Spectrometric Elucidation of Acrimarines, the First Naturally Occurring Acridone–Coumarin Dimers†

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The structures of acrimarine-A (**1**), -B (**2**), -C (**3**), -D (**4**), -E (**5**), -F (**6**), and -G (**7**), novel acridone alkaloids carrying a coumarin unit, from the root of *Citrus funadoko* have been elucidated by spectrometric studies using ^{1}H-^{13}C long-range COSY experiments; acrimarine-A (**1**) and -F (**6**) have also been synthesized from the corresponding acridones and coumarins.

Citrus plant (Rutaceae) roots contain many kinds of coumarins.[1] We have previously shown that some plants of this genus also contain acridone alkaloids[2] as well as coumarins. In our continuing phytochemical studies of *Citrus* plants,[2,3] we have isolated seven novel acridone–coumarin dimers, named acrimarine-A (**1**), -B (**2**), -C (**3**), -D (**4**), -E (**5**), -F (**6**), and -G (**7**) from the root of *C. funadoko* Hort. ex. Y. Tanaka (funadoko), a natural hybrid of the Sweet orange (Rutaceae) cultivated in Japan. This is the first report of the occurrence of acridone–coumarin dimers in Nature, and we report here the structural elucidation of these novel alkaloids.

An acetone extract of the root of *C. funadoko* was fractionated by a combination of silica gel column and preparative thin layer chromatographies as shown in the Scheme to give the new alkaloids, named acrimarines, along with known acridones and coumarins.

Structure of Acrimarine-A (**1**).—Acrimarine-A (**1**) was obtained as a pale yellow oil, $[\alpha]_D$ −9.76° (chloroform), and the molecular formula was determined as $C_{31}H_{29}NO_8$ by a high resolution mass spectrum. The NMR spectra of (**1**) in H-H and H-C COSY (correlation spectroscopy) revealed the presence of three methoxy, one *N*-methyl, and two vinyl methyl groups (Table). The observation of a strongly hydrogen-bonded proton signal at δ_H 15.08, a lower methyl proton signal at δ_H 3.95, and a carbonyl and an *N*-methyl carbon signal at δ_C 180.4 and 40.0, respectively in the ^{1}H or ^{13}C NMR spectra, together with UV absorptions and a strong IR band at ν_{max} 1 620 cm^{-1} suggested the presence of 1-hydroxy-*N*-methyl-9-acridone system in this alkaloid. Additionally, a coumarin nucleus in the molecule was shown by the appearance of AB-type proton signals at δ_H 6.22 and 7.64 (*J* 9.4 Hz), a lactone carbonyl carbon signal at δ_C 161.3, and an IR band at ν_{max} 1 730 cm^{-1}. In the aromatic proton region of the ^{1}H NMR spectrum, *ortho*-coupled doublets [δ_H 6.94 and 8.17 (*J* 9.2 Hz)] and three 1 H singlets (δ_H 6.35, 6.78, and 7.62) were observed. The lower field doublet at δ_H 8.17 was characteristic of 8-H in the acridone,[4] and a singlet at δ_H 7.62 was assignable to 5′-H in the coumarin.[1] The remaining NMR signals at δ_H 5.53 and 5.97 (each 1 H doublet, coupled to each other, *J* 7.8 Hz) accompanied with two vinyl methyls (δ_H 1.65 and 1.81) indicated the presence of a prenyl group connected with two aryl entities. The mass spectrum also supported this structural feature in showing two prominent ions at *m/z* 242 ($C_{15}H_{14}O_3$, 29%) and 301 ($C_{16}H_{15}NO_5$, 100%) corresponding to coumarin and acridone units, respectively, and together they comprise the molecular ion (*m/z* 543). In nuclear Overhauser effect (NOE) experiments, irradiation of the doublet at δ_H 5.53 (1″-H) gave a 7% enhancement of the singlet at δ_H 7.62 (5′-H), as well as the doublet at δ_H 5.97 (2″-H) and, inversely, irradiation of the doublet at δ_H 5.97 (2″-H) gave 6 and 7% enhancements of the signals at δ_H 5.53 (1″-H) and 7.62 (5′-H), respectively. These data indicated the location of the prenyl entity in the coumarin unit at C-6′. Further, irradiation of the *N*-methyl (δ_H 3.95) and *O*-methyl (δ_H 3.92 and 4.00) signals showed 8, 9, and 11% enhancements of the signals at δ_H 6.35 (4-H), 6.78 (8′-H), and 6.94 (7-H), respectively, indicating the location of the prenyl group in the acridone skeleton at C-2 (not C-4) and two methoxys at C-7′ and C-6. No NOE enhancement at any aromatic protons was observed on irradiation of the methoxy protons at δ_H 3.75 (C-5). The above data were in accordance with structure (**1**) for acrimarine-A. In agreement with this proposition, we applied the ^{1}H-^{13}C long range COSY to acrimarine-A (**1**). The H-bonded proton signal at δ_H 15.08 showed long-range correlations with the carbon signals at δ_C 162.7 (1-C), 109.1 (2-C), and 104.8 (9a-C). Further, the proton signal at δ_H 5.53 (1″-H) was correlated with carbon signals at δ_C 162.7 (1-C), 109.1 (2-C), 161.3 (3-C), 128.6 (5′-C), and 129.4 (6′-C). Other long-range correlations observed are shown by arrows in the Figure (a). On the basis of these results, the structure of acrimarine-A is proposed as (**1**). Structural components of acrimarine-A (**1**) are the previously known acridone, grandisine-II (**8**)[5] and a coumarin, suberosin (**12**),[6] both were isolated from the same plant. Next, we tried to synthesize acrimarine-A (**1**) from these acridone and coumarin units. The haematoporphyrin-sensitized photo-oxygenation of suberosin (**12**) derived from umbelliferone (**13**) by Cairns synthetic route,[7] followed by treatment with triphenylphosphine gave the isomeric alcohols (**14**) and (**15**). One of the reaction products was identical with a natural specimen of suberenol (**14**).[8] An ethanolic solution of (**14**) and grandisine-II (**8**) isolated from *C. grandis*[5] was stirred at room temperature in the presence of

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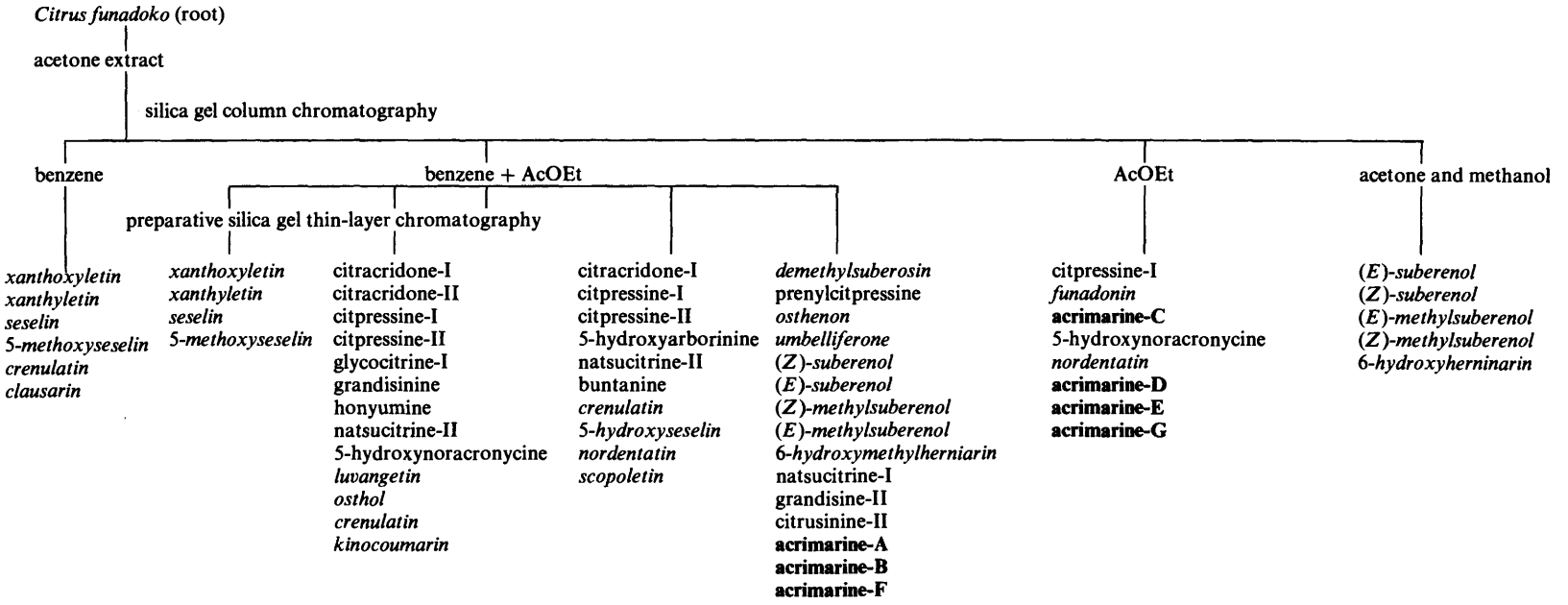


Scheme. Isolation procedure of new acrimarines from the roots of *Citrus funadoko*.

Table. ^1H and ^{13}C NMR spectra of acrimarines.

	1		2		3		4		5		6		7	
	δ_H	δ_C	δ_H	δ_C	δ_H	δ_C	δ_H	δ_C	δ_H	δ_C	δ_H	δ_C	δ_H	δ_C
1-OH	15.08	162.7	14.32	161.4	14.47	163.7	14.49	163.9	14.31	161.4	15.96	162.4	15.24	164.1
2		109.1		111.5	6.34	93.0	6.32	92.8		111.5		112.0		106.1
3		161.3		163.7		162.9		162.9		163.6		164.1		162.4
3-OMe			3.85	55.9	3.90	56.1	3.89*	56.2*	3.84	55.9	3.98*	55.9*		
4	6.35	92.3	6.19	87.3		105.3		105.3	6.20	87.4	6.46	88.3	6.47	92.4
4a		146.1		140.9		139.4		139.6		140.7		146.4		135.1*
5		136.9		133.6		132.4		134.0		135.0		136.3		148.2
5-OMe	3.75	61.3	4.01*	61.0	3.84	60.8	3.84*	60.7	3.98	61.2	3.78	60.9		
6		157.6		154.7*		152.4		154.8		154.2		157.8	7.28 d (8.1)	121.2
6-OMe	4.00	56.3*	4.00*	55.7			3.99*	56.0*						
7	6.94 d (9.2)	107.3	6.90 d (9.1)	107.3	6.84 d (9.1)	112.1	6.90 d (9.2)	107.2	6.84 d (8.8)	111.9	7.21 d (8.8)	112.8	7.12 t (8.1)	123.2
8	8.17 d (9.2)	123.2	8.06 d (9.1)	122.3	7.95 d (9.1)	122.7	8.05 d (9.2)	122.1	8.00 d (8.8)	123.0	8.45 d (8.8)	123.5	7.90 d (8.1)	118.5
8a		117.5		115.2		113.9		114.4		115.0		117.0		125.2
9		180.4		181.0		181.3		181.6		180.8		180.8		181.8
9a		104.8		104.3		104.2		104.3		104.4		105.6		114.3
10a		138.4		134.9		135.6		135.4		132.2		139.4		132.6*
N-Me	3.95	40.0									3.93*	40.0	4.02	41.5
N-H			8.45		9.05		9.09		8.34					
2′		161.3		161.9		161.5		161.2				161.3		161.8
3′	6.22 d (9.4)	113.0	6.20 d (9.4)	112.2	6.23 d (9.4)	113.1	6.25 d (9.4)	113.1	6.21 d (9.4)	112.2	6.31 d (9.4)	113.8	6.15 d (9.5)	113.6
4′	7.64 d (9.4)	143.9	7.66 d (9.4)	144.4	7.66 d (9.4)	143.8	7.65 d (9.4)	143.6	7.68 d (9.4)	144.4	7.82 d (9.4)	144.6	7.88 d (9.5)	145.6
4′a		112.3		112.2		112.1		112.0		111.5		112.2		112.9
5′	7.62	128.6	7.56	128.3	7.48	127.3	7.47	127.3	7.57	128.4	8.05	129.2	7.73	131.5
6′		129.4		130.8		129.1		129.1		130.5		130.5		111.6
7′		159.8		160.9		160.7		160.8		160.9		160.3		147.3
7′-OMe	3.92	56.2*	3.75	56.2	3.76	56.1	3.77*	56.6*	3.74	55.7	3.73	56.1*	3.87	57.0
8′	6.78	99.0	6.68	98.4	6.73	99.2	6.76	99.2	6.67	98.4	6.86	98.9	6.83	99.7
8′a		154.4		154.4*		154.7		154.8		152.0		154.9		155.8
1″	5.53 d (7.8)	34.0	5.71 d (9.4)	32.7	5.67 d (7.4)	34.1	5.67 d (7.8)	34.2	5.72 d (9.4)	32.7	6.27 d (7.4)	33.3	5.83 d (8.8)	34.2
2″	5.97 d (7.8)	123.0	5.96 d (9.4)	124.4	5.76 d (7.4)	123.1	5.77 d (7.8)	123.1	5.96 d (9.4)	124.4	6.47 d (7.4)	126.0	6.09 d (8.8)	126.8
3″		136.9		132.8		136.2		136.0		132.8		132.1		132.5
3″-Me	1.65	18.4	1.70	18.1	1.64	18.3	1.64	18.2	1.70	18.1	1.83	18.3	1.73	18.7
	1.81	25.8	1.79	26.0	1.82	25.9	1.82	26.0	1.79	25.9	1.90	26.0	1.75	26.5

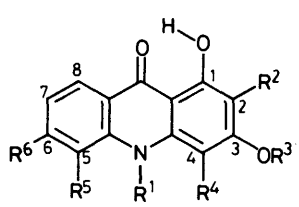
Values are in δ ppm. Figures in parentheses are coupling constant (J) in Hz. * Values with this superscript can be interchanged.

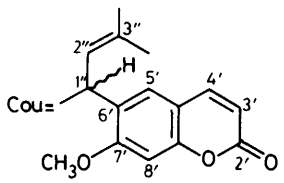
Nafion-H (solid) to afford (**1**) in 75% yield, which was found to be identical with natural acrimarine-A by IR, ^1H NMR, and co-TLC comparisons. On the basis of the spectral and chemical results stated above, we assigned structure (**1**) to acrimarine-A leaving the absolute stereochemistry undetermined.

Structure of Acrimarine-B (**2**).—Acrimarine-B (**2**) was obtained as yellow prisms, m.p. 288–290 °C, $[\alpha]_D$ −7.14° (chloroform). The mass spectrum showed the molecular ion at m/z 543 analyzing for $C_{31}H_{29}NO_8$, isomeric with acrimarine-A (**1**), and displayed important fragments at m/z 242 and 301, the same as those in (**1**). The ^1H NMR features were also similar to those of (**1**), and indicated a lower field singlet at δ_H 14.32, characteristic of an H-bonded OH attached to C-1 in the 9-acridone, *ortho*-coupled proton doublets at δ_H 6.90 and 8.06 (each 1 H, J 9.1 Hz) assignable to 7-H and 8-H, three singlets at δ_H 6.19 (4 or 2-H), 7.56 (5′-H), and 6.68 (8′-H), two AB-type signals at δ_H 6.20 and 7.66 (each 1 H, d, J 9.4 Hz), and δ_H 5.71 and 5.96 (each 1 H d, J 9.4 Hz)] due to 3′-H and 4′-H in the coumarin, and 1″-H and 2″-H in a prenyl entity, respectively. The presence of two vinyl methyls and four methoxy groups were also revealed. However, the ^{13}C NMR spectrum lacked the signal owing to an *N*-methyl group, and the ^1H NMR spectrum showed a singlet at δ_H 8.45 assignable to the NH group. In differential NOE experiments, irradiation of methoxy signals at δ_H 4.01 (and 4.00), 3.85, and 3.75 gave 12, 17, and 21% enhancements of the aromatic proton signals at δ_H 6.90 (d, 7-H), 6.19 (s, 4-H), and 6.68 (s, 8′-H), respectively, and irradiation of the NH proton signal (δ_H 8.45) induced an 11% enhancement of the aromatic proton singlet at δ_H 6.19 (4-H) indicating the location of the prenylcoumarin entity at C-2.

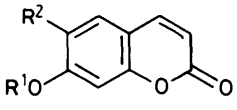
The results of the ^1H-^{13}C long-range COSY spectrum as shown by arrows in the Figure (b) established the structure of acrimarine-B as (**2**), except for the absolute stereochemistry. Acrimarine-B (**2**) corresponds to a dimer of suberosin (**12**) and the des-*N*-methyl analogue of citpressine-II (**9**)[9] which also co-occurred in the same plant.

Structure of Acrimarine-C (**3**).—Acrimarine-C (**3**) was isolated as a pale yellow oil, $[\alpha]_D$ −6.17° (chloroform), and gave a molecular ion at m/z 529 which corresponded to $C_{30}H_{27}NO_8$, a difference of CH_2 compared with (**1**) or (**2**). The characteristic mass fragments appeared at m/z 242 ($C_{15}H_{14}O_3$, 37%) and 287 ($C_{15}H_{13}NO_5$, 100%) shifted 14 mass unit compared with those of (**1**) or (**2**). The ^1H NMR signal pattern resembled that of (**2**) (Table), except for a lack of one methoxy group, indicating the presence of suberosin (**12**) and 1,3,5,6-oxygenated 9-acridone units in acrimarine-C, similar to (**2**). In NOE experiments,

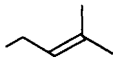




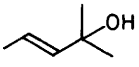
	R_1	R_2	R_3	R_4	R_5	R_6
(1)	Me	Cou	H	H	OMe	OMe
(2)	H	Cou	Me	H	OMe	OMe
(3)	H	H	Me	Cou	OMe	OH
(4)	H	H	Me	Cou	OMe	OMe
(5)	H	Cou	Me	H	OMe	OH
(6)	Me	Cou	Me	H	OMe	OH
(7)	Me	Cou	H	H	OH	H
(8)	Me	H	H	H	OMe	OMe
(9)	Me	H	Me	H	OMe	OMe
(10)	Me	H	Me	H	OMe	OH
(11)	Me	H	Me	H	OH	H



(12) R_1 = Me, R_2 =

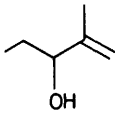


(13) $R_1 = R_2$ = H



(14) R_1 = Me, R_2 =

(15) R_1 = Me, R_2 =



irradiation of methoxy protons at δ_H 3.76 and 3.90 resulted in 11 and 15% increases of the signals at δ_H 6.73 (8′-H) and 6.34 (2- or 4-H), respectively. However, no NOE enhancement was observed on irradiation of a methoxy signal at δ_H 3.84. A characteristically different feature from (**1**) or (**2**) in the NOE experiments appeared on irradiation of the NH proton at δ_H 9.05 and a doublet at δ_H 5.67 (1″-H). Irradiation of the NH singlet (δ_H 9.05) gave 8 and 7% increases both of a pair of doublets at δ_H 5.67 (1″-H) and 5.76 (2″-H), respectively. Inversely, 4 and 6% increases of the NH singlet appeared in each case on irradiation of a pair of doublets at δ_H 5.67 (1″-H) and 5.76 (2″-H), respectively. These data indicated the location of a suberosin (**12**) unit at C-4 in the acridone nucleus. In order to confirm this, LSPD and ^1H-^{13}C long-range COSY experiments were carried out. In an LSPD experiment, the double-doublet at δ_C 93.0 collapsed to a doublet on irradiation of the H-bonded proton at δ_H 14.47. In the ^1H-^{13}C long-range COSY spectrum, an observation of correlation between the H-bonded proton at δ_H 14.47 and carbon at δ_C 93.0 bearing a proton with δ_H 6.34 (2-H) strongly supported the location of the suberosin (**12**) unit at C-4 as in (**3**). Other results of the ^1H-^{13}C long-range COSY [see arrows in the Figure (c)] also supported structure (**3**) for acrimarine-C corresponding to a dimer between suberosin (**12**), a common structural component of acrimarines, and the des-*N*-methylated analogue of citpressine-I (**10**).[9] The absolute stereochemistry remains to be determined.

Structure of Acrimarine-D (**4**).—Acrimarine-D (**4**), $[\alpha]_D$ −3.0° (chloroform), was isolated as a yellow oil and the molecular formula $C_{31}H_{29}NO_8$, the same as that of acrimarine-B (**2**), was determined by a high resolution mass spectrum. The ^1H and ^{13}C NMR spectra were shown to be good similarities with those of (**3**), except for an additional methoxy signal and small chemical-shift differences of some signals (see Table) indicating the presence of the suberosin (**12**) and 1,3,5,6-oxygenated 9-acridone units in the molecule. The location of the prenyl side chain at C-4 in the acridone and at C-6′ in the coumarin moiety were indicated by the following spectral evidence: (*a*) In the nuclear Overhauser enhancement and exchange spectroscopy (NOESY) spectrum, a cross peak between an NH signal at δ 9.09 and the signal at δ 5.67 assignable to 1″-H was appeared. (*b*) In the ^1H-^{13}C long-range COSY spectrum, correlations for an H-bonded proton (δ_H 14.49) to 2-C (δ_C 92.8) and 1″-H (δ_H 5.67) to 5′-C (δ_C 127.3) were observed. Other results of the ^1H-^{13}C long-range COSY spectrum are shown in the Figure (d) by arrows. On the basis of these results, structure (**4**) was assigned to acrimarine-D, the absolute stereochemistry remaining undetermined.

Structure of Acrimarine-E (**5**).—Acrimarine-E (**5**) was obtained as pale yellow prisms, m.p. 274–276 °C, $[\alpha]_D$ +20.1° (acetone); a high resolution mass spectral analysis showed that the molecular formula was $C_{30}H_{27}NO_8$, corresponding to that of the demethyl derivative of (**2**) or (**4**). The ^1H NMR features of this alkaloid were similar with those of acrimarine-B (**2**) except for a lack of a methoxy signal among two lower field C-5 and C-6 methoxys at δ 4.00 and 4.01, respectively in the spectrum of (**2**). In the NOE experiments, irradiation of methoxy signals at δ 3.74 and 3.84 showed 23 and 19% increases of signals at δ 6.67 (8′-H) and 6.20 (2-H or 4-H), respectively. However, no enhancement of the signal for 7-H at δ 6.84 was observed on irradiation of a lower methoxy signal at δ 3.98. Irradiation of an NH proton (δ 8.34) resulted in a 10% enhancement of the signal at δ 6.20 assignable to 4-H; this indicated the location of a coumarin unit at C-2 in the acridone system. These results led us to assign structure (**5**) to acrimarine-E, the absolute stereochemistry remaining undetermined.

Structure of Acrimarine-F (**6**).—Acrimarine-F (**6**) was isolated as a pale yellow powder, $C_{31}H_{29}NO_8$. The ^1H and/or ^{13}C NMR spectra, which was measured in [$^2H_5$]-pyridine for low solubilities both in $CDCl_3$ and [$^2H_6$]acetone showed the presence of an H-bonded hydroxy, three methoxys, an *N*-methyl, and two vinyl methyls (Table). Among remaining signals, three AB-type doublets were assignable to pairs of 3′-H and 4′-H, 7-H and 8-H, and 1″-H and 2″-H, and three 1H-singlets to 4-H (or 2-H), 5′-H, and 8′-H (Table). In NOE experiments, irradiation of 3H-singlets at δ 3.93 and 3.98 gave 10 and 14% enhancements of the signal at δ 6.46 assignable to 4-H, respectively, and irradiation of a methoxy signal at δ 3.73 showed a 16% increase of the signal of 8′-H (δ 6.86). These results suggested structure (**6**) for acrimarine-F, corresponding to an *N*-methyl derivative of acrimarine-E (**5**). The reaction between suberenol (**14**) and citpressine-I (**10**) isolated from *C. depressa* in the presence of Nafion-H (solid) gave (**6**) in 68% yield, which was found to be identical with natural acrimarine-F by ^1H NMR and IR comparisons.

Structure of Acrimarine-G (**7**).—Acrimarine-G (**7**) was obtained as a yellow oil, $[\alpha]_D$ +8.0° (chloroform). The molecular formula was established as $C_{29}H_{25}NO_7$ by a high resolution mass spectrum using fast atom bombardment (FAB) mass spectrometry. The ^1H and ^{13}C NMR in H-C COSY spectra (Table) coupled with the observation of 19% NOE enhancement between a methoxy signal at δ 3.87 and a 1H-singlet at δ 6.83 revealed, as in other acrimarines, the presence of a 6-prenylated 7-methoxycoumarin entity. An H-bonded hydroxy, and *N*-methyl, and two D_2O exchangeable proton signals due to two hydroxy groups were also observed. The proton decoupling experiments of aromatic protons at δ 7.28 (d, *J* 8.1 Hz), 7.12 (t, *J* 8.1 Hz), and 7.90 (d, *J* 8.1 Hz) indicated these were

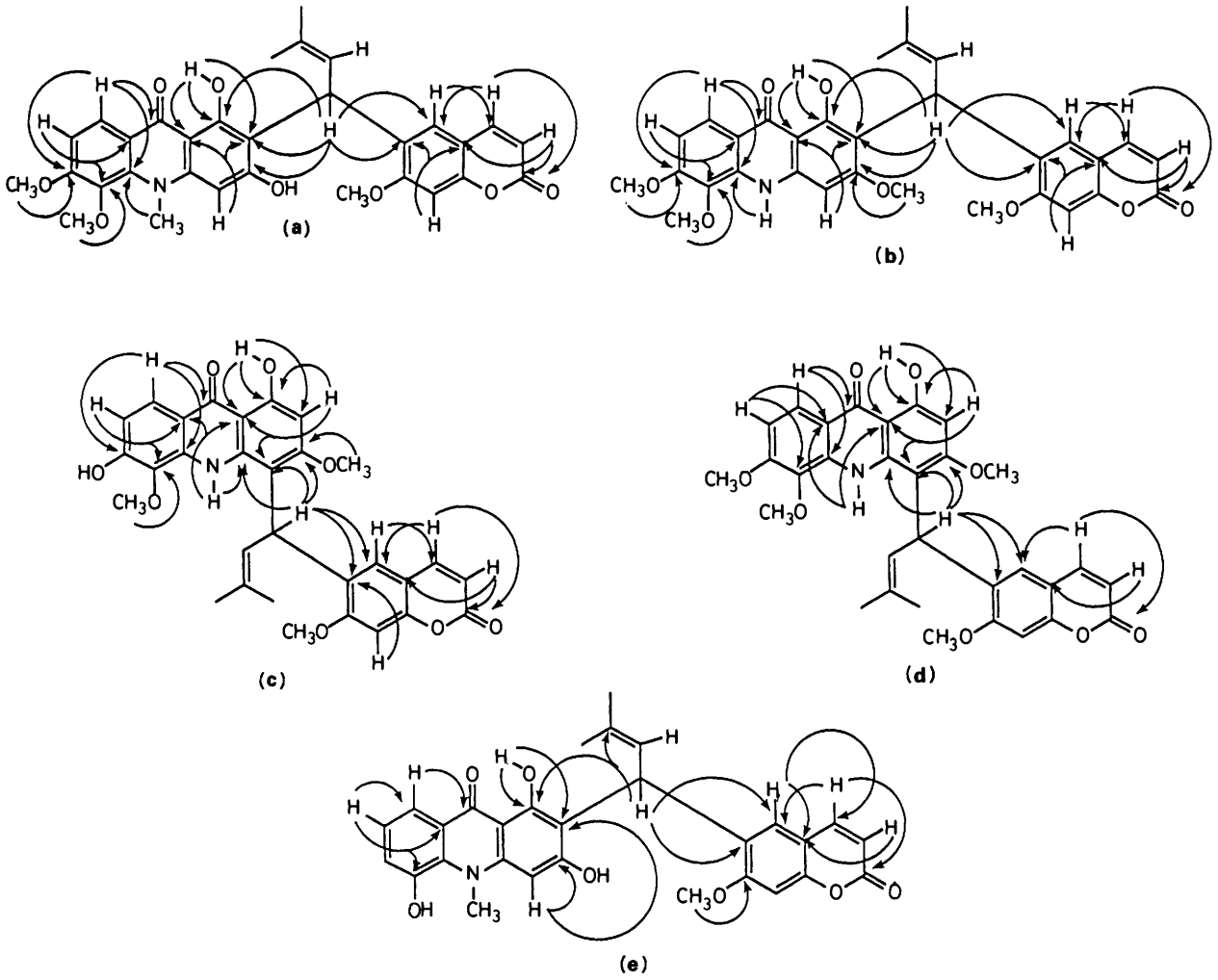


Figure. H-C Correlations (^2J and ^3J) from the results of ^{1}H-^{13}C long-range COSY spectra recorded at J 5 Hz: (a) acrimarine-A (**1**); (b) acrimarine-B (**2**); (c) acrimarine-C (**3**); (d) acrimarine-D (**4**); (e) acrimarine-G (**7**).

attributed to 6-H, 7-H, and 8-H, respectively, the last proton being deshielded by a 9-carbonyl group. Appearance of a 13% NOE enhancement of the signal at δ 6.47 on irradiation of the *N*-methyl signal at δ 4.02 showed the location of the coumarin moiety at C-2. On the basis of the results stated above and those of the ^{1}H-^{13}C long-range COSY correlation shown in Figure (e) by arrows, we assigned structure (**7**), corresponding to a dimer of suberosin (**12**) and a des-*O*-methyl analogue of citrusamine (**11**)[1b] to acrimarine-G, the absolute configuration remaining undetermined.

Since the first isolation of acridone alkaloids from natural sources,[10] many monomeric and binary acridones have been found.[11] However, the isolation of the acrimarines represents the first example of an acridone–coumarin dimer from natural sources.

Experimental

M.p.s were determined on a Yanagimoto hot-stage apparatus, EI, FAB, and HR mass spectra on a Hitachi M-52, Hitachi M-80, or JMS-HX-110 mass spectrometer, IR spectra on Jasco IR-810 IR spectrophotometer in $CHCl_3$, UV spectra on a Jasco UVIDEC-610C double-beam spectrophotometer in MeOH, and optical rotations on DIP-181 (JASCO) in $CHCl_3$ at 20 °C, unless otherwise stated. All ^{1}H and ^{13}C NMR spectra were measured on a JEOL GX-270 or GX-400 NMR spectrometer (with $SiMe_4$ as an internal standard) in $CDCl_3$, unless otherwise stated. ^{1}H-^{13}C Long-range COSY spectra were recorded at J_{HC} 5 Hz in $CDCl_3$ and nuclear Overhauser enhancements were determined by differential NOE spectroscopy or NOESY (nuclear Overhauser enhancement and exchange spectroscopy) on JEOL GX-400 spectrometer. All TLC and preparative TLC was done on Kieselgel 60 F_{254} (Merck), column chromatography on Wakogel C-200.

Isolation and Separation of Acrimarines.—The dried roots (1 kg) of *Citrus funadoko* Hort. ex. Y. Tanaka (Rutaceae) grown in the orchard of Okitsu Branch, Fruit Tree Research Station, Ministry of Agriculture, Forestry, and Fisheries, Shimizu, Sizuoka were extracted with acetone at room temperature. The acetone extract (104.6 g) was chromatographed over silica gel with successive elution with benzene, ethyl acetate, acetone, and methanol. Each fraction was subjected repeatedly to preparative TLC using appropriate combinations of acetone, hexane, isopropyl ether, and $CHCl_3$ to give acrimarines as well as coumarins and acridones. Yields of acrimarines from dried roots of the plant (1 kg) were as follow: acrimarine-A (**1**) 16.2 mg; -B (**2**) 17.3 mg; -C (**3**) 45.8 mg; -D (**4**) 7.1 mg; -E (**5**) 35.6 mg; -F (**6**) 7.0 mg; and -G (**7**) 3.7 mg. The characterisation of coumarins and acridones isolated in this plant will be reported elsewhere.

Acrimarine-A (**1**). Yellow oil; $[\alpha]_D$ −9.76° (*c* 0.082, $CHCl_3$);

λ_{max} 205, 259sh, 276, 295sh, and 332 nm; ν_{max} 3 400br, 1 730, 1 620, and 1 595 cm^{-1}; *m/z* (EI) 543 (M^+, 4%, Found: M^+, 543.1874. $C_{31}H_{29}NO_8$ requires *M*, 543.1890), 500 (8), 301 (100, Found: M^+ 301.0942. $C_{16}H_{15}NO_5$ requires *M*, 301.0949), 286 (67), 271 (16), 242 (29, Found: M^+, 242.0901. $C_{15}H_{14}O_3$ requires *M*, 242.0941), and 227 (22).

Acrimarine-B (**2**). Yellow prisms, m.p. 288–290 °C (from acetone); $[\alpha]_D$ −7.14° (*c* 0.056, $CHCl_3$); λ_{max} 204, 224, 252sh, 274, 288sh, and 330 nm; ν_{max} 3 410, 1 720, 1 635, 1 615, and 1 605 cm^{-1}; *m/z* (EI) 543 (M^+, 75%, Found: M^+, 543.1874. $C_{31}H_{29}NO_8$ requires *M*, 543.1891), 500 (100), 314 (23), 301 (25), 286 (4), 242 (12), and 227 (7).

Acrimarine-C (**3**). Yellow oil, $[\alpha]_D$ −6.17° (*c* 0.081, $CHCl_3$); λ_{max} 209, 256, 266, 284sh, and 328 nm; ν_{max} 3 380br, 1 725, 1 640, 1 620, and 1 610 cm^{-1}; *m/z* (EI) 529 (M^+, 15%, Found: M^+, 529.1711. $C_{30}H_{27}NO_8$ requires *M*, 529.1734), 486 (22), 287 (100, Found: M^+, 287.0729. $C_{15}H_{13}NO_5$ requires *M*, 287.0792), 272 (62), 244 (34), 242 (37, Found: M^+, 242.0927. $C_{15}H_{14}O_3$ requires *M*, 242.0942), and 227 (32).

Acrimarine-D (**4**). Yellow oil, $[\alpha]_D$ −3.0° (*c* 0.103, $CHCl_3$); λ_{max} 205, 220, 256, 266, 285sh, 297, and 328 nm; ν_{max} 3 380, 1 720, 1 635, 1 620, and 1 600 cm^{-1}; *m/z* (EI) 543 (M^+, 30%, Found: M^+, 543.1916. $C_{31}H_{29}NO_8$ requires *M*, 543.1892), 512 (8), 301 (100), 286 (20), 272 (6), 242 (40), and 227 (30).

Acrimarine-E (**5**). Yellow prisms from acetone, m.p. 274–276 °C; $[\alpha]_D$ +20.1° (*c* 0.050, acetone); λ_{max} 204, 224, 257, 274, 295sh, and 331 nm; ν_{max} 3 400br, 1 680, 1 640, and 1 610 cm^{-1}; *m/z* (EI) 529 (M^+, 5%, Found: M^+, 529.1734. $C_{30}H_{27}NO_8$ requires *M*, 529.1734), 287 (100, Found: M^+, 287.0741. $C_{15}H_{13}NO_5$ requires *M*, 287.0792), 272 (47), 242 (42, Found: M^+, 242.0892. $C_{15}H_{14}O_3$ requires *M*, 242.0941), and 227 (37).

Acrimarine-F (**6**). Pale yellow powder; $[\alpha]_D$ could not be taken because of its low solubility in organic solvents; λ_{max} 204, 226, 259, 278, and 332 nm; ν_{max}(KBr) 3 250, 1 700, 1 635, 1 620, 1 595, and 1 560 cm^{-1}; *m/z* (EI) 543 (M^+, 71%, Found: M^+, 543.1915. $C_{31}H_{29}NO_8$ requires *M*, 543.1891), 500 (100), 314 (23), 301 (18, Found: M^+, 301.0954. $C_{16}H_{15}NO_5$ requires *M*, 301.0949), 242 (11, Found: M^+, 242.0975. $C_{15}H_{14}O_3$ requires *M*, 242.0942), and 227 (7).

Acrimarine-G (**7**). Yellow oil, $[\alpha]_D$ +8.0° (*c* 0.075, $CHCl_3$); λ_{max} 206, 223, 258, 268, 277, 288, 323, and 336sh nm; ν_{max} 3 350br, 1 720, 1 620, 1 600, and 1 570 cm^{-1}; *m/z* (EI) 257 (91%), 242 (100), and 227 (45); *m/z* (FAB) 500 $[M + H]^+$ (Found: $M^+ + H$, 500.1752. $C_{29}H_{26}NO_7$ requires $M + H$, 500.1709).

Photo-oxidation of Suberosin (**12**).—Oxygen gas was bubbled through a solution of (**12**) (500 mg) in pyridine (40 ml) containing haematoporphyrin (50 mg), and the solution was irradiated with a high-pressure Hg lamp using a Pyrex glass filter for 30 min. The mixture was evaporated to dryness. The methanolic solution (20 ml) of the residue was stirred with triphenylphosphine (591 mg) for 41 h at room temperature after which the mixture was evaporated to dryness. The residue was subjected to silica gel column chromatography eluting with a mixture of isopropyl ether and acetone (10:1 and then 7:1) to give suberenol (**14**) (44%) and tamalin (**15**) (44%). Suberenol (**14**): colourless prisms from ether, m.p. 166–168 °C; δ_H 7.64 (1 H, d, *J* 9.4 Hz, 4-H), 7.49 (1 H, s, 5-H), 6.89 (1 H, d, *J* 16.1 Hz, 1′-H), 6.79 (1 H, s, 8-H), 6.37 (1 H, d, *J* 16.1 Hz, 2′-H), 6.27 (1 H, d, *J* 9.4 Hz, 3-H), 3.92 (3 H, s, 7-OCH_3), and 1.45 (6 H, s, 3′-gem CH_3); ν_{max}($CHCl_3$) 3 400, 1 730, and 1 620 cm^{-1}; *m/z* (EI) 260 (M^+, 31%), 245 (70), 227 (12), 213 (10), 203 (70), and 189 (100). Tamalin (**15**): colourless prisms, m.p. 113 °C; δ_H 7.63 (1 H, d, *J* 9.4 Hz, 4-H), 7.29 (1 H, s, 5-H), 6.80 (1 H, s, 8-H), 6.25 (1 H, d, *J* 9.4 Hz, 3-H), 4.94 (1 H, s, 4′-H), 4.85 (1 H, s, 4′-H), 4.32 (1 H, dd, *J* 8.4 and 4.0 Hz, 2′-H), 3.91 (3 H, s, 7-OCH_3), 3.01 (1 H, dd, *J* 13.8 and 4.0 Hz, 1′-H), 2.76 (1 H, dd, *J* 13.8 and 8.4 Hz, 1′-H), and 1.83 (3 H, s, 3′-gem CH_3); ν_{max}($CHCl_3$) 3 500, 1 720, 1 620, and 1 280 cm^{-1}; *m/z* (EI) 260 (M^+, 17%), 190 (100), 189 (99), 161 (16), 159 (26), and 131 (28).

Acrimarine-A (**1**) *from Grandisine-II* (**8**) *and Suberenol* (**14**).—To an ethanolic solution of (**8**) (10 mg) and (**14**) (8.6 mg) was added Nafion-H (solid, Aldrich) (20 mg), and the mixture was stirred at room temperature. After 19 and then 5 h, aliquots (each 6.5 mg) of (**14**) were added and the mixture further stirred for 64 h. The reaction mixture was filtered, and the filtrate was evaporated to dryness. The residue was subjected to preparative silica gel TLC (isopropyl ether and ethyl acetate, 2:1) to afford (**1**) (13.4 mg) as yellow prisms, m.p. 150–152 °C. This product was found to be identical with natural acrimarine-A (**1**) by spectral comparisons (IR and ^1H NMR).

Acrimarine-F (**6**) *from Citpressine-I* (**10**) *and Suberenol* (**14**).—An ethanolic solution of (**10**) (10 mg), (**14**) (8.6 mg), and Nafion-H (solid) (20 mg) was stirred at room temperature for 4.5 h. After this, (**14**) (5.3 mg) was added to the reaction mixture which was then further stirred for 68 h. The mixture was filtered, and the filtrate was evaporated to dryness. The residue was treated with methanol to give (**6**) (12.2 mg) as pale yellow prisms, m.p. 255–258 °C. This product was found to be identical with natural acrimarine-F (**6**) by spectral comparisons {IR (KBr), and ^1H NMR in [$^2H_5$]pyridine}.

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