Diterpenoid Alkaloids from Aphids *Brachycaudus aconiti* and *Brachycaudus napelli* Feeding on *Aconitum napellus*[1]

Hongmei Liu and Alfred Katz*

Natural Products Research Laboratory Dr. Alfred Katz, Oberwilerstrasse 9, CH-4054 Basel, Switzerland

Received August 30, 1995[⊗]

A novel norditerpenoid alkaloid, brachyaconitine (**3**), which possesses a *trans*-3-hexenoyl side chain in the molecular structure, has been isolated from aphids *Brachycaudus aconiti* feeding on *Aconitum napellus*, along with 11 known alkaloids. Aphids *Brachycaudus napelli* living on *A. napellus* also yielded brachyaconitine (**3**) along with 12 known alkaloids. The structure of the new alkaloid **3** was derived from its spectroscopic data and was confirmed by semisynthesis from aconitine.

Aphids *Brachycaudus aconiti* Mordv. and *Brachycaudus napelli* Schrk. (*Aphididae*) are the only two European *Brachycaudus* species living on *Aconitum* and *Delphinium* (Ranunculaceae).[2] Both plant genera contain diterpenoid alkaloids as the principal secondary metabolites. The occurrence of diterpenoid alkaloids in the aphids *B. napelli* feeding on *Aconitum napellus* L. and *Acontium paniculatum* Lam. has been reported.[3] Aconitine was isolated from the $CHCl_3$ extract of the aphids from *A. napellus*.[3] The chemistry of *B. aconiti* has not yet been examined.

In a chemical investigation of the aphids *B. aconiti* feeding on *A. napellus*, we have isolated a novel norditerpenoid alkaloid, designated as brachyaconitine (**3**); eight known norditerpenoid alkaloids, lipoaconitine (**1**), 14-*O*-acetylneoline (**2**), aconitine (**4**), 8-*O*-acetyl-15α-hydroxyneoline (**9**), neoline (**10**), isotalatizidine (**11**), virescenine (**12**), and senbusine A (**13**); and three known diterpenoid alkaloids, 12-*epi*-dehydronapelline (**5**), songorine (**6**), and 12-*epi*-napelline (**7**). In a continuing chemical study of the aphids *B. napelli* from *A. napellus*, brachyaconitine (**3**) and the above-mentioned 11 known alkaloids, as well as a known norditerpenoid alkaloid 14-*O*-acetylsenbusine A (**8**), have been isolated. We now describe the isolation of these alkaloids, the structure determination and semisynthesis of brachyaconitine (**3**), and the identification of the known alkaloids. Spectroscopic data of the previously known 8-*O*-acetyl-15α-hydroxyneoline (**9**)[4] and complete ^{1}H-NMR spectral assignments for the known 14-*O*-acetylneoline (**2**)[5] are reported for the first time in this paper.

Results and Discussion

An infested *A. napellus* plant harbors aphids usually in its upper half. Often the back of the leaf and the upper third of the stem are most heavily infested. The aphids feeding on *A. napellus* were collected with the aid of a small, soft paintbrush in five localities of Switzerland. One batch was identified as *B. aconiti* and the other four as *B. napelli*. The aphids were killed with $CHCl_3$ vapors, dried *in vacuo*, and extracted with pentane followed by $CHCl_3$ at pH 9 and then at pH 12. The pH 9 $CHCl_3$ extracts contained a complex mixture of alkaloids and small amounts of impurities, while the other extracts showed very weak alkaloidal spots on TLC. By repeated column chromatography and preparative TLC, alkaloids **1**−**13** were isolated from the pH 9 $CHCl_3$ extracts.

Brachyaconitine (**3**) was isolated as a colorless, oily alkaloid. It has a rancid odor like the aphids. The molecular formula of **3**, $C_{38}H_{54}NO_{11}$, was derived from the high resolution FABMS. The IR spectrum of **3** in KBr showed the presence of hydroxyl (3490 cm^{-1}, br), ester carbonyl (1722 cm^{-1}), and aromatic (1603, 1585, 1452 cm^{-1}) groups. The 712 cm^{-1} IR band indicated a monosubstituted aromatic nucleus in the molecule. The UV absorptions at λ max 230 (log ϵ 4.22), 274 (log ϵ 3.17) and 280 (sh, log ϵ 3.11) nm confirmed the aromatic moiety. The presence of an *N*-ethyl group at δ_H 1.10 ppm (3H, t, J = 7.1 Hz, with the diastereotopic methylene resonances at δ_H 2.40 and 2.74 ppm, 1H each, m) and of four methoxyl groups at δ_H 3.15, 3.27, 3.30, and 3.76 ppm (3H each, s) in the ^{1}H-NMR spectrum (Table 1) suggested that alkaloid **3** is a C_{19} norditerpenoid alkaloid.

The ^{1}H-NMR spectrum of **3** resembled the reported spectrum of aconitine,[6] except for the absence of an 8-acetyl resonance (usually at δ_H 1.25−1.45 ppm, 3H, s)[7] and the presence of three additional multiplets at δ_H 1.86 (2H), 5.04 (1H), and 5.08 ppm (1H) as well as two doublets of doublets at δ_H 2.20 (1H) and 2.48 ppm (1H) and a triplet at δ_H 0.89 ppm (3H, J = 7.1 Hz), which is characteristic for a terminal ethyl group (Table 1). The COSY NMR experiments of **3** displayed the correlations of these additional resonance signals (Table 1). The multiplet at δ_H 1.86 ppm (2H) was assigned to a methylene group coupled with the neighboring methyl protons at δ_H 0.89 ppm. The two double-bond protons were identified by their chemical shifts (δ_H 5.04, 5.08 ppm, 1H each, m) and patterns in the ^{1}H-NMR spectrum and correlated with each other in the COSY spectrum. They were easily distinguished because one of them (δ_H 5.04 ppm) showed coupling with the two protons at δ_H 2.20 ppm (dd) and δ_H 2.48 ppm (dd), which also coupled with one another, whereas its partner (δ_H 5.08 ppm) correlated with the methylene protons at δ_H 1.86 ppm (2H, m). These observations and other connectivities found in the COSY spectrum suggested a 3-hexenoyl side-chain.

Accordingly, the FABMS of **3** showed $[M + 1]^+$ at m/z 700 (100), $[M + 1 - CH_3OH]^+$ at m/z 668 (21), and a fragment at m/z 586 (27) due to loss of the hexenoic acid from the $[M + 1]^+$ peak leading to the alkaloidal moiety of benzoylaconine.

[⊗] Abstract published in *Advance ACS Abstracts,* January 15, 1996.

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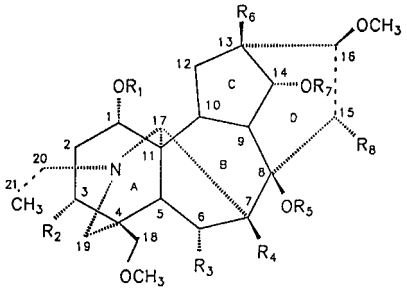
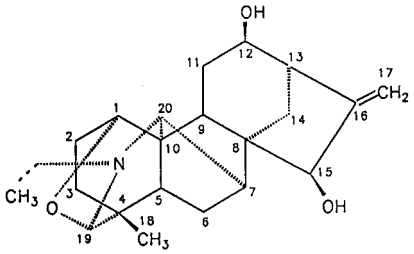


	R_1	R_2	R_3	R_4	R_5	R_6	R_7	R_8
1	Me	OH	OMe	H	Lip.[a]	OH	Bz	OH
2	H	H	OMe	H	H	H	Ac	H
3	Me	OH	OMe	H	Hex.[b]	OH	Bz	OH
4	Me	OH	OMe	H	Ac	OH	Bz	OH
8	H	H	OH	H	H	H	Ac	H
9	H	H	OMe	H	Ac	H	H	OH
10	H	H	OMe	H	H	H	H	H
11	H	H	H	H	H	H	H	H
12	H	H	H	OH	H	H	H	H
13	H	H	OH	H	H	H	H	H

[a] Lip.= -$CO(CH_2)_{14}CH_3$ (palmitoyl), -$CO(CH_2)_7CH{=}CH(CH_2)_7CH_3$ (oleoyl)

-$CO(CH_2)_7CH{=}CHCH_2CH{=}CH(CH_2)_4CH_3$ (linoleoyl)

[b] Hex.= -$COCH_2CH{=}CHCH_2CH_3$



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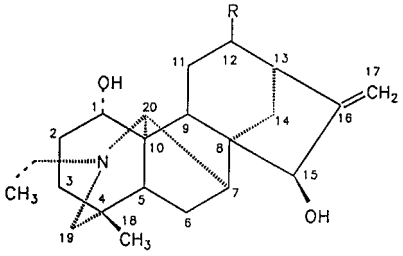

6 R= =O

7 R= α-H, β-OH

The aconitine-type norditerpenoid alkaloids are mostly oxygenated at C-1, C-8, C-14, and C-16, often at C-6 and C-18, and less commonly at other sites.[7] In the case of brachyaconitine (**3**), oxygenation at C-3 was indicated by a ABXY system of H-1 and 2H-2 as well as H-3 in the ^{1}H-NMR spectrum[4] and was further supported by the observation of the COSY NMR experiments. Hydroxylation at C-13 was suggested by the appearance of the resonance at δ_H 4.88 ppm as a doublet (J = 4.8 Hz), which was as expected for 14α-benzoylation, without oxygenation at C-9.[4] The doublet of doublets at δ_H 4.48 ppm (J = 5.1, 3.0 Hz) attributable to H-15β

Table 1. ^{13}C-, ^{1}H-NMR Chemical Shift Assignments and ^{1}H−^{1}H Correlations of **3**[a]

position	δ_C	δ_H	correlation (COSY)
1	82.3	3.15 m	H-2α, H-2β
2	33.5	α 2.38 m	H-1, H-2β, H-3
		β 2.00 m	H-1, H-2α, H-3
3	71.5	3.78 m	H-2α, H-2β
4	43.1		
5	46.6	2.12 d, J = 6.3 Hz	H-6, H-17
6	83.4	4.03 d, J = 6.3 Hz	H-5, H-7
7	44.8	2.85 s	H-6
8	92.3		
9	44.2	2.92 m	H-10, H-14
10	41.0	2.13 m	H-9, H-12α, H-12β
11	50.1		
12	35.8	α 2.15 m	H-10, H-12β
		β 2.74 m	H-10, H-12α
13	74.0		
14	78.9	4.88 d, J = 4.8 Hz	H-9
15	78.9	4.48 dd, J = 5.1, 3.0 Hz	H-16, OH-15
16	90.0	3.34 d, J = 5.1 Hz	H-15
17	61.1	3.11 s	H-5
18	76.6	a 3.49 d, J = 8.9 Hz	H-18b
		b 3.63 d, J = 8.9 Hz	H-18a
19	47.1	α 2.35 d, J = 11.2 Hz	H-19β
		β 2.89 d, J = 11.2 Hz	H-19α
20	48.9	a 2.40 m	H-20b, H-21
		b 2.74 m	H-20a, H-21
21	13.3	1.10 t, J = 7.1 Hz	H-20a, H-20b
OMe-1	55.9	3.27 s	
OMe-6	58.2	3.15 s	
OMe-16	61.2	3.76 s	
OMe-18	59.1	3.30 s	
OH-15		4.40 d, J = 3.0 Hz	H-15
aromatic			
C=O	166.0		
1′	129.7		
2′	129.7	8.04 d, J = 8.4 Hz	H-3′
3′	128.7	7.45 t, J = 8.4 Hz	H-2′, H-4′
4′	133.3	7.58 t, J = 8.4 Hz	H-3′, H-5′
5′	128.7	7.45 t, J = 8.4 Hz	H-4′, H-6′
6′	129.7	8.04 d, J = 8.4 Hz	H-5′
C-8 side chain			
1″	173.6		
2″	38.4	a 2.20 dd, J = 16.5, 5.3 Hz	H-2″b, H-3″
		b 2.48 dd, J = 16.5, 6.1 Hz	H-2″a, H-3″
3″	119.4	5.04 m	H-2″a, H-2″b, H-4″
4″	136.7	5.08 m	H-3″, H-5″a, H-5″b
5″	25.3	a 1.86 m	H-4″, H-6″
		b 1.86 m	H-4″, H-6″
6″	13.3	0.89 t, J = 7.1 Hz	H-5″a, H-5″b

[a] Spectra were recorded in $CDCl_3$. Chemical shifts are in ppm downfield to TMS. ^{1}H-NMR and COSY spectra are from the natural product; ^{13}C-NMR spectrum is from the synthetic product.

revealed the presence of an α-hydroxyl group at C-15.[7] It is noteworthy that the strong coupling between H-15β and OH-15 was observed in the COSY NMR experiments, resulting in a doublet of doublets at δ_H 4.48 ppm (J = 5.1, 3.0 Hz) for H-15β and a doublet at δ_H 4.40 ppm (J = 3.0 Hz) for the hydroxyl proton. Four doublets at δ_H 4.03 (J = 6.3 Hz), 3.34 (J = 5.1 Hz), 3.49 (J = 8.9 Hz), and 3.63 ppm (J = 8.9 Hz) were assigned to H-6β, H-16α, H-18a, and H-18b, respectively, and indicated three methoxyl groups at C-6, C-16, and C-18.[4,7] The fourth methoxyl group was located at C-1 in α-configuration by the chemical shift of H-1β, δ_H 3.15 ppm (m), as exhibited by the alkaloids of this type.[4] The feature of the H-6β proton as a doublet at δ_H 4.03 ppm (J = 6.3 Hz) in the ^{1}H-NMR spectrum excluded the possibility of a C-5 substituent, inasmuch as the H-6β proton had no coupling with H-7 due to the dihedral angle (ca. 110°) of H-6β/H-7. The exclusion of oxygenation at C-10 was

Table 2. ^{13}C- and ^{1}H-NMR Chemical Shift Assignments for Compounds **2** and **9**[a]

	2		**9**	
position	δ_C	δ_H	δ_C	δ_H
1	72.5	3.68 br s	71.8	3.65 s
2	30.1[b]	α 1.55 m	29.6	α 1.56 m
		β 1.55 m		β 1.56 m
3	29.5[b]	α 1.62 m	29.6	α 1.62 m
		β 1.90 m		β 1.88 m
4	38.3		38.1	
5	44.8	2.20 d, J = 6.4 Hz	43.1	2.27 d, J = 6.4 Hz
6	83.8	4.12 d, J = 6.4 Hz	84.0	4.09 d, J = 6.4 Hz
7	52.9	2.00 s	44.0	2.91 s
8	75.2		91.8	
9	46.5	2.25 t, J = 5.4 Hz	46.7	2.36 t, J = 5.4 Hz
10	43.6	1.90 m	43.6	1.92 m
11	50.0		49.4	
12	29.8[b]	α 1.80 dd, J = 13.5, 4.9 Hz	29.6	α 1.88 m
		β 2.10 m		β 2.07 m
13	36.8	2.62 dd, J = 7.8, 4.9 Hz	41.2	2.30 dd, J = 7.6, 4.9 Hz
14	77.7	4.86 t, J = 4.9 Hz	74.9	4.12 t, J = 4.9 Hz
15	43.0	α 2.32 m	76.0	4.41 dd, J = 5.2, 2.8 Hz
		β 1.92 m		
16	82.4	3.30 m	88.6	3.22 d, J = 5.2 Hz
17	63.7	2.66 s	63.0	2.79 s
18	80.6	a 3.25 d, J = 8.8 Hz	79.8	a 3.05 d, J = 9.0 Hz
		b 3.64 d, J = 8.8 Hz		b 3.63 d, J = 9.0 Hz
19	57.3	α 2.31 d, J = 10.8 Hz	56.4	α 2.26 d, J = 10.6 Hz
		β 2.68 d, J = 10.8 Hz		β 2.63 d, J = 10.6 Hz
20	48.6	a 2.48 dq, J = 13.2, 7.1 Hz	49.0	a 2.43 m
		b 2.57 dq, J = 13.2, 7.1 Hz		b 2.79 m
21	13.1	1.13 3H, t, J = 7.1 Hz	13.0	1.13 3H, t, J = 7.1 Hz
OMe-6	58.3	3.35 s	58.4	3.28 s
OMe-16	56.4	3.27 s	57.9	3.49 s
OMe-18	59.5	3.33 s	59.2	3.33 s
$OCOCH_3$	170.4		172.6	
$OCOCH_3$	21.4	2.07 s	22.4	2.09 s

[a] Spectra were recorded in $CDCl_3$. Chemical shifts are in ppm downfield to TMS. [b] The literature assignments[13,14] have been revised.

indicated by the vicinal coupling of H-9 with two protons (H-14β and H-10β) in the COSY spectrum.

Thus, in analogy to the structures of long-chain fatty acid esters of norditerpenoid alkaloids,[8−10] a 3-hexenoic acid ester at C-8 of 14-benzoylaconine was inferred for alkaloid **3** and was designated as brachyaconitine, a previously undescribed compound. The configuration of the double bond of the 3-hexenoyl group could not be determined from the present spectral data. Due to the small amount of **3** isolated, no satisfactory ^{13}C-NMR and HETCOR spectra could be obtained.

On the basis of the facile replacement of the C-8 acetate group of norditerpenoid alkaloids[11] and the preparation of C-8 long-chain fatty acid esters of norditerpenoid alkaloids,[8,10] the preparation of brachyaconitine (**3**) was made by refluxing aconitine with *trans*-3-hexenoic acid[12] and adding Et_2NH in THF. The workup and fractionation of the reaction mixture gave a major product as a colorless oil in ca. 46% yield. Its IR spectrum was superimposable on that of brachyaconitine (**3**). The comparison of its R_f values in various solvent systems, FABMS, UV, and ^{1}H-NMR spectra with those of **3** also showed identity. With the help of the ^{13}C-NMR (for spectral data, see Table 1), HETCOR, and COLOC experiments of the desired product, the structure of brachyaconitine (**3**) was further confirmed as the C-8 *trans*-3-hexenoic acid ester of 14-benzoylaconine.

The known alkaloids, lipoaconitine (**1**), aconitine (**4**), 12-*epi*-dehydronapelline (**5**), songorine (**6**), 12-*epi*-napelline (**7**), 14-*O*-acetylsenbusine A (**8**), neoline (**10**), isotalatizidine (**11**), virescenine (**12**), and senbusine A (**13**), were identified by comparing their TLC behavior, IR, and ^{1}H-NMR spectra with those of authentic samples. On the basis of the detailed NMR investigation (^{1}H-, ^{13}C-, COSY, HETCOR, and ROESY NMR experiments), alkaloids **2** and **9** were identified as 14-*O*-acetylneoline and 8-*O*-acetyl-15α-hydroxyneoline, respectively. Accurate ^{13}C- and detailed ^{1}H-NMR assignments for **9**, as well as the complete ^{1}H-NMR assignments for **2**, were accomplished for the first time (for spectral data see, Table 2). The previously assigned ^{13}C-NMR values for C-2, C-3, and C-12 of 14-*O*-acetylneoline[13,14] have been revised.

Most alkaloids isolated from aphids have been found previously to be present in the plants of *A. napellus*,[6,15] that is, aconitine (**4**), 14-*O*-acetylneoline (**2**), 12-*epi*-dehydronapelline (**5**), songorine (**6**), 12-*epi*-napelline (**7**), neoline (**10**), isotalatizidine (**11**), virescenine (**12**), and senbusine A (**13**). Three alkaloids, lipoaconitine (**1**),[8] 14-*O*-acetylsenbusine A (**8**),[16] and 8-*O*-acetyl-15α-hydroxyneoline (**9**),[4] have been reported from other species of *Aconitum*, but not from *A. napellus*. Brachyaconitine (**3**), an aconitine-type alkaloid with an unusual *trans*-3-hexenoyl side chain, is a novel alkaloid. We do not know yet whether the aphids take up brachyaconitine (**3**) from the plants or whether they produce it from the aconitine taken up before. Most attention should be given to the possibility of biotransformation from aconitine in the aphid body inasmuch as brachyaconitine has an unusual molecular structure as compared to the naturally occurring alkaloids in the *Aconitum* plants.

Alkaloidal patterns of the aphids *B. aconiti* and *B. napelli* from different localities are very similar. Aconitine, the main alkaloid of *A. napellus*,[17] is also the prevailing alkaloid in all the aphids.

Experimental Section

General Experimental Procedures. Optical rotations were measured on a Perkin-Elmer Model 241 polarimeter in $CHCl_3$. UV spectra were taken on a Perkin-Elmer Lambda 5 UV/vis spectrophotometer, using EtOH as solvent. IR spectra were determined in KBr pellets on a Perkin-Elmer 281 infrared spectrometer. EIMS were recorded on a VG TS 250 mass spectrometer at 70 eV. FABMS were obtained in the positive mode on a VG 70-SE mass spectrometer in a thioglycerine or a nitrobenzyl alcohol matrix. NMR spectra were recorded on a Bruker AM 400 spectrometer operating at 400.13 MHz for ^1H and at 100.61 MHz for ^{13}C. Column chromatography was carried out with Merck neutral Al_2O_3 90 (particle size 0.063−0.200 mm, activity IV_a) and TLC on Merck Si gel 60 F_{254} (0.25 mm) and Al_2O_3 60 F_{254} (0.25 mm) plates.

Animal Material. The aphids *B. aconiti* feeding on *A. napellus* were collected in Ftan, Oberengadin (GR), Switzerland, in Aug 1993. The aphids *B. napelli* from *A. napellus* were collected in four Swiss localities: Basel in May−Aug 1993, Schwarzsee (FR) in July 1993, Sils (Oberengadin, GR) in Aug 1993, and Strada (Unterengadin, GR) in Aug 1993. The aphids were identified by Prof. Dr. G. Lampel, Institute of Zoology, University of Fribourg, Switzerland, where the voucher specimens have been deposited.

Extraction and Isolation. The dried, finely powdered aphids (1.24 g of *B. aconiti*; 3.28 g, 1.15 g, 11.13 g, and 2.68 g of *B. napelli*) were first defatted with pentane and then extracted with $CHCl_3$ at pH 9 and pH 12 by addition of 25% aqueous NH_4OH solution. The $CHCl_3$ extracts obtained at pH 9 were concentrated *in vacuo* to give crude alkaloidal mixtures (93 mg from *B. aconiti*; 177 mg, 43 mg, 782 mg, and 115 mg from *B. napelli*). The mixtures were each subjected to column chromatography on Al_2O_3 eluted with a gradient solvent system of cyclohexane, EtOAc, and EtOH. The resulting fractions were evaporated *in vacuo* and examined by TLC for their alkaloidal compositions. Homogenous fractions, showing similar spots, were combined for further fractionation (F_1−F_{10}). Fraction F_5 was obtained from *B. napelli* only, the others from both *B. aconiti* and *B. napelli*.

From fractions F_2, F_3, and F_4, lipoaconitine (**1**) (6.4 mg), 14-*O*-acetylneoline (**2**) (6.1 mg), brachyaconitine (**3**) (4.0 mg), aconitine (**4**) (92.0 mg), 12-*epi*-dehydronapelline (**5**) (1.79 mg), and songorine (**6**) (3.5 mg) were isolated after repeated chromatography on Al_2O_3 columns and plates followed by purification of the isolates by preparative TLC on Al_2O_3. Fraction F_5 was subjected to preparative TLC on Al_2O_3 to afford 14-*O*-acetylsenbusine A (**8**) (4.8 mg). Fractions F_6 and F_7 were separated with multiple preparative TLC on Al_2O_3 and Si gel to yield 12-*epi*-napelline (**7**) (6.5 mg), 8-*O*-acetyl-15α-hydroxyneoline (**9**) (4.6 mg), neoline (**10**) (22.0 mg), isotalatizidine (**11**) (14.7 mg), and virescenine (**12**) (12.7 mg). After purification of fraction F_8 on Al_2O_3 plates, senbusine A (**13**) (6.4 mg) was obtained.

Brachyaconitine (**3**) (natural product) was obtained as colorless oil: $[\alpha]^{22}_D$ ±0° (*c* 0.07, $CHCl_3$); UV (EtOH) λ max (log ϵ) 230 (4.22), 274 (3.17), 280 (3.11) nm; IR (KBr) ν max 3489 (OH), 2931 (CH), 1722 (C=O, ester), 1451, 1382, 1320, 1282, 1180, 1097, 983, 711 cm^{-1}; HRFABMS *m/z* 700.3699 $[M + 1]^+$ ($C_{38}H_{54}NO_{11}$ requires: 700.3697); FABMS *m/z* 700 $[M + 1]^+$ (100), 668 $[M + 1 - MeOH]^+$ (21), 586 $[M + 1 - C_6H_{10}O_2]^+$ (27); for ^1H- and ^{13}C-NMR assignments, see Table 1.

8-*O*-Acetyl-15α-hydroxyneoline (**9**) was obtained as a colorless amorphous mass: $[\alpha]^{22}_D$ +4.11° (*c* 0.07, $CHCl_3$); IR (KBr) ν max 3472 (OH), 2932 (CH), 1705 (C=O, ester), 1460, 1372, 1265, 1200, 1108, 1002, 982, 755 cm^{-1}; FABMS *m/z* 496 $[M + 1]^+$ (100), 478 $[M + 1 - H_2O]^+$ (34), 436 $[M + 1 - C_2H_4O_2]^+$ (84); for ^1H- and ^{13}C-NMR assignments, see Table 2.

Preparation of Brachyaconitine (3). *trans*-3-Hexenoic acid (0.12 mL, 1 mmol) in 1.5 mL of THF was slowly added to 0.108 mL of Et_2NH (1 mmol) in 1.5 mL of THF under a magnetic stirrer at 0 °C. The mixture was continuously stirred for about 30 min at 0 °C. Aconitine (50 mg, 0.077 mmol) in 2.5 mL of THF was added to the resulting mixture at room temperature, which was then refluxed at 80 °C for about 24 h. The reaction solution was diluted with H_2O (2 mL), basified to pH 10.5 by addition of 25% NH_4OH aqueous solution, and extracted with $CHCl_3$ (4 × 1.5 mL). The combined $CHCl_3$ extract was washed with H_2O, dried over anhydrous Na_2SO_4, and concentrated *in vacuo* to give an oily mixture. By preparative TLC on Al_2O_3, the major product brachyaconitine (**3**) (25 mg) was obtained in ca. 46% yield. The synthetic material was identical to the natural product with regard to R_f values, MS, UV, IR, and ^1H-NMR.

Acknowledgment. We are grateful to Prof. Dr. H. H. A. Linde, Pharmaceutical Institute of the University of Basel, Switzerland, for providing the facilities to record spectra at the Pharmaceutical Institute; to Mr. Ch. Quiquerez, MS Laboratory, Sandoz AG, Basel, Switzerland, for the measurement of mass spectra; to Mr. J. France, NMR Laboratory, Sandoz AG, Basel, Switzerland, for recording NMR spectra; and to Prof. Dr. G. Lampel, Institute of Zoology, University of Fribourg, Switzerland, for the identification of aphids.

References and Notes

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NP960047R