# Studies on the Constituents of Yalaha. Structures of a New Acridone Alkaloid and Two New Coumarins[1)]

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**A new acridone alkaloid, 1,3,5-trihydroxy-10-methylacridone (8), and two new coumarins, *trans*-clausarinol (9) and khelmarin-D (11), were isolated from the root of Yalaha [several hybrid seedlings resulting from a cross of Duncan grapefruit (*Citrus paradisi* MACF.) × Dancy tangerine (*C. tangerina* HORT. ex TANAKA)], and structures were determined on the basis of spectroscopic evidence. Seventy known coumarins, acridone alkaloids and miscellaneous compounds were also characterized.**

**Key words** acridone alkaloid; coumarin; Yalaha; *Citrus*; Rutaceae

We have reported the isolation and structure elucidation of new acridone coumarin dimers, called neoacrimarines-A (**1**), -B (**2**),[2)] -E (**3**),[3)] acrimarines-I (**4**), -J (**5**),[4)] -N (**6**), and dioxinoacrimarine-A (**7**)[3)] from the root of Yalaha [several hybrid seedlings resulting from a cross of Duncan grapefruit (*Citrus paradisi* MACF.) × Dancy tangerine (*C. tangerina* HORT. ex TANAKA). On continuing our phytochemical studies of this plant, the acetone extract of the root of Yalaha was treated as shown in Fig. 1, and a new acridone alkaloid, 1,3,5-trihydroxy-10-methylacridone (**8**), and two new coumarins, *trans*-clausarinol (**9**) and khelmarin-D (**11**) were isolated. Together with these new compounds, thirty-eight monomeric coumarins, one dimeric coumarin, eighteen simple acridone alkaloids, one acridone–lignan, seven acridone–coumarin dimers, two flavonoids, and three aromatic compounds were also isolated and characterized. Here, we describe the structure of these new compounds and full details of the isolation and characterization of known compounds.

1,3,5-Trihydroxy-10-methylacridone (**8**) was isolated as a yellow oil. The molecular formula $C_{14}H_{11}NO_4$ was deduced from the HR-MS and showed the exact mass at *m/z* 257.0690. This was then confirmed by Electron impact (EI)-MS which showed molecular ion at *m/z* 257. The IR (1710, 1520, 1475, 1420 $cm^{-1}$) and UV [202, 261, 282 (sh), 300 (sh), 305 (sh), 340 (sh)] absorptions indicated the presence of a 9-acridone skeleton.[5)] The $^1H$-NMR

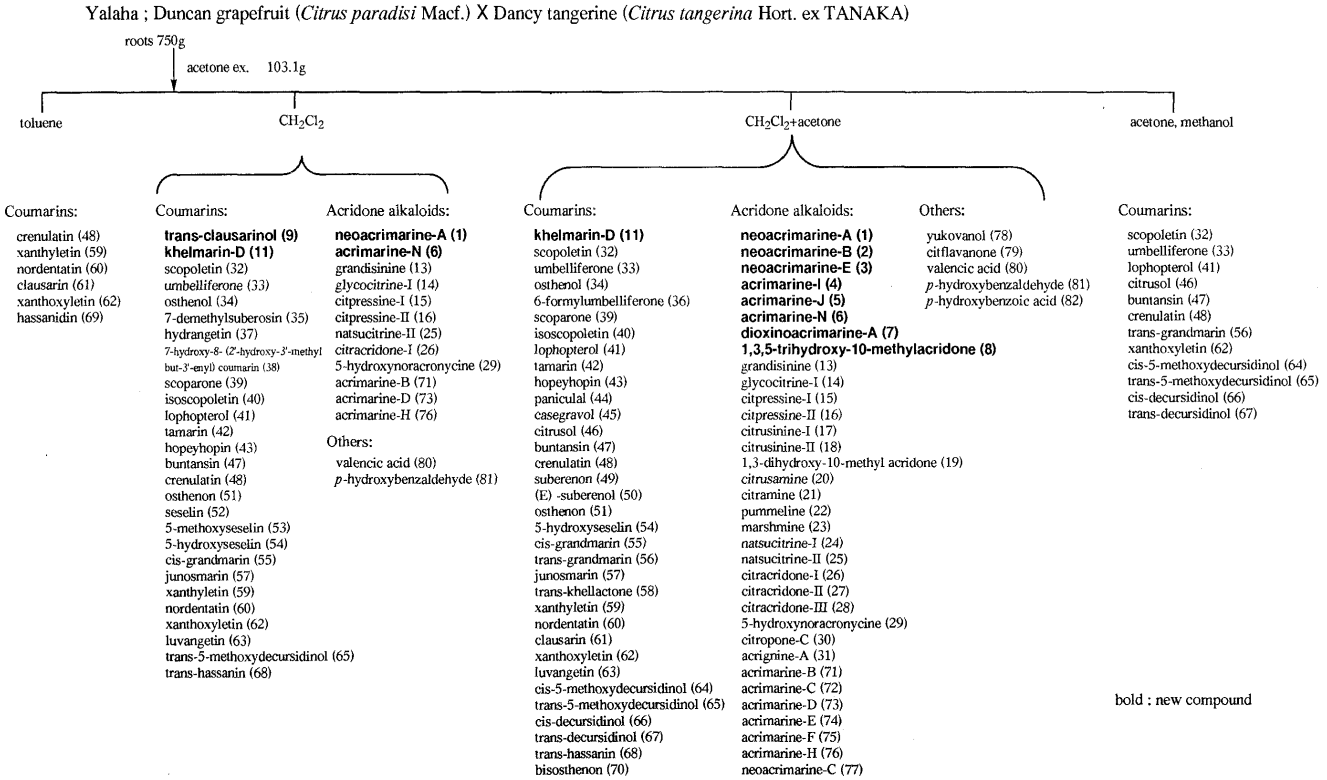


Fig. 1

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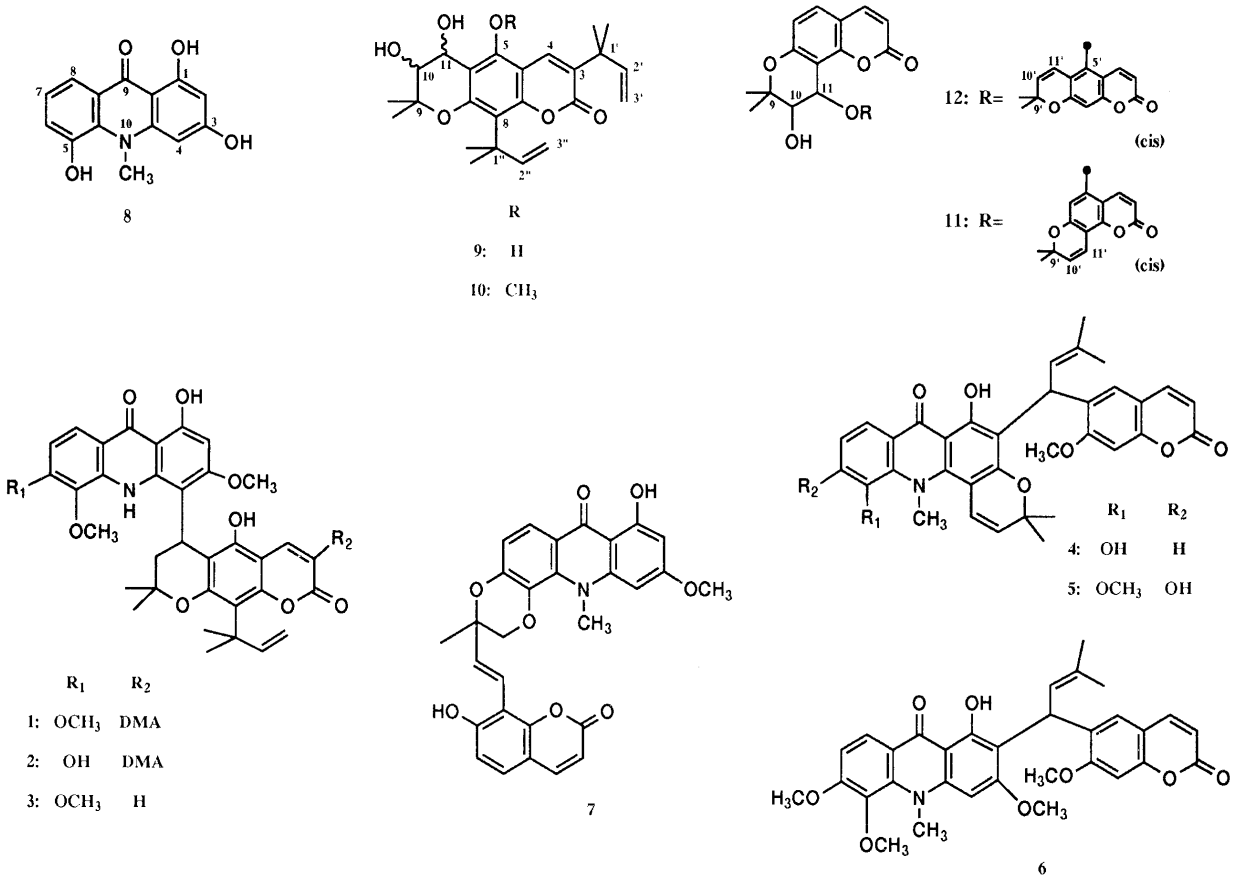



Chart 1

spectrum of **8** showed the characteristic signal of chelated hydroxyl group at $\delta$ 14.64 (1H, s). In the aromatic proton region, ABC-type signals at $\delta$ 7.75 (1H, dd, $J$=7.9, 1.8 Hz), 7.24 (1H, dd, $J$=7.9, 1.8 Hz) and 7.15 (1H, t, $J$= 7.9 Hz) and *meta*-coupled signals at $\delta$ 6.33 and 6.07 (each 1H, d, $J$=1.8 Hz) were observed. Because the lowest signal at $\delta$ 7.75 was considered to be deshielded by 9-carbonyl group, ABC-type signals were assigned to H-8, H-6 and H-7, respectively, and hence the *meta*-coupled signals were deduced as H-4 and H-2. The signal at $\delta$ 3.96 in the $^1$H- and $\delta$ 40.61 in the $^{13}$C-NMR spectrum indicated the presence of an *N*-methyl group. In the nuclear Overhauser effect (NOE) experiment, irradiation of the *N*-methyl signal at $\delta$ 3.96 showed a 12% increment of the signal at $\delta$ 6.33, thus this signal was assigned to H-4. These results led us to conclude the structure **8** for this alkaloid.

*trans*-Clausarinol (**9**) was isolated as a colorless oil, $[\alpha]_D$ $-27.8°$ ($CHCl_3$). The molecular formula was established as $C_{24}H_{30}O_6$ by HR FAB-MS which showed the molecular ion at $m/z$ 415.2076 $[M+H]^+$. The IR (3350, 1705, 1605, 1590 cm$^{-1}$) and UV (212, 269, 290, 327 nm) spectra indicated the presence of a 5,7-dioxygenated coumarin nucleus.[6] In the $^1$H-NMR spectrum of **9**, the signals assignable to two 1,1-dimethylallyl groups [$\delta$ 6.21 (1H, dd, $J$=17.6, 10.7 Hz), 4.87 (1H, d, $J$=17.6 Hz), 4.82 (1H, d, $J$=10.7 Hz), 1.64, 1.58 (each 3H, s), 6.16 (1H, dd, $J$=17.6, 10.7 Hz), 5.07 (1H, d, $J$=17.6 Hz), 5.06 (1H, d, $J$= 10.7 Hz), 1.46 (6H, s)], and characteristic H-4 signal of coumarin skeleton[6] was observed at $\delta$ 7.93 as a singlet. The remaining signals at $\delta$ 4.88, 3.75 (each 1H, d, $J$=8.3 Hz) and 1.21, 1.49 (each 3H, s) in the $^1$H-NMR coupled with the signals at $\delta$ 79.5 (s), 75.4 (d), 70.3 (d), 18.4 (q), 28.9 (q) in the $^{13}$C-NMR spectrum suggested the presence of 3,4-dihydroxy-2,2-dimethyldihydropyran ring.[7] In the heteronuclear multiple-bond connectivity (HMBC) spectrum, the characteristic H-4 signal at $\delta$ 7.93 showed cross peaks with carbons at $\delta$ 152.3 (C-5), 153.3 (C-8a), 160.3 (C-2) and 40.1 (C-1′). The carbon signal at $\delta$ 40.1 showed cross peaks with the methyl signal at $\delta$ 1.46, and the vinyl proton signals at $\delta$ 6.16, 5.06 and 5.07. The aromatic carbon signal at $\delta$ 113.8 due to C-8 showed cross peaks with the methyl signals at $\delta$ 1.64 and 1.58, and the vinyl proton signals at $\delta$ 6.21, 4.82 and 4.87. These results indicated the location of two 1,1-dimethylallyl groups to be at C-3 and C-8. Comparison of $^1$H- and $^{13}$C-NMR data with those of clausarin (**61**)[8] (Table 1) suggested the structure of *trans*-clausarinol to be dihydroxylated clausarin. The relative configuration of H-10 and H-11 was assigned to be *trans* by its relative large $J$-values (8.3 Hz) and no enhancement was observed between these protons in the NOE experiment. To confirm the orientation of the pyran ring, *trans*-clausarinol was treated with diazomethane to give *O*-methyl ether (**10**). In the NOE experiment of **10**, irradiation of the newly generated methoxyl group at $\delta$ 3.94 showed 6% and 5% increments of the signals of H-4 ($\delta$ 7.68) and H-11 ($\delta$ 4.82), respectively. This supported the speculation of the linear structure of the pyran ring and the structure of *trans*-clausarinol was established as

Table 1. $^1$H and $^{13}$C-NMR Data for *trans*-Clausarinol (**9**) and Clausarin (**61**)

| | **9** | | **61** | |
|---|---|---|---|---|
| | $\delta_C$ | $\delta_H$ | $\delta_C$ | $\delta_H$ |
| 2 | 160.3 | | 160.8 | |
| 3 | 128.7 | | 128.5 | |
| 4 | 133.5 | 7.93 (s) | 134.2 | 7.85 (s) |
| 4a | 104.1 | | 104.4 | |
| 5 | 152.3 | | 147.0 | |
| 6 | 104.4 | | 106.4 | |
| 7 | 154.0 | | 155.1 | |
| 8 | 113.8 | | 115.2 | |
| 8a | 153.3 | | 153.2 | |
| 9 | 79.5 | | 79.9 | |
| 9-Me | 18.4 | 1.20 (3H, s) | 27.3 | 1.47 (6H, s) |
| | 26.2 | 1.49 (3H, s) | | |
| 10 | 75.4 | 3.75 (d, 8.3) | 129.3 | 5.67 (d, 9.8) |
| 11 | 70.3 | 4.88 (d, 8.3) | 115.8 | 6.50 (d, 9.8) |
| 1′ | 40.1 | | 40.9 | |
| 1′-Me | 26.2 | 1.46 (6H, s) | 29.5 | 1.63 (6H, s) |
| 2′ | 145.7 | 6.16 (dd, 17.6, 10.7) | 150.1 | 6.29 (dd, 17.6, 10.5) |
| 3′ | 111.8 | 5.06 (d, 10.7) | 107.9 | 4.93 (dd, 17.6, 1.2) |
| | | 5.07 (d, 17.6) | | 4.85 (dd, 10.5, 1.2) |
| 1″ | 41.0 | | 40.2 | |
| 1″-Me | 29.7 | 1.64 (3H, s) | 26.2 | 1.43 (6H, s) |
| | 28.9 | 1.58 (3H, s) | | |
| 2″ | 150.3 | 6.21 (dd, 17.6, 10.7) | 145.6 | 6.18 (dd, 17.6, 10.5) |
| 3″ | 107.6 | 4.82 (d, 10.7) | 111.9 | 5.11 (dd, 17.6, 1.0) |
| | | 4.87 (d, 17.6) | | 5.07 (dd, 10.5, 1.0) |

*J* values in parentheses are expressed in Hz.

**9**, leaving the absolute stereochemistry undetermined.

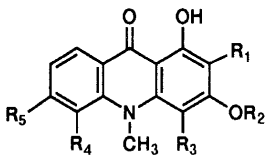
Khelmarin-D (**11**) was obtained as a light yellow oil. The molecular formula $C_{28}H_{24}O_8$ was deduced from the HR-MS. The IR spectrum showed the presence of conjugated carbonyl (1735 cm$^{-1}$) and the UV spectrum showed characteristic absorption maxima at 207, 220 (sh), 285 (sh), 294 and 324 nm, which were ascribable to the 7-oxygenated 8-substituted coumarin moiety.[6] The $^1$H-NMR spectrum showed signals due to two pairs of characteristic H-4 and H-3 of coumarin skeleton [$\delta$ 7.71, 6.02 (each 1H, d, $J$=9.7 Hz), 7.57, 6.14 (each 1H, d, $J$=9.8 Hz)], *ortho*-coupled aromatic protons [$\delta$ 7.38, 6.83 (each 1H, d, $J$=8.7 Hz)], and a lone aromatic proton [$\delta$ 6.76 (1H, s)]. The presence of 2,2-dimethylpyran and 3,4-dioxygenated 2,2-dimethyldihydropyran moieties was suggested by the signals at $\delta$ 6.82, 5.62 (each 1H, d, $J$=10.1 Hz), 1.52, 1.50 (each 3H, s) and by the signals at $\delta$ 5.83 (1H, d, $J$=4.7 Hz), 4.16 (1H, dd, $J$=4.7, 7.4 Hz), 2.43 (1H, d, $J$=7.4 Hz), 1.53, 1.56 (each 3H, s), respectively. These data suggested the dimeric structure composed of khellactone and pyranocoumarin moieties. Comparison of $^1$H-NMR data with that of khelmarin-B (**12**)[9] (Table 2) showed similar signal patterns and the difference in the two compounds was considered to arise from the orientation of the lower part of pyranocoumarin. The signals at $\delta$ 5.83 and 4.16 were assignable to H-11 and H-10 on the 3,4-dioxygenated 2,2-dimethyldihydropyran ring from the chemical shifts,[7] and the presence of hydroxyl group at C-10 was suggested by the coupling constants. In the NOE experiment, irradiation of the signal at $\delta$ 5.83 (H-11) induced 16% and 9% enhancement of the signal at $\delta$ 6.76 (H-6′) and 4.16 (H-10), respectively. When the signal at $\delta$ 4.16 was irradiated, 7% and 2% increments were observed of the signals at $\delta$ 5.83 and 6.76. The results indicated the *cis*-relationships of H-10 and H-11, the angular orientation of the lower pyranocoumarin; the location of the ether linkage was also determined between C-11 and C-5′. On the basis of these spectral data, we proposed the structure **11** for khelmarin-D, the absolute stereochemistry remaining undetermined.

Table 2. $^1$H-NMR Chemical Shifts for Khelmarins-D (**11**) and -B (**12**)

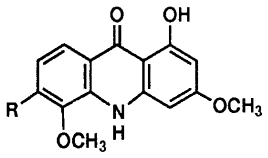
| | **11** | **12** |
|---|---|---|
| H-3 | 6.02 (d, 9.7) | 5.96 (d, 9.5) |
| H-4 | 7.71 (d, 9.7) | 7.43 (d, 9.5) |
| H-5 | 7.38 (d, 8.7) | 7.32 (d, 8.7) |
| H-6 | 6.83 (d, 8.7) | 6.80 (d, 8.7) |
| 9-Me | 1.53 | 1.65 |
| | 1.56 | 1.69 |
| H-10 | 4.16 (dd, 4.7, 7.4) | 4.11 (dd, 4.4, 11.0) |
| 10-OH | 2.43 (d, 7.4) | 2.98 (d, 11.0) |
| H-11 | 5.83 (d, 4.7) | 5.67 (d, 4.4) |
| H-3′ | 6.14 (d, 9.8) | 5.85 (d, 9.5) |
| H-4′ | 7.57 (d, 9.8) | 7.38 (br d, 9.5) |
| H-6′ | 6.76 (s) | |
| H-8′ | | 6.57 (s) |
| 9′-Me | 1.50 | 1.55 |
| | 1.52 | 1.44 |
| H-10′ | 5.62 (d, 10.1) | 5.67 (d, 10.3) |
| H-11′ | 6.82 (d, 10.1) | 6.73 (d, 10.3) |

*J* values in parentheses are expressed in Hz.

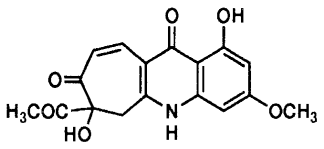
As known compounds, eighteen simple acridone alkaloids; grandisinine (**13**),[10] glycocitrine-I (**14**),[11] citpressine-I (**15**), -II (**16**),[12] citrusinine-I (**17**), -II (**18**),[13] 1,3-dihydroxy-10-methylacridone (**19**), citrusamine (**20**),[14] citramine (**21**),[15] pummeline (**22**),[16] marshmine (**23**),[17] natsucitrine-I (**24**), -II (**25**),[18] citracridone-I (**26**), -II (**27**),[12] -III (**28**),[19] 5-hydroxynoracronycine (**29**),[20] citropone-C (**30**)[21]: an acridone-lignan; acrignine-A (**31**)[22]: thirty-eight monomeric coumarins; scopoletin (**32**),[23] umbelliferone (**33**),[24] osthenol (**34**),[25] 7-demethylsuberosin (**35**),[26] 6-formylumbelliferone (**36**),[27] hydrangetin (**37**),[28] 7-hydroxy-8-(2′-hydroxy-3′-methyl but-3′-enyl) coumarin (**38**),[29] scoparone (**39**),[30] isoscopoletin (**40**),[31] lophopterol (**41**),[32] tamarin (**42**),[33] hopeyhopin (**43**),[34] paniculal (**44**),[35] casegravol (**45**),[36] citrusol (**46**),[37] buntansin (**47**),[38] crenulatin (**48**),[39] suberenon (**49**),[40] (*E*)-suberenol (**50**),[41] osthenon (**51**),[15] seselin (**52**),[42] 5-methoxyseselin (**53**),[10] 5-hydroxyseselin (**54**), *cis*-grandmarin (**55**),[27] *trans*-grandmarin (**56**),[43] junosmarin (**57**),[44] *trans*-khellactone (**58**),[45] xanthyletin (**59**),[46] nordentatin (**60**),[47] clausarin (**61**),[8] xanthoxyletin (**62**),[48] luvangetin (**63**),[49] *cis*-5-methoxydecursidinol (**64**), *trans*-5-methoxydecursidinol (**65**),[50] *cis*-decursidinol (**66**), *trans*-decursidinol (**67**),[51] *trans*-hassanin (**68**), hassanidin (**69**)[50]: one dimeric coumarin; bisosthenon (**70**)[52]: seven acridone-coumarin dimers; acrimarine-B (**71**), -C (**72**), -D (**73**), -E (**74**), -F (**75**),[53] -H (**76**),[43] neoacrimarine-C (**77**)[54]: two flavonoids; yukovanol (**78**)[55] citflavanone (**79**)[56] and three other aromatic compounds; valencic acid (**80**),[56] *p*-hydroxybenzaldehyde (**81**) and *p*-hydroxybenzoic acid (**82**) were also isolated and identified by



| | $R_1$ | $R_2$ | $R_3$ | $R_4$ | $R_5$ |
|---|---|---|---|---|---|
| 13: | H | $CH_3$ | prenyl | $OCH_3$ | OH |
| 14: | H | $CH_3$ | prenyl | OH | H |
| 15: | H | $CH_3$ | H | $OCH_3$ | OH |
| 16: | H | $CH_3$ | H | $OCH_3$ | $OCH_3$ |
| 17: | H | $CH_3$ | $OCH_3$ | OH | H |
| 18: | H | H | $OCH_3$ | OH | H |
| 19: | H | H | H | H | H |
| 20: | H | $CH_3$ | H | OH | H |
| 21: | $OCH_3$ | H | H | $OCH_3$ | OH |
| 22: | H | $CH_3$ | H | H | OH |
| 23: | H | $CH_3$ |  | OH | H |



| R | |
|---|---|
| 24: | OH |
| 25: | $OCH_3$ |



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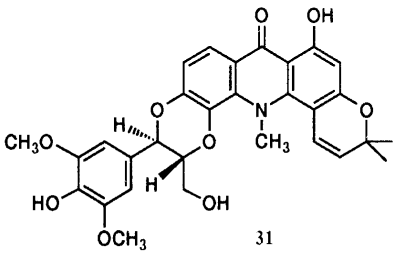

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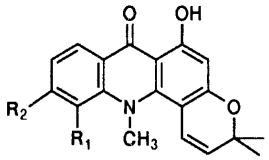
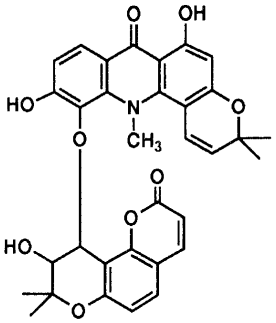


| | $R_1$ | $R_2$ |
|---|---|---|
| 26: | $OCH_3$ | OH |
| 27: | $OCH_3$ | $OCH_3$ |
| 28: | OH | OH |
| 29: | OH | H |



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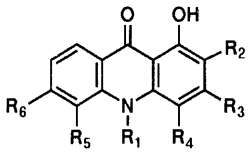
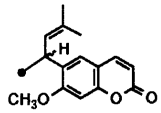


Cou = 

| | $R_1$ | $R_2$ | $R_3$ | $R_4$ | $R_5$ | $R_6$ |
|---|---|---|---|---|---|---|
| 71: | H | Cou | $OCH_3$ | H | $OCH_3$ | $OCH_3$ |
| 72: | H | H | $OCH_3$ | Cou | $OCH_3$ | OH |
| 73: | H | H | $OCH_3$ | Cou | $OCH_3$ | $OCH_3$ |
| 74: | H | Cou | $OCH_3$ | H | $OCH_3$ | OH |
| 75: | $CH_3$ | Cou | $OCH_3$ | H | $OCH_3$ | OH |
| 76: | $CH_3$ | Cou | $OCH_3$ | H | OH | H |

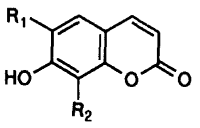
Chart 2

direct comparison with samples isolated previously in our laboratories or spectral data published in the literature.

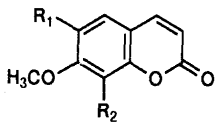
## Experimental

Optical rotations were measured with a JASCO DIP 360 digital polarimeter. $^1H$- and $^{13}C$-NMR spectra were recorded on JEOL GX-270, GX-400 and GSX-500 spectrometers. Chemical shifts are shown on the $\delta$ (ppm) scale with tetramethylsilane (TMS) as an internal reference. HMBC spectra were measured at $J=8$ Hz on the JEOL GX-400 spectrometer. EI- and HR-MS were taken with a Hitachi M-80 spectrometer having a direct inlet system. FAB and HR-FAB MS were measured with a JMS-HX-110 spectrometer. UV spectra were recorded on a Shimadzu UV-160A spectrometer in EtOH, and IR spectra on a Shimadzu IR-450 spectrometer.

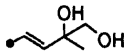
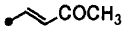
**Extraction and Isolation** The root of Yalaha [several hybrid seedlings resulting from a cross of Duncan grapefruit (*Citrus paradisi* MACF.) × Dancy tangerine (*C. tangerina* HORT. ex TANAKA)] (750 g), cultivated and collected at the Fruit Tree Research Station, were extracted with acetone under reflux. The extract (103.1 g) was subjected to silica gel (2 kg) column chromatography. Successive elution with toluene, $CH_2Cl_2$, acetone and MeOH gave four fractions. Each fraction was further subjected to silica gel column chromatography, preparative centrifugal chromatography, and PTLC [solvent: isopropylether, benzene–acetone (8 : 2), benzene–AcOEt (7 : 3), $CHCl_3$–acetone (9 : 1), hexane–acetone (8 : 2)] to give the following compounds. From the toluene fraction: clausarin (**61**) 0.0106 g, xanthoxyletin (**62**) 0.0452 g, xanthyletin (**59**) 3.9836 g, nordentatin (**60**) 0.0017 g, crenulatin (**48**) 0.0115 g, hassanidin (**69**) 0.0116 g. From the $CH_2Cl_2$ fraction: 5-methoxyseselin (**53**) 0.0160 g, seselin (**52**) 0.043 g, xanthoxyletin (**62**) 0.9126 g, xanthyletin (**59**) 0.0586 g, 7-demethylsuberosin (**35**) 0.0035 g, luvangetin (**63**) 0.0138 g, 5-hydroxyseselin (**54**) 0.0063 g, junosmarin (**57**) 0.0055 g, nordentatin (**60**) 0.4768 g, umbelliferone (**33**) 0.0170 g, crenulatin (**48**) 0.1514 g, osthenol (**34**) 0.0226 g, scopoletin (**32**) 0.1012 g, scoparone (**39**) 0.0122 g, isoscopoletin (**40**) 0.0020 g, lophopterol (**41**) 0.0228 g, osthenon (**51**) 0.0071 g, hopeyhopin (**43**) 0.0296 g, *trans*-5-methoxydecursidinol (**65**) 0.0432 g, *cis*-grandmarin (**55**) 0.0244 g, *trans*-hassanin (**68**) 0.0245 g, buntansin (**47**) 0.0318 g, 7-hydroxy-8-(2′-hydroxy-3′-methyl but-3′-enyl) coumarin (**38**) 0.0050 g, tamarin (**42**) 0.0392 g, hydrangetin (**37**) 0.0038 g, *trans*-clausarinol (**9**) 0.0365 g, khelmarin-D (**11**) 0.0035 g, glycocitrine-I (**14**) 0.0119 g, grandisinine (**13**) 0.0150 g, 5-hydroxynoracronycine (**29**) 0.0111 g, citracridone-I (**26**) 0.1268 g, citpressine-I (**15**) 0.2552 g, citpressine-II (**16**) 0.0204 g, natsucitrine-II (**25**) 0.0074 g, acrimarine-B (**71**) 0.0740 g, acrimarine-D (**73**) 0.0151 g, acrimarine-H (**76**) 0.0016 g, acrimarine-N (**6**) 0.0357 g, neoacrimarine-A (**1**) 0.0105 g, valencic acid (**80**) 0.0071 g, and *p*-hydroxybenzaldehyde (**81**) 0.0017 g. From the $CH_2Cl_2$-acetone eluate: clausarin (**61**) 0.0106 g, xanthoxyletin (**62**) 0.0441 g, xanthyletin (**59**) 0.0075 g, luvangetin (**63**) 0.0002 g, 5-hydroxyseselin (**54**) 0.0046 g, junosmarin (**57**) 0.1369 g, nordentatin (**60**) 0.2005 g, umbelliferone (**33**) 0.0313 g, crenulatin (**48**) 0.2598 g, osthenol (**34**) 0.0107 g, scopoletin (**32**) 0.1453 g, scoparone (**39**) 0.0105 g, isoscopoletin (**40**) 0.0019 g, 6-formylumbelliferone (**36**) 0.0028 g, lophopterol (**41**) 0.0844 g, osthenon (**51**) 0.0038 g, suberenon (**49**) 0.0283 g, (*E*)-suberenol (**50**) 0.1349 g, hopeyhopin (**43**) 0.0017 g, paniculal (**44**) 0.0015 g, *cis*-5-methoxydecursidinol (**64**) 0.0207 g, *trans*-5-methoxydecursidinol (**65**) 0.1513 g, *cis*-decursidinol (**66**) 0.0338 g, *trans*-decursidinol (**67**) 0.2183 g, *cis*-grandmarin (**55**) 0.0407 g, *trans*-grandmarin (**56**) 0.0290 g, *trans*-hassanin (**68**) 0.0022 g, citrusol (**46**) 0.1415 g, buntansin (**47**) 0.1061 g, tamarin (**42**) 0.0035 g, *trans*-khellactone (**58**) 0.0010 g, casegravol (**45**) 0.0035 g, bisosthenon (**70**) 0.0072 g, khelmarin-D (**11**) 0.0069 g, glycocitrine-I (**14**) 0.0340 g, grandisinine (**13**) 0.1286 g, 5-hydroxynoracronycine (**29**) 0.1465 g, citracridone-I (**26**) 0.4575 g, citracridone-II (**27**) 0.0382 g, citracridone-III (**28**) 0.0506 g, citpressine-I (**15**) 0.2860 g, citpressine-II (**16**) 0.0440 g, natsucitrine-I (**24**) 0.0412 g,

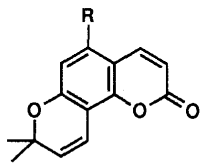


| | $R_1$ | $R_2$ |
|---|---|---|
| 32: | $OCH_3$ | H |
| 33: | H | H |
| 34: | H | prenyl |
| 35: | prenyl | H |
| 36: | CHO | H |
| 37: | H | $OCH_3$ |
| 38: | H |  |

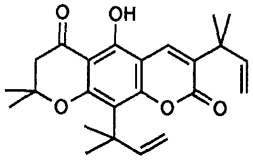


| | $R_1$ | $R_2$ |
|---|---|---|
| 39: | $OCH_3$ | H |
| 40: | OH | H |
| 41: |  | H |
| 42: |  | H |
| 43: |  | H |
| 44: | H | CHO |

| | $R_1$ | $R_2$ |
|---|---|---|
| 45: | H |  |
| 46: |  | H |
| 47: | COOH | H |
| 48: | CHO | H |
| 49: |  | H |
| 50: |  | H |
| 51: | H |  |



| | R |
|---|---|
| 52: | H |
| 53: | $OCH_3$ |
| 54: | OH |



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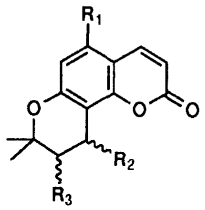
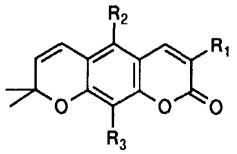
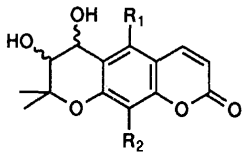


| | $R_1$ | $R_2$ | $R_3$ | |
|---|---|---|---|---|
| 55: | $OCH_3$ | OH | OH | (cis) |
| 56: | $OCH_3$ | OH | OH | (trans) |
| 57: | H | OH | $OCOCH_2CH(CH_3)_2$ | (trans) |
| 58: | OH | OH | H | (trans) |

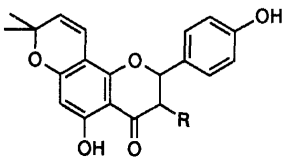


| | $R_1$ | $R_2$ | $R_3$ |
|---|---|---|---|
| 59: | H | H | H |
| 60: | H | OH | DMA |
| 61: | DMA | OH | DMA |
| 62: | H | $OCH_3$ | H |
| 63: | H | H | $OCH_3$ |



| | $R_1$ | $R_2$ | |
|---|---|---|---|
| 64: | $OCH_3$ | H | (cis) |
| 65: | $OCH_3$ | H | (trans) |
| 66: | H | H | (cis) |
| 67: | H | H | (trans) |
| 68: | $OCH_3$ | DMA | (trans) |

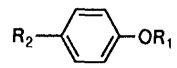
DMA = 1,1-dimethylallyl



R

78: OH

79: H



| | $R_1$ | $R_2$ |
|---|---|---|
| 80: | prenyl | COOH |
| 81: | H | CHO |
| 82: | H | COOH |

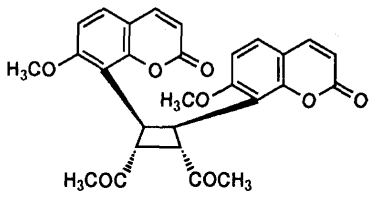


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Chart 3

natsucitrine-II (**25**) 0.1094 g, citrusinine-I (**17**) 0.0834 g, citrusinine-II (**18**) 0.0046 g, citrusamine (**20**) 0.0248 g, citramine (**21**) 0.0040 g, pummeline (**22**) 0.0015 g, 1,3-dihydroxy-10-methylacridone (**19**) 0.0149 g, marshmine (**23**) 0.0079 g, citropone-C (**30**) 0.0996 g, acrignine-A (**31**) 0.0079 g, 1,3,5-trihydroxy-10-methylacridone (**8**) 0.0007 g, acrimarine-B (**71**) 0.3212 g, acrimarine-C (**72**) 0.0270 g, acrimarine-D (**73**) 0.0450 g, acrimarine-E (**74**) 0.0697 g, acrimarine-F (**75**) 0.0415 g, acrimarine-H (**76**) 0.0036 g, acrimarine-I (**4**) 0.0063 g, acrimarine-J (**5**) 0.0177 g, acrimarine-N (**6**) 0.0030 g, neoacrimarine-A (**1**) 0.0768 g, neoacrimarine-B (**2**) 0.0159 g, neoacrimarine-C (**77**) 0.0154 g, neoacrimarine-E (**3**) 0.0261 g, dioxinoacrimarine-A (**7**) 0.0039 g, yukovanol (**78**) 0.0014 g, citflavanone (**79**) 0.0009 g, valencic acid (**80**) 0.0084 g, *p*-hydroxybenzoic acid (**82**) 0.0047 g, and *p*-hydroxybenzaldehyde (**81**) 0.0045 g. From the acetone and MeOH fraction: xanthoxyletin (**62**) 0.0061 g, umbelliferone (**33**) 0.0100 g, crenulatin (**48**) 0.0051 g, scopoletin (**32**) 0.0069 g, lophopterol (**41**) 0.0037 g, *cis*-5-methoxydecursidinol (**64**) 0.0028 g, *trans*-5-methoxydecursidinol (**65**) 0.0216 g, *cis*-decursidinol (**66**) 0.0157 g, *trans*-decursidinol (**67**) 0.0757 g, *trans*-grandmarin (**56**) 0.0424 g, citrusol (**46**) 0.0746 g, and buntansin (**47**) 0.0029 g.

**1,3,5-Trihydroxy-10-methylacridone (8)** Yellow oil. UV $\lambda_{max}^{EtOH}$ nm: 202, 261, 282 (sh), 300 (sh), 305 (sh), 340 (sh). IR $\nu_{max}^{CHCl_3}$ $cm^{-1}$: 1710, 1520, 1475, 1420. HR-MS Calcd for $C_{14}H_{11}NO_4$ 257.0688. Found: 257.0690. EI-MS *m/z*: 257 ($M^+$, base peak), 243, 242, 214. $^1$H-NMR (DMSO-$d_6$) $\delta$: 14.64 (1H, s), 10.58 (1H, br s), 10.39 (1H, br s), 7.75 (1H, dd, $J$=7.9, 1.8 Hz), 7.24 (1H, dd, $J$=7.9, 1.8 Hz), 7.15 (1H, t, $J$=7.9 Hz), 6.33 (1H, d, $J$=1.8 Hz), 6.07 (1H, d, $J$=1.8 Hz), 3.96 (3H, s). $^{13}$C-NMR (DMSO-$d_6$) $\delta$: 179.50 (C-9), 164.72 (C-3), 164.21 (C-1), 147.27 (C-4a or C-5), 147.09 (C-5 or C-4a), 133.34 (C-10a), 122.97 (C-8a), 122.24 (C-7), 119.87 (C-6), 115.78 (C-8), 103.67 (C-9a), 95.66 (C-4), 91.17 (C-2), 40.61 (N-Me).

***trans*-Clausarinol (9)** Colorless oil. $[\alpha]_D$ −27.8° ($c$=0.072, $CHCl_3$). HR FAB-MS Calcd for $C_{24}H_{31}O_6$ 415.2121 $[M+H]^+$. Found: 415.2076. EI-MS *m/z*: 414 ($M^+$), 412, 396 (base peak), 381, 327, 299. UV $\lambda_{max}^{EtOH}$ nm: 212, 269, 290, 327. IR $\nu_{max}^{CHCl_3}$ $cm^{-1}$: 3350, 1705, 1605, 1590.

$^1$H- and $^{13}$C-NMR ($CDCl_3$): see Table 1.

***O*-Methyl *trans*-Clausarinol (10)** Ethereal diazomethane (10 ml) prepared in the usual manner was added to a solution of *trans*-clausarinol (**9**) (11.3 mg) in 5 ml of methanol, and the mixture was allowed to stand overnight at room temperature. The solvent was evaporated, and the residue was subjected to PTLC [benzene–acetone (8 : 2)] to give **10** (7.6 mg) as a colorless oil, $[\alpha]_D$ −46.9° ($c$=0.128, $CHCl_3$). HR-MS Calcd for $C_{25}H_{32}O_6$ 428.2199. Found 428.2198. EI-MS $m/z$: 428 ($M^+$), 413, 395, 356, 341 (base peak), 313, 301, 285. UV $\lambda_{max}^{EtOH}$ nm: 213, 257, 265, 330. IR $\nu_{max}^{CHCl_3}$ cm$^{-1}$: 3400, 1715, 1600. $^1$H-NMR ($CDCl_3$) $\delta$: 7.68 (1H, s), 6.24 (1H, dd, $J$=17.5, 10.7 Hz), 6.17 (1H, dd, $J$=17.5, 10.7 Hz), 5.11 (1H, dd, $J$=0.8, 10.7 Hz), 5.09 (1H, dd, $J$=1.3, 17.5 Hz), 4.90 (1H, dd, $J$=0.9, 17.5 Hz), 4.85 (1H, dd, $J$=1.3, 10.7 Hz), 4.82 (1H, d, $J$=7.3 Hz), 3.94 (3H, s), 3.72 (1H, d, $J$=7.3 Hz), 1.66 (3H, s), 1.63 (3H, s), 1.49 (3H, s), 1.48 (6H, s), 1.26 (3H, s). $^{13}$C-NMR ($CDCl_3$) $\delta$: 159.10 (s), 154.26 (s), 154.03 (s), 153.18 (s), 149.81 (d), 145.48 (d), 132.06 (d), 131.18 (s), 119.06 (s), 114.62 (s), 112.25 (t), 108.10 (t), 107.79 (s), 79.05 (s), 75.05 (d), 68.34 (d), 62.63 (q), 41.45 (s), 40.40 (s), 29.73 (q), 28.93 (q), 26.09 (q), 26.06 (q), 25.66 (q), 19.15 (q).

**Khelmarin-D (11)** Light yellow oil. $[\alpha]_D$ +32.7° ($c$=0.2355, $CHCl_3$). HR-MS Calcd for $C_{28}H_{24}O_8$: 488.1471. Found: 488.1470. EI-MS $m/z$: 488 ($M^+$), 331, 245, 244, 229 (base peak), 203. UV $\lambda_{max}^{MeOH}$ nm: 207, 220 (sh), 285 (sh), 294, 324. IR $\nu_{max}^{CHCl_3}$ cm$^{-1}$: 3500, 1735, 1610. $^1$H-NMR ($CDCl_3$): see Table 2.

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