6.4)	1.26 and 1.33 [each 6H, each s, 2 x $C(CH_3)_2$], 1.60-1.90(4H, m, 3- and 7-H), 2.70-2.90(4H, m, 4- and 8-H), 6.56-6.75(2H, m, 5- and 7-H), and 7.72(1H, d, J=9 Hz, 8-H).

Table 2. (*Contd*)

Compound	Yield [%]	M.p. [°C]	Molecular formula	Found(Calcd.) C [%]	H [%]	NMR(δ, J in Hz)
22[b]	20.3[f]	196-197	$C_{18}H_{16}O_5$	69.1 (69.2)	5.3 (5.1)	1.62 and 1.73 [each 3H, each s, $C(CH_3)_2$], 3.19(2H, d, J=7 Hz, CH_2), 5.16(1H, m, CH), 6.36(1H, s, 4-H), 6.68-6.88(2H, m, 5- and 7-H) and 7.89(1H,d, J=9 Hz, 8-H)[k]
23[b]	31.3[f]	189-190	$C_{18}H_{16}O_5$	69.0 (69.2)	5.1 (5.1)	1.61 and 1.81[each 3H, each s, $C(CH_3)_2$], 3.36(2H, d, J=7 Hz, CH_2), 5.16(1H, m, CH), 6.21(1H, s, 2-H), 6.67-6.86(2H, m, 5- and 7-H), and 7.91(1H, d, J=9 Hz, 8-H)[k]
24	73.0[i]	159-160	$C_{20}H_{20}O_5$	70.4 (70.6)	6.0 (5.9)	1.75 and 1.91[each 3H, each s, $C(CH_3)_2$], 3.48(2H, d, J=7 Hz, CH_2), 3.93(6H, s, 3- and 6- OCH_3), 5.15(1H, m, CH), 6.27(1H, s, 2-H), 6.65-6.88(2H, m, 5- and 7-H), 8.00(1H, d, J=9 Hz, 8-H) and 13.20(1H, s, exchanged with D_2O, 1-OH).
25	80.0[f]	272-273	$C_{18}H_{16}O_5$	69.1 (69.2)	5.2 (5.1)	1.30[6H,s, $C(CH_3)_2$], 1.78 and 2.65(each 2H, each t, J=7 Hz, 1- and 2-H), 5.87(1H, s, 5-H), 6.54-6.78(2H, m, 9- and 11-H) and 7.72(1H, d, J=9 Hz, 8-H)[k].
26[d]	47.0[g]	165-166 (161-162)[14]	$C_{19}H_{18}O_5$	69.8 (70.0)	5.6 (5.5)	1.30[6H, s, $C(CH_3)_2$], 1.77 and 2.65(each 2H, each t, J=7 Hz, 3- and 4-H), 3.80(3H, s, 9-OCH_3), 6.14(1H, s, 12-H), 6.60-6.80(2H, m, 8- and 10-H), 7.95(1H, d, J=9 Hz, 7-H) and 13.40(1H, s, exchanged with D_2O, 5-OH).
27[d]	40.0[g]	295-296	$C_{19}H_{18}O_5$	69.8 (70.0)	5.5 (5.5)	1.58[6H, s, $C(CH_3)_2$], 2.01 and 2.80(each 2H, each t, J=7 Hz, 3- and 4-H), 4.00(3H, s, 9-OCH_3), 6.79(1H, s, 6-H), 6.95-7.15(2H, m, 8- and 10-H), and 8.05(1H, d, J=9 Hz, 11-H)[l]
28[e]	50.0[f]	280-281 (277-278)[14]	$C_{18}H_{16}O_5$	69.0 (69.2)	5.2 (5.1)	1.29[6H, s, $C(CH_3)_2$], 1.75 and 2.70(each 2H, each t, J=7 Hz, 3- and 4-H), 6.08(1H, s, 12-H), 6.55-6.82(2H, m, 8- and 10-H), and 7.80(1H, d, J=9 Hz, 7-H)[k]
29[e]	40.0[f]	288-289 (283-284)[14]	$C_{18}H_{16}O_5$	69.0 (69.2)	5.3 (5.1)	1.34[6H, s, $C(CH_3)_2$], 1.78 and 2.59 (each 2H, each t, J=7 Hz, 3- and 4-H), 6.34(1H, s, 6-H), 6.60-6.82(2H, m, 8- and 10-H), and 7.79(1H, d, J=9 Hz, 11-H)[k].
30	86.0[g]	191-192	$C_{19}H_{18}O_5$	69.9 (70.0)	5.7 (5.5)	1.28[6H, s, $C(CH_3)_2$], 1.76 and 2.66(each 2H, each t, J=7 Hz, 1- and 2-H), 3.73(3H, s, 10-OCH_3), 6.07(1H, s, 5-H), 6.61-6.81(2H, m, 9- and 11-H), 8.03(1H, d, J=9 Hz, 8-H) and 12.76(1H, s, exchanged with D_2O, 6-OH).

Table 2. (*Contd*)

Compound	Yield [%]	M.p. [°C]	Molecular formula	Found C [%]	(Calcd.) H [%]	NMR(δ, J in Hz)
31.	86.0[h]	156-157	$C_{20}H_{20}O_5$	70.5 (70.6)	6.1 (5.9)	1.42[6H, s, $C(CH_3)_2$], 1.87 and 2.86(each each t, J=7 Hz, 3- and 4-H), 3.89 and 3.99(each 3H, each s, 5- and 9-OCH_3), 6.48(1H, s, 12-H), 6.60-6.82(2H,m, 8- and 10-H) and 8.07(1H, d, J=9 Hz, 7-H).
32	77.0[h]	251-252	$C_{20}H_{20}O_5$	70.5 (70.6)	6.0 (5.9)	1.41[6H, s, $C(CH_3)_2$], 1.90 and 2.85(each 2H, each t, J=7 Hz, 1- and 2-H), 3.85 and 3.90(each 3H, each s, 6- and 10-OCH_3), 6.18(1H, s, 5-H), 6.65-6.85(2H, m, 9- and 11-H) and 8.10(1H, d, J=9 Hz, 8-H).
33	60.0[f] (4:1)	291-292	$C_{18}H_{14}O_5$	69.5 (69.7)	4.7 (4.5)	1.40[6H, s, $C(CH_3)_2$], 5.48(1H, d, J=10 Hz, 3-H), 6.11(1H, s, 12-H), 6.49(1H, d, J=10 Hz, 4-H), 6.60-6.77(2H, m, 8- and 10-H) and 7.73(1H, d, J=9 Hz, 7-H)[k]
34	80.0[g] (1:19)	169-170	$C_{19}H_{16}O_5$	70.2 (70.4)	5.1 (4.9)	1.44[6H, s, $C(CH_3)_2$], 3.82(3H, s, 9-OCH_3) 5.48(1H, d, J=10 Hz, 3-H), 6.18(1H, s, 12H), 6.52-6.82(3H, m, 4-, 8- and 10-H), 7.95(1H, d, J=9 Hz, 7-H) and 13.34(1H, s, exchanged with D_2O, 5-OH).
35	80.0[f] (4:1)	251-252	$C_{18}H_{14}O_5$	69.6 (69.7)	4.6 (4.5)	1.42 [6H, s, $C(CH_3)_2$], 5.65(1H, d, J=10 Hz, 2-H), 6.05(1H, s, 5-H), 6.60-6.87(3H, m, 1-, 9- and 11-H), and 7.83(1H, d, J=9 Hz, 8-H)[k].
36	60.0[h]	184-185	$C_{24}H_{22}O_8$	65.6 (65.7)	5.2 (5.0)	1.62 and 1.70[each 3H, each s, $C(CH_3)_2$], 2.26 and 2.42(6H and 3H resp.,each s,1-,3-6-$OCOCH_3$), 3.22(2H, d, J=7 Hz, CH_2), 5.05(1H, m, CH), 7.02(1H, s, 4-H), 7.08-7.42(2H, m, 5- and 7-H)and 8.20(1H, d, J=9 Hz, 8-H).
37	64.0[h]	195-196	$C_{24}H_{22}O_8$	65.5 (65.7)	5.1 (5.0)	1.75 and 1.90[each 3H each s, $C(CH_3)_2$], 2.36 and 2.50(6H and 3H resp.,each s,1-,3-6-$OCOCH_3$); 3.55(2H, d, J=7 Hz, CH_2), 5.12(1H, m, CH), 6.80(1H, s, 2-H), 7.05 (1H, dd, J=9 Hz, 2.5 Hz, 7-H), 7.23(1H, d, J=2.5 Hz, 5-H) and 8.17(1H, d, J=9 Hz, 8-H

*** See table 1.
a - Values in the parentheses given after the yield are the ratio of benzene-petroleum ether used as eluant

Table 2. (*Contd*)

b - Mixture of 18 + 7 + 22 + 23 separated by column chromatography on silica gel, eluting with benzene - petroleum ether (3:7) for 18, benzene - petroleum ether (4:1) for 7, benzene for 22 and benzene - ethyl acetate (19:1) for 23.

c - Mixture of 8 + 12 + 14 separated by column chromatography on silica gel, eluting with benzene - petroleum ether (1:4) for 8, benzene - petroleum ether (2:3) for 12 and benzene - petroleum ether (7:3) for 14.

d - Mixture of 26 + 27 separated by column chromatography on silica gel, eluting with benzene - petroleum ether (1:19) for 26 and benzene - petroleum ether (4:1) for 27.

e - Mixture of 28 + 29 separated by column chromatography on silica gel, eluting with benzene - petroleum ether (4:1) for 28 and benzene - ethyl acetate (17:3) for 29.

Recrystallisation solvents: f - acetone - chloroform; g - chloroform; h - benzene - petroleum ether; i - chloroform - methanol.

j solvent: $CDCl_3$ + DMSO-d_6

k solvent: DMSO-d_6

l solvent: $CDCl_3$ + CF_3COOH

EXPERIMENTAL

M.ps are uncorrected. NMR spectra were recorded on a Perkin-Elmer R-32 (90 MHz) spectrometer for solutions in $CDCl_3$ with TMS as the internal standard. Silica gel (60–120 mesh) was used for all chromatographic separations.

Reaction of 1,3 - *dihydroxy* - 6 - *methoxyanthone with* 1 - *bromo* - 3 - *methylbut* - 2 - *ene*

General procedure. To a soln of 1,3-dihydroxy - 6 - methoxyanthone[10](5.0 g, 19.4 mmol) in anhyd MeOH (200.0 ml) was added a methanolic soln of NaOMe (7.5 g of Na in 75.0 ml of MeOH). The mixture was cooled to 0° and treated with 1 - bromo - 3 - methylbut - 2 - ene (8.0 ml, 68.2 mmol) and then refluxed for 3 hr. After removal of the solvent under reduced pressure, the residue was diluted with water (100.0 ml) acidified with cold dil HCl and extracted with EtOAc. The organic extract was dried (Na_2SO_4) and distilled. The residue, thus obtained, was chromatographed on silica gel and eluted successively with benzene–petroleum ether (1:4), benzene–petroleum ether (2:3) and benzene–petroleum ether (7:3) to give (i) 1,3 - dihydroxy - 6 - methoxy - 2,4 - bis(3 - methylbut - 2 - enyl) - 9H - 9 - one (8); yield: 2.5 g (32.7%), m.p. 163–164°; (ii) 1 - hydroxy - 6 - methoxy - 3 - (3 - methylbut - 2 - enyloxy) - 9H - xanthen - 9 - one (12); yield: 0.1 g (1.6%), m.p. 114–115° (lit.[12] m.p. 110–112°); and (iii) 1,3 - dihydroxy - 6 - methoxy - 2 - (3 - methylbut - 2 - enyl) - 9H - xanthen - 9 - one (14); yield 2.0 g (31.7%), m.p. 195–196°.

The products obtained are given in Table 2.

1 - *Hydroxy* - 3,6 - *dimethoxy* - 2,4 - *bis*(3 - *methylbut* - 2-*enyl*) - *9H* - *xanthen* - *9* - *one* (**10**)

General procedure for methylation. **8** (0.1 g, 0.26 mmol) in dry acetone (20.0 ml) was refluxed with Me_2SO_4 (0.03 ml, 0.26 mmol) in presence of anhyd K_2CO_3 (0.4 g) for 4 hr. Inorganic salts were filtered off and washed with more acetone. The combined filtrate distilled and the residue treated with crushed ice. The separated solid was then crystallised from benzene–petroleum ether to give **10** as yellow needles (0.09 g), m.p. 125–126°. The products obtained are given in Table 2.

Formic acid cyclization of 1,3 - *dihydroxy* - 6 - *methoxy* - 2,4 - *bis*(3 - *methylbut* - 2 - *enyl*) - *9H* - *xanthen* - 9 - *one* (**8**)

General procedure. A soln of **8** (0.05 g) in formic acid (5.0 ml) was heated on a steam-bath for 2 hr. The product was poured into ice and the solid thus separated was crystallised from benzene–petroleum ether to give **11** as white prisms (0.035 g), m.p. 193–194°. The products obtained are given in Table 2.

Oxidative cyclization of 1,3,6-*trihydroxy* - 2 - (3 - *methylbut*-2 - *enyl*) - *9H* - *xanthen* - 9 - *one*(**22**) *with DDQ*

General procedure. **22** (0.05 g, 0.16 mmol) in dry benzene (10.0 ml) was refluxed for 1 hr with DDQ (0.04 g, 0.16 mmol). The soln was filtered, the filtrate distilled and the residue thus obtained was purified by column chromatography and the column eluted with benzene–petroleum ether (4:1) to give **33** as yellow needles (0.03 g), m.p. 291–292°. The products obtained are given in Table 2.

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REFERENCES

[1]O. R. Gottlieb, *Phytochem* **7**, 411 (1968).
[2]I. Carpenter, H. D. Locksley and F. Scheinmann, *Phytochem* **8**, 2013 (1969).
[3]M. U. S. Sultanbawa, *Tetrahedron* **36**, 1465 (1980).
[4]P. Yates and G. H. Stout, *J. Am. Chem. Soc.* **80**, 1691 (1958).
[5]P. Yates and H. B. Bhat, *Can. J. Chem.* **46**, 3770 (1968).
[6]A. Jefferson, A. J. Quillimann, F. Scheinmann and K. Y. Sim, *Aust. J. Chem.* **23**, 2539 (1970).
[7]T. R. Govindachari, P. S. Kalyanaraman, N. Muthukumaraswamy and B. R. Pai, *Tetrahedron* **27**, 3919 (1971).

[8]V. H. Deshpande, A. V. Rama Rao, M. Varadan and K. Venkataraman, *Ind. J. Chem.* **11**, 518 (1973).
[9a]A. K. Sen, K. K. Sarkar, P. C. Majumder and N. Banerji, *Ibid.* **19**, 1008 (1980); [b]A. K. Sen, K. K. Sarkar, P. C. Majumder, N. Banerji, R. Uusvuori and T. A. Hase, *Phytochem*, **21**, 1747 (1982).
[10]P. K. Grover, G. D. Shah and R. C. Shah, *J. Chem. Soc.* (C) 3982 (1955).
[11]V. K. Ahluwalia, R. S. Jolly and A. K. Tehim, *Ibid.* Perkin T 1, 1229 (1983).
[12]A. C. Jain and S. M. Anand, *Ibid.* Perkin T 1 329 (1974).
[13]E. Ritchie, W. C. Taylor and J. S. Shannon, *Tetrahedron Letters.* 1437 (1964).
[14]P. R. Iyer and G. D. Shah, *Ind. J. Chem.* **8**, 691 (1970).