Alkaloids of *Arundo donax* L.
15.* A new dimeric indole alkaloid arundarine from the roots of *Arundo donax* L.

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The structure of a new dimeric indole alkaloid, arundarine, isolated from the roots of the plant *Arundo donax* L. (Poaceae) was determined. On the basis of spectroscopic data, arundarine was identified as 5-[3-(2-dimethylaminoethyl)indol-1-yl]-6-hydroxy-N^2-methyl-1,2,3,4-tetrahydro-β-carboline.

Key words: *Arundo donax* L., Poaceae, arundarine, isolation, structure.

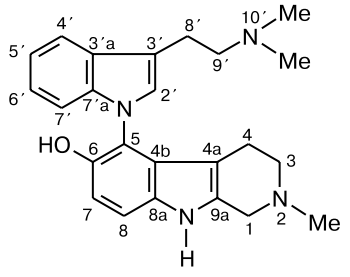
Previously,[2,3] we described the isolation and structure determination of a new dimeric alkaloid arundinine from the roots of the perennial giant reed *Arundo donax* L., which grows in the Fergana region, Uzbekistan. In continuation of the investigation of the alkaloid composition of the roots of the plant *A. donax* L. (family Poaceae, Gramineae) collected during an early vegetation period, we isolated the known bases, donaxaridine,[4] *N*-methyltetrahydro-β-carboline,[1] arundacine, and arundanine.[5,6] Rechromatography of certain fractions let to isolation of a new alkaloid with m.p. 250—252 °C and the composition $C_{24}H_{28}N_4O$, which differed from the known alkaloids in physicochemical characteristics. The new compound was called arundarine.

The IR spectrum of arundarine (**1**) exhibits absorption bands for the active hydrogen atoms (NH, OH), Me and CH_2 groups, and the aromatic ring. The mass spectrum of the base confirmed the proposed formula, as it contains a molecular ion peak with *m/z* 388, which differs from that for arundanine[6] by 2 a.m.u., attesting to a dimeric structure of the base. The mass spectrum contains also fragmentation ion peaks with *m/z* 373 $[M - 15]^+$, 330 $[M - 58]^+$, 130, and 58, typical of indole alkaloids.[7] The peak with *m/z* 57 is the most abundant. The occurrence of the peak with *m/z* 330 $[M - 58]^+$ indicates the presence of a $CH_2—NMe_2$ group in the arundarine structure, while the ion peak with *m/z* 130 shows that this group is attached to the indole ring.

The structure of the second moiety of dimer **1** was derived from comparison of the spectroscopic characteristics of arundarine with those of the known alkaloid arundanine.[2]

The full structure of the alkaloid was determined using homo- and heteronuclear 2D NMR techniques: COSY, ROESY, HSQC, and HMBC. The ^1H NMR spectrum of base **1** in DMSO represents a set of characteristic groups of signals: those for the aromatic protons at δ 6.76—7.59, five aliphatic CH_2-group protons at δ 1.35—3.42, and *N*-methyl, NH, and OH protons. The assignment of the ^1H and ^{13}C NMR signals is presented in Table 1.

Analysis of the COSY, HSQC, and HMBC spectra of the saturated part of the molecule provides unambiguous signal assignment for the aliphatic part. The combined HSQC and HMBC spectra are shown in Fig. 1.



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The two-proton singlet at δ 3.42 in the ^1H NMR spectrum has a cross-peak with the carbon signal at δ 52.1. This can correspond only to the methylene group at C(1) whose protons are isolated and do not show coupling with other protons. Two two-proton multiplets at δ 2.93 and δ 2.66 in the COSY spectrum show a closed spin-coupled system with almost equivalent geminal protons in each of

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Table 1. ^{1}H and ^{13}C NMR spectra of arundarine in DMSO-d_6

Fragment or atom	δ (*J*/Hz)	
	^{1}H	^{13}C
C(1)H_2	3.42 (s)	52.1
C(9a)	—	134.15
MeN(2)	2.24 (s)	45.3
C(3)H_2	2.23, 2.30 (both m)	52.4
C(4)H_2	1.84, 1.355 (both dt, *J* = 15.8, *J* = 5.5)	20.95
C(4a)	—	104.5
C(4b)	—	125.5
C(5)	—	114.9
C(6)	—	146.4
O(6)H	8.73 (br.s)	—
C(7)H	6.78 (d, *J* = 8.6)	110.6
C(8)H	7.20 (d, *J* = 8.6)	111.3
C(8a)	—	130.75
N(9)H	10.66 (s)	—
C(2′)H	7.12 (s)	128.35
C(3′)	—	112.4
C(3′a)	—	127.2
C(4′)H	6.76 (d, *J* = 8.7)	110.65
C(5′)H	7.015 (m)	118.3
C(7′)H	7.59 (d, *J* = 8.7)	118.25
C(6′)H	7.005 (m)	120.9
C(7′a)	—	138.1
C(8′)H_2	2.93 (br.s)	22.7
C(9′)H_2	2.66 (t, *J* = 7.8)	59.7
N(10′)Me_2	2.30 (s)	44.9

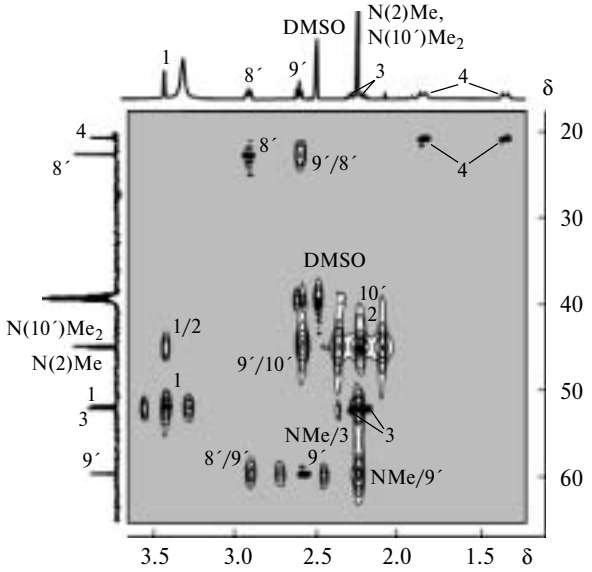

Fig. 1. Heteronuclear $^{1}H—^{13}C$ correlation spectra (black responses correspond to signals of the HSQC spectrum, and light ones, to signals of the HMBC spectrum).

the pairs. The HSQC spectrum (see Fig. 1) also confirms the equivalence of geminal protons in these methylene pairs. For each carbon signal (δ 22.7 and 59.7), only one proton cross-peak is observed. Naturally, these signals should be assigned to positions 8′ and 9′. This is confirmed by both the chemical shifts of the signals for carbon atoms and the cross-peaks observed in the HMBC spectrum: the signal for the methylene H(9′) protons has a cross-peak with the signals for the carbon atoms of the NMe_2 group.

The four protons in the C(3)H_2—C(4)H_2 fragment are nonequivalent forming four separate signals: a pair at δ 2.23 and δ 2.30 and the other pair, at δ 1.35 and δ 1.84. This follows from the double proton cross-peaks in the HSQC spectrum with the corresponding signals for the carbon atoms (see Fig. 1). The assignment can rely again on the ^{13}C NMR chemical shifts: δ 52.4 (C(3)) and δ 20.95 (C(4)).

The assignment of the signals for the *N*-methyl groups based on the HSQC spectrum is obvious: the nine-proton singlet for the three *N*-methyl groups (δ 2.27) shows a common cross-peak with the C atoms of the N(2)Me and N(10′)Me_2 fragments with relative intensities of ~1 : 2.

In the low-field region of the ^{1}H NMR spectrum, the obvious assignment can be made for the NH proton (δ 10.66), the OH proton (δ 8.73) (both assignments are confirmed by cross-peaks in the HMBC spectrum), and the singlet with δ 7.12, which belongs to the olefinic proton at C(2′).

Among other signals, two doublets for the H(7) and H(8) protons at δ 6.78 and δ 7.20, respectively, are clearly distinguished. The alternative H(7)/H(8) assignment is based on the HMBC spectrum, in particular, coupling with the C(4b), C(5), C(6), and C(8a) atoms bearing no protons.

The remaining four protons at the C(4′)—C(7′) atoms are manifested as three signals whose positions are indicated in Table 1. The sequence of the H(4′)—H(7′) signals was assigned based on the HMBC spectra. The key heteronuclear $^{1}H—^{13}C$ geminal and vicinal couplings (the main cross-peaks in the HMBC spectrum) are outlined below and in Fig. 1 (partly).

Correlation peaks	
protons	carbon atoms
N(2)Me	C(1), C(3)
H(1)	CH_3N(2), C(3), C(9a), C(4a)
H(7)	C(5), C(6), C(8a)
H(8)	C(4b), C(6)
O(6)H	C(5)
N(9)H	C(9a), C(4a), C(4b), C(8a)
H(4′)	C(5′), C(3′a)
H(7′)	C(6′), C(7′a)
H(8′)	C(9′), C(2′), C(3′)
H(9′)	C(10′), C(3′)
N(10′)Me_2	C(9′)

The spectroscopic characteristics considered above correspond to structure **1**, which differs from the structure

of arundanine in that the side *N*-dimethylaminoethyl chain in the second moiety of the arundarine dimer is closed to give tricyclic N^2-methyltetrahydro-β-carboline. Our reasons concerning the structure of the second moiety of the dimer are also confirmed by the fact that the alkaloid *N*-methyltetrahydro-β-carboline, whose structure was confirmed by X-ray diffraction analysis, was isolated for the first time from the same plant (*A. donax*) in our previous study.[1]

Thus, based on the foregoing, arundarine can be described as 5-[3-(2-dimethylaminoethyl)indol-1-yl]-6-hydroxy-N^2-methyl-1,2,3,4-tetrahydro-β-carboline.

Experimental

IR spectrum was recorded on a Perkin—Elmer 2000 FT IR spectrometer for KBr pellets; the mass spectrum was obtained on an MKh 1310 mass spectrometer equipped with a direct sample injection system. The NMR spectra were recorded on a Bruker AM-500 instrument operating at 500 (^{1}H) and 125.8 MHz (^{13}C).

Column chromatography was performed using Al_2O_3 (neutral) 100/60 μm, TLC was carried out on Al_2O_3 and SiO_2 plates 5/40 μm (elution with $CHCl_3$—MeOH, 2 : 1 (system *1*), $CHCl_3$—MeOH, 9 : 1 (system *2*)).

Arundarine (1). A mixture of alkaloids from the roots of *A. donax* (19 g) collected in the beginning of vegetation was chromatographed on a column with Al_2O_3. The alkaloids were eluted with $CHCl_3$ and $CHCl_3$—MeOH mixtures with different component ratios. Rechromatography of the chloroform eluates gave 18 mg of a while crystalline base, m.p. 250—252 °C, poorly soluble in organic solvents ($CHCl_3$, acetone, MeOH), R_f 0.3 (TLC, SiO_2, system *1*), R_f 0.68 (TLC, Al_2O_3, system *2*). IR, ν/cm^{-1}: 3251, 3050, 2949, 2760, 1597, 1459, 1445, 1388, 1351, 1243, 1153, 1133, 1053, 969, 739. MS, *m/z* (I_{rel} (%)): 388 $[M]^+$ (14), 373 $[M - 15]^+$ (30), 374 (11), 330 $[M - 58]^+$ (12), 273 (5), 202 (3), 188 (3), 130 (8), 115 (5), 77 (8), 58 (12), 57 (100).

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