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INSECTICIDAL ROCAGLAMIDE DERIVATIVES FROM *AGLAIA ELLIPTICA* AND *A. HARMSIANA*

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Key Word Index—*Aglaia elliptica*; *A. harmsiana*; Meliaceae; rocaglamide derivatives; structure elucidation; natural insecticides; *Spodoptera littoralis*.

Abstract—Fruits of *Aglaia elliptica* and leaves of *A. harmsiana* yielded seven insecticidal rocaglamide derivatives including five components which proved to be new natural products. Structure elucidation of the new compounds is described. All rocaglamide derivatives isolated exhibited strong insecticidal activity towards neonate larvae of the polyphagous pest insect *Spodoptera littoralis* when incorporated into an artificial diet with LC_{50} values varying from 0.8–19.7 ppm. The known didesmethylrocaglamide was the most active compound encountered. Its LC_{50} (0.8 ppm) and EC_{50} (0.05 ppm) were identical to those of azadirachtin which was included as a positive control.

INTRODUCTION

The family Meliaceae is the source of numerous secondary products that exhibit significant insecticidal activity. A well known example is the famous natural insecticide azadirachtin from *Azadirachta indica* which is already marketed as a botanical insecticide in the U.S.A. as well as in other countries such as India [1, 2]. More recently, extracts from species of the genus *Aglaia* (also Meliaceae) were reported to contain insecticidal compounds [3–5]. Aromatic compounds featuring a cyclopentatetrahydrobenzofuran skeleton were shown to be the causative agents for the described insecticidal properties of extracts derived from *A. odorata* [6, 7]. Recently, we showed that another *Aglaia* species, namely *A. duperreana* collected in Vietnam, contains several novel rocaglamide derivatives with insecticidal properties comparable to those of azadirachtin [8]. In the present study, we have analysed fruit and leaves of two further *Aglaia* species from Indonesia which include *A. elliptica* Bl. and *A. harmsiana* Perkins and report on the isolation of five new, as well as two known, rocaglamide derivatives with pronounced insecticidal activity towards neonate larvae of the polyphagous pest insect *Spodoptera littoralis* (Noctuidae).

RESULTS AND DISCUSSION

Crude methanolic extracts from fruits of *A. elliptica* as well as from leaves of *A. harmsiana* exhibited significant insecticidal activity towards neonate larvae of the polyphagous pest insect *S. littoralis*. When the extract was incorporated into an artificial diet at an arbitrarily chosen concentration of 1000 ppm and offered to neonate larvae of *S. littoralis* in a chronic feeding bioassay none of the insects were found to survive beyond the first 2 or 3 days of the experiment (data not shown).

Repeated chromatographic separation of the fruit extract from *A. elliptica* resulted in the isolation of six insecticidal compounds (**1**–**6**). Based on their spectral characteristics and comparison with published data [6–11], compound **1** was readily identified as rocaglamide previously isolated from *A. odorata* [6–7] as well as from *A. duperreana* [8]. Compound **2** was the known didesmethylrocaglamide previously reported from the bark of *A. argentea* [11], whereas compounds **3**–**6** were new natural products.

The new compounds (**3**–**6**) feature the same cyclopentatetrahydrobenzofuran skeleton as rocaglamide (**1**) or as didesmethylrocaglamide (**2**) and differ from the latter compounds only with regard to their sub-

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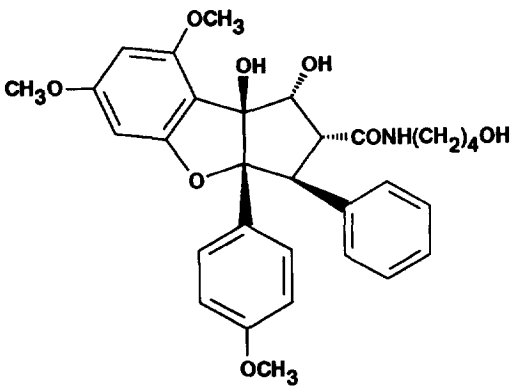

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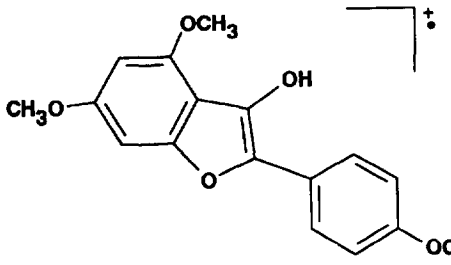
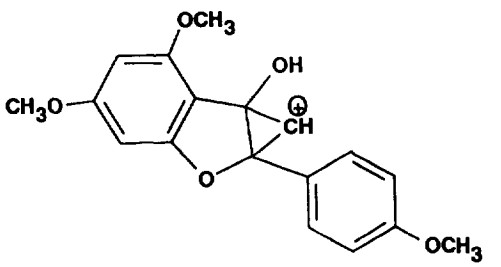


m/z 300



m/z 313

Fig. 1. Plausible structures of ions *m z* 313 and 300 arising from fragmentation of compound **3** under EI-MS conditions.

stituents at C-1 and/or C-2. The mass spectra of compounds **3**–**6** showed characteristic pairs of fragments at *m/z* 300 and 313, respectively. Plausible structures for the ions *m/z* 300 (HR EI-MS found: 300.0996, calc.: 300.0998) and 313 (HR EI-MS found: 313.1072, calc.: 313.1076) arising from fragmentation of compound **3** in the EI-mass spectrum are given in Fig. 1.

In compound **3**, the $CONH_2$ group of **2** is replaced by $CONH(CH_2)_4OH$ substituent as evident from inspection of the ^1H NMR spectrum of **3** which showed triplets at δ 3.18 and 3.50 as well as a multiplet at δ 1.49 (Table 1). The corresponding carbon signals were observed at δ 40.1, 26.8, 30.7 and 62.5 in the ^{13}C NMR spectrum of **3** (Table 2). Compound **4** was identified as a new *O*-acetyl derivative of **3**. The presence of an acetyl substituent in **4** was evident from its mass spectrum. The molecular ion of **4** was observed at *m/z* 591 which is 42 mass units higher than the molecular ion of **3**. The mass spectrum of **4** furthermore revealed a characteristic fragment at *m/z* 531 corresponding to the loss of acetic acid. Assignment of the acetate unit at C-1 was evident from inspection of the ^1H NMR spectrum of **4** (Table 1). The resonance of H-1 (δ 6.07) of compound **4** had undergone a large downfield shift compared to the signal of H-1 of compound **3** (δ 4.80).

Compounds **5** and **6** gave identical M_rs (M^+ observed at *m/z* 547). Based on their ^1H and ^{13}C NMR spectra (Tables 1 and 2) both compounds were identified as new derivatives of **3** differing from the latter by the nature of their amino acyl side chain which had cyclized to form a tetrahydrofuran ring. Since the ^1H and ^{13}C NMR spectra of **5** and **6** were almost superimposable, both compounds could only differ from each other with regard to the stereochemistry at one or more of their stereocentres. Since compounds **5** and **6** were isolated from the same source as **1**–**4** they should have the same absolute configuration at the stereocentres C-1, C-2, C-3, C-3a and C-8b as shown for rocaglamide (**1**). The only stereocentre left in the structures of **5** and **6** is C-a of the furan ring. Hence, it is assumed that the latter two compounds differ from each other with regard to their configuration at C-a. Apparently, the asymmetric carbon present in the aminoacyl bound tetrahydrofuran ring of **5** and **6** has no influence on the CD-spectra of **5** and **6**, which are dominated by the nature of the cyclopentatetrahydrobenzofuran moiety forming the backbone of the rocaglamide derivatives and thus by the 3D-array of the main molecular chromophores, the three aromatic rings.

Leaves of *A. harmsiana* yielded compound **7** as the

Table 1. ^{1}H NMR data of compounds **1** and **3–7**

H	1	3	4	5	6	7
1	5.01 (*d*, 6.8)	4.80 (*d*, 6.0)	6.07 (*d*, 5.7)	4.82 (*d*, 6.2)	4.81 (*d*, 5.8)	4.75 (*bd*, 5.8)
2A						2.82 (*ddd*, 14.2, 13.4, 6.2)
2B	4.17 (*dd*, 6.8, 13.6)	3.85 (*dd*, 5.9, 14.3)	4.01 (*dd*, 5.9, 14.5)	3.90 (*dd*, 5.7, 14.5)	3.90 (*dd*, 5.7, 14.5)	2.13 (*dd*, 6.3, 13.4)
3	4.41 (*d*, 13.6)	4.32 (*d*, 14.3)	4.26 (*d*, 14.5)	4.33 (*d*, 14.2)	4.34 (*d*, 14.3)	3.90 (*dd*, 6.2, 14.2)
5	6.35 (*d*, 1.9)	6.31 (*d*, 2.0)	6.31 (*d*, 2.0)	6.33 (*d*, 1.9)	6.31 (*d*, 1.9)	6.31 (*d*, 1.8)
7	6.23 (*d*, 2.0)	6.20 (*d*, 2.0)	6.17 (*d*, 2.0)	6.21 (*d*, 1.9)	6.20 (*d*, 1.9)	6.23 (*d*, 1.8)
2′	7.17 (*m*)	7.20 ("*d*", 8.9)	7.24 ("*d*", 9.0)	7.18 ("*d*", 8.9)	7.19 ("*d*", 9.0)	7.09 (*d*, 2.0)
3′	6.69 (*d*, 9.0)	6.66 ("*d*", 8.9)	6.67 ("*d*", 9.0)	6.66 ("*d*", 8.9)	6.65 ("*d*", 9.0)	
5′	6.69 (*d*, 9.0)	6.66 ("*d*", 8.9)	6.67 ("*d*", 9.0)	6.66 ("*d*", 8.9)	6.65 ("*d*", 9.0)	6.74 (*d*, 8.6)
6′	7.17 (*m*)	7.20 ("*d*", 8.9)	7.24 ("*d*", 9.0)	7.18 ("*d*", 8.9)	7.19 ("*d*", 9.0)	6.94 (*dd*, 2.0, 8.7)
2″, 6″	6.91 (*m*)	6.99 (*m*)	6.97 (*m*)	6.98 (*m*)	6.97 (*m*)	7.01 (*m*)
3″, 4″, 5″	7.05 (*m*)	7.06 (*m*)	7.06 (*m*)	7.06 (*m*)	7.05 (*m*)	7.09 (*m*)
OMe-6	3.87 (*s*)	3.86 (*s*)	3.86 (*s*)	3.86 (*s*)	3.86 (*s*)	3.86 (*s*)
OMe-8	3.89 (*s*)	3.88 (*s*)	3.79 (*s*)	3.88 (*s*)	3.87 (*s*)	3.91 (*s*)
OMe-4′	3.71 (*s*)	3.70 (*s*)	3.71 (*s*)	3.71 (*s*)	3.70 (*s*)	3.76 (*s*)
N-Me	2.92 (*s*); 3.39 (*s*)					
NH-CH_2		3.18 (*t*)	3.10 (*m*)			
CH_2-CH_2		1.49 (*m*)	1.48 (*m*)			
CH_2-OH		3.50 (*t*)	3.52 (*m*)			
OCO-CH_3			1.89 (*s*)			
a				5.61 (*dd*, 3.7, 6.1)	5.60 (*dd*, 3.7, 6.0)	
bA				2.12 (*m*)	2.12 (*m*)	
bB				1.82 (*m*)	1.82 (*m*)	
cA				2.08 (*m*)	2.08 (*m*)	
cB				1.95 (*m*)	1.95 (*m*)	
dA				3.86 (*dd*, 5.7, 7.8)	3.86 (*dd*, 5.7, 7.8)	
dB				3.76 (*dd*, 6.5, 13.7)	3.77 (*dd*, 5.8, 14.3)	
O-Rham. a′						5.21 (*bs*)
b′						4.22 (*m*)
c′						3.53 (*m*)
d′						3.53 (*m*)
e′						3.82 (*dd*, 8, 6.2)
Me-Rham.						1.28 (*d*, 6.3)
OMe-Rham.						3.54 (*s*)

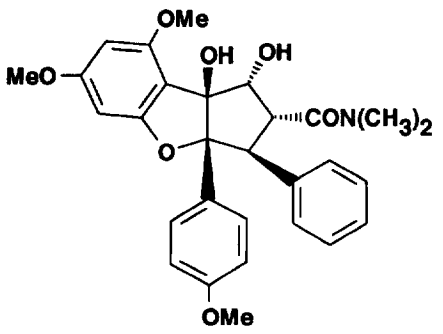
"*d*" = The signals H-2′,6′ and H-3′,5′ are part of AA′XX′ spin systems

Table 2. ^{13}C NMR data for compounds **1** and **3–7**

C	1	3	4	5	6	7
1	79.8	80.7	80.7	80.7	80.5	80.1
2	37.4	52.6	51.5	52.5	52.6	37.8
3	57.0	56.9	57.5	56.4	56.7	54.8
3a	102.6	102.7	102.4	102.7	102.7	104.0
5	90.3	90.0	89.5	90.0	89.9	90.0
7	93.2	93.0	92.7	93.0	93.0	93.7
8a	109.5	109.4	108.8	109.5	109.4	109.5
8b	95.2	95.2	93.9	95.0	95.2	95.9
1′	129.4	129.5	129.4	129.5	129.6	130.2
2′	130.2	130.3	130.2	130.3	130.3	119.9
3′	113.3	113.1	113.2	113.1	113.1	145.3
5′	113.3	113.1	113.2	113.1	113.1	112.0
6′	130.2	130.3	130.2	130.3	130.3	124.3
1″	139.8	139.1	138.7	139.2	139.2	140.3
2″, 6″	129.1	129.4	129.2	129.3	129.3	129.2
3″, 5″	128.4	128.5	128.5	128.5	128.5	128.6
4″	127.1	127.3	127.4	127.2	127.2	127.3
4′,8,4a,6	159.8	159.8	159.9	159.8	159.8	150.5
	159.2	159.4	159.7	159.3	159.5	159.1
	162.2	162.3	161.8	162.3	162.3	162.0
	165.3	165.2	165.4	165.2	165.2	165.2
ArOMe	56.1, 56.1, 55.5	56.1, 56.0, 55.5	56.1, 55.7, 55.4	56.1, 56.0, 55.4	56.1, 56.0, 55.4	56.3, 56.1, 56.1
N-Me	36.0, 30.7					
C=O	171.7	172.7	171.3	172.4	172.4	
OCO-CH_3			170.7			
OCO-CH_3			21.0			
CH_2 a		40.1	40.2			
CH a				82.0	81.9	
CH_3 b		26.8	26.6	32.2	32.2	
c		30.7	30.7	25.4	25.4	
d		62.5	62.5	68.1	68.2	
O-Rham. a′						101.4
b′						68.0
c′						81.9
d′						72.8
e′						70.7
Me-Rham						18.1
OMe-Rham						57.4

only rocaglamide derivative, which also proved to be a new natural product. The quasi molecular ion of the new compound observed at m/z 609 $[M-H]^-$ (FAB-MS, negative mode) suggested the absence of an amino acyl group at C-2. This assumption was corroborated by inspection of the ^1H and ^{13}C NMR spectra of **7**. In the ^{13}C NMR spectrum of **7** no signal indicative of a carbonyl group (usually in the range of δ 171–175 as shown for compounds **1** and **3–6**, Table 2) was observed, whereas the signal of C-2 (usually found between δ 51–52) was detected at δ 37.8 (Table 2) and was a methylene carbon from the DEPT-135 spectrum. In the ^1H NMR spectrum of **7** an additional one proton signal (H-2A), split into a *ddd* due to coupling with H-1, H-2B and H-3, was detected (Table 1). Combining this information, it was concluded that the new compound (**7**) was a derivative of rocaglaol previously reported from *A. odorata* [7]. Inspection of the aromatic proton signals reflecting the B-ring of compound **7** indicated a 3′,4′-substitution pattern as well as the presence of a modified rhamnose unit. Assignment of the methoxy group at C-4′ was based on ^1H NOE experiments since irradiation of the three proton signal at δ 3.76 caused an enhancement of the one proton signal at δ 6.74 (H-5′). Thus, the rhamnose unit had to reside at C-3′ of the rocaglamide B-ring. The presence of a methoxy group at C-c′ of the rhamnose unit was likewise confirmed by NOE experiments. Irradiation at the singlet at δ 3.54 (aliphatic methoxy group) caused an enhancement of the signal of H-c′. The nature of the glycosidic bond is α. Compound **7** is the first rocaglamide glycoside isolated from nature.

The absolute configuration of rocaglamide (**1**) is known through enantioselective synthesis [13]. The optical rotation of rocaglamide isolated from *A. ellip-*



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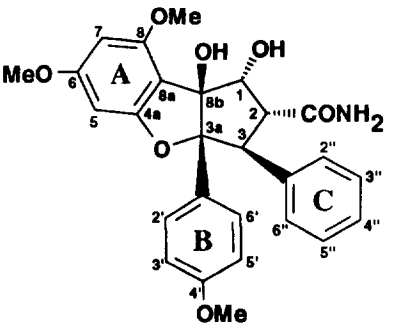

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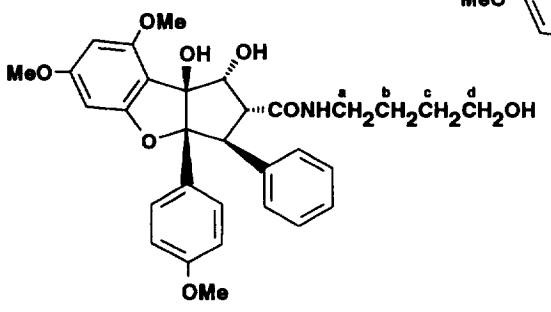

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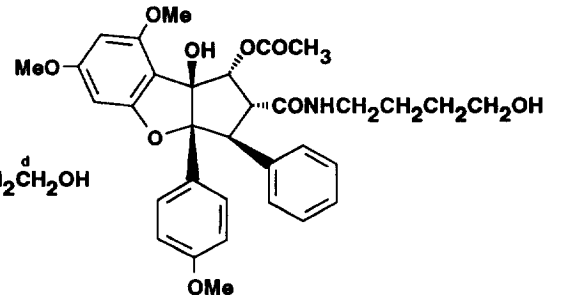

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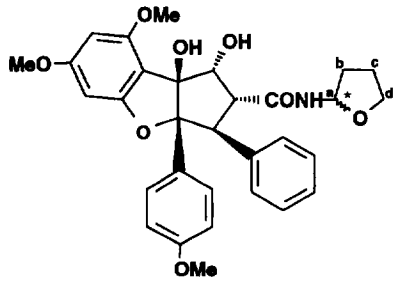
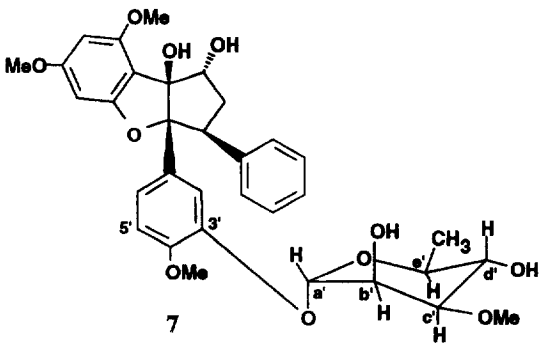


5,6

*stereocentre



7

Structure 1.

tica was $[\alpha]_D^{20} - 89.9^\circ$ ($c = 0.17$, $CHCl_3$) which is virtually identical to the optical rotation reported for the synthetic product $[\alpha]_D^{20} - 88.8^\circ$ ($c = 1.03$, $CHCl_3$) [13]. Hence, the absolute configuration of rocaglamide from *A. elliptica* is as depicted in structure **1**. The absolute configurations of compounds **2**–**7** were deduced through comparison of their CD spectra as well as of their ^1H NMR spectra with those of rocaglamide (**1**). The CD spectra of **1**–**7** are very similar showing prominent negative Cotton effects between 218–220 nm as most characteristic features. Hence, it seems feasible that compounds **2**–**7** should have the same absolute configuration as the asymmetric carbons C-3, C-3a, C-8b and possibly C-1 which are adjacent to the three aromatic rings that form the major molecular chromophores of the cyclopentatetrahydrobenzofuran moieties. The asymmetric carbon C-2, however, has apparently no influence on the CD spectra of the rocaglamide derivatives since compound **7** which lacks the stereocentre at C-2 but shows an additional asymmetric carbon in the sugar residue has virtually the same CD spectrum as those

Table 3. LC_{50} and EC_{50} values of insecticidal rocaglamide derivatives **1**–**7** and of azadirachtin towards neonate larvae of *Spodoptera littoralis*

Compound	LC_{50}	EC_{50} (ppm)
1	0.9±0.36	0.08±0.09
2	0.8±0.30	0.05±0.07
3	1.5±0.53	0.37±0.11
4	19.7±2.65	4.73±0.56
5	2.0±0.54	0.33±0.24
6	2.1±0.60	0.35±0.35
7	8.5±1.14	0.80±0.87
Azadirachtin	0.9±0.35	0.04±0.08

Chronic feeding experiments: Neonate larvae of *S. littoralis* ($n = 20$) were released on diet spiked with various concentrations of the analysed compounds (0.01–30 ppm). After six days of exposure, survival and weight of the surviving larvae were measured and compared to controls that had been exposed to diet treated with solvent (Me_2CO) only. From the dose–response curves LC_{50} and EC_{50} values were calculated by probit analysis

of compounds **1**–**6**. Assignment of the configuration at C-2 of compounds **2**–**6** was deduced by inspection of their ^1H NMR spectra (Table 1). The vicinal coupling constants $J_{(1\ 2B)}$ and $J_{(2B\ 3)}$ of compounds **2**–**6** are very similar to those of rocaglamide (**1**) (Table 1), hinting at the same relative configuration of C-1 and C-2 in relation to C-3, C-3a and C-8b. Since the latter, from the CD behaviour, should have the same absolute stereo array as **1**, for which the absolute configuration had been unambiguously identified [13], compounds **2**–**6** should have the same configuration at C-2 as rocaglamide (**1**).

All rocaglamide derivatives isolated from fruits of *A. elliptica* and leaves of *A. harmsiana* were incorporated into an artificial diet over a range of concentrations and assayed for insecticidal activity against neonate larvae of *S. littoralis*. The well known insecticidal compound azadirachtin was included in these experiments as a positive control. The LC_{50} of each compound was calculated by probit analysis (Table 3). Didesmethylrocaglamide (**2**) was the most active compound encountered. The LC_{50} of **2** was 0.8 ppm whereas its EC_{50} was 0.05 ppm. With regard to its insecticidal activity didesmethylrocaglamide is comparable to azadirachtin (Table 3). The LC_{50}s of the rocaglamide derivatives **3**, **5** and **6** ranged from 1.5–2.1 ppm and were thus only slightly higher than that of the most active compound **2**. Among the rocaglamide derivatives tested compound **4** had the lowest insecticidal activity (LC_{50} 19.7 ppm) (Table 3) which can be attributed to the presence of an acetic acid moiety esterified at C-1. A similar reduction of insecticidal activity caused by the presence of an acetyl substituent was noted in a recent study on rocaglamide derivatives from *A. duppereana* [8].

The experimental evidence provided in this study, as well as in previous studies, proves that rocaglamide derivatives are powerful natural insecticides and may hold potential as new lead structures for plant protection.

EXPERIMENTAL

Isolation and spectroscopic identification of compounds. Plant material was supplied from the Botanic Gardens at Bogor, Indonesia. Voucher specimens are kept on file in the Julius-von-Sachs-Institute. Air dried fruits of *A. elliptica* (650 g dry wt.) and leaves of *A. harmsiana* (250 g dry wt.) were ground and exhaustively extracted with MeOH. Following evapn of the solvent the extract was partitioned between H_2O–hexane, H_2O–EtOAc and H_2O–*n*-BuOH (H_2O saturated). Each fr. obtained was submitted to a bioassay with neonate larvae (see below). In this bioassay, the insecticidal activity was found to reside in the EtOAc-fr. Bioassay-guided fractionation of the EtOAc-fr. was achieved through repeated chromatographic sepn employing silica gel (Merck, Darmstadt, FRG) (mobile phase: CH_2Cl_2–iso-propanol 9:1) and Sephadex LH-20 (Sigma, Deisenhofen, FRG) (mobile phase: (Me_2CO). Final purification was obtained using RP-18 lobar columns (Merck, Darmstadt, FRG) (mobile phase: mixts of MeOH and H_2O). Frs were monitored by TLC on premade silica gel plates (F_{254}) (Merck, Darmstadt, FRG) (mobile phase: CH_2Cl_2–iso-propanol 9:1). Rocaglamide derivatives were detected by their dark absorbance under UV_{254} nm or after spraying with anisaldehyde reagent. Yields of compounds **1**–**7** were: **1**: 5.0 mg; **2**: 8.7 mg; **3**: 6.1 mg; **4**: 9.0 mg; **5**: 4.0 mg; **6**: 5.7 mg; **7**: 18.2 mg.

^1H and ^{13}C *NMR*. CD_3OD, Bruker AM 300 or ARX 400 NMR spectrometers; EI-MS: 70 eV, direct inlet; FAB-MS: glycerol as matrix. High resolution data were determined by peak matching at a resolution of approximately 10000 (10% valley). The structures of **1**–**7** were determined from 1D (^1H and ^{13}C) and 2D (COSY, ^1H-detected direct, and long-range ^{13}C-^1H correlations as well as by NOE experiments).

Experiments with insects. Larvae of *S. littoralis* were from a laboratory colony reared on artificial diet under controlled conditions at 26 as described previously [12]. Feeding studies were conducted with neonate larvae ($n = 20$ for each treatment). Neonate larvae were kept on diet treated with various concentrations of the test compounds (0.01; 0.10; 0.25; 0.50; 0.75; 1.0; 2.0; 4.0; 6.0; 8.0; 10.0; 15.0; 20.0; 25.0; and 30.0 ppm). After 6 days, the survival and to weights of the surviving larvae were recorded and compared with controls. LC_{50}s and EC_{50}s were calculated from dose–response curves by probit-analysis. Azadirachtin, which was used as a positive control, was obtained from Roth (Karlsruhe, F.R.G.).

Compound **1**: $[\alpha]_D^{20} -89.0°$ ($c = 0.17$, $CHCl_3$). CD: 217 nm ($\Delta\varepsilon$-17). EI-MS (m/z, rel. int.): 505 $[M]^+$ (19), 487 (8), 390 (40), 313 (59), 300 (57), 285 (37), 205 (26), 181 (40), 176 (100), 135 (18), 131 (18).

Compound **2**: $[\alpha]_D^{20} -56.9°$ ($c = 0.25$, $CHCl_3$). CD:

218 nm ($\Delta\varepsilon$-6), 230 nm (sh) ($\Delta\varepsilon$-3). EI-MS (*m/z*, rel. int.): 477 $[M]^+$ (8), 459 (10), 415 (10), 390 (17), 313 (36), 301 (98), 300 (100), 285 (34), 181 (26), 148 (28).

Compound **3**: $[\alpha]_D^{20} -61.4$ ($c = 0.21$, $CHCl_3$). CD: 218 nm ($\Delta\varepsilon$-11), 225 nm (sh) ($\Delta\varepsilon$-4). EI-MS (*m/z*, rel. int.): 549 $[M]^-$ (14), 531 (12), 442 (8), 415 (10), 391 (12), 390 (70), 313 (72), 300 (76), 285 (40), 249 (30), 220 (100), 181 (32), 131 (30).

Compound **4**: $[\alpha]_D^{20} -71.7$ ($c = 0.20$, $CHCl_3$). CD: 218 nm ($\Delta\varepsilon$-9), 232 nm (sh) ($\Delta\varepsilon$-2). EI-MS (*m/z*, rel. int.): 591 $[M]^+$ (12), 573 (24), 531 (58), 513 (8), 442 (56), 415 (60), 390 (40), 313 (100), 300 (94), 285 (40), 262 (24), 220 (15), 181 (32).

Compound **5**: $[\alpha]_D^{20} -45.3$ ($c = 0.22$, $CHCl_3$). CD: 218 nm ($\Delta\varepsilon$-11), 232 nm (sh) ($\Delta\varepsilon$-2). EI-MS (*m/z*, rel. int.): 547 $[M]^+$ (12), 529 (5), 459 (6), 442 (8), 415 (8), 390 (36), 313 (44), 301 (65), 300 (100), 285 (44), 218 (64), 181 (37), 148 (36).

Compound **6**: $[\alpha]_D^{20} -22.2$ ($c = 0.08$, $CHCl_3$). CD: 218 nm ($\Delta\varepsilon$-9), 235 nm (sh) ($\Delta\varepsilon$-2). EI-MS (*m/z*, rel. int.): 547 $[M]^-$ (12), 529 (3), 459 (5), 442 (10), 415 (10), 390 (36), 313 (42), 301 (60), 300 (100), 285 (42), 218 (63), 181 (35), 148 (30).

Compound **7**: $[\alpha]_D^{20} -133.0$ ($c = 0.19$, $CHCl_3$). CD: 220 nm ($\Delta\varepsilon$-9), 230 nm ($\Delta\varepsilon$-6). FAB-MS (glycerol as matrix): 609 $[M-H]^-$. EI-MS (*m/z*, rel. int.): 450 (12), 432 (8), 406 (4), 329 (16) 316 (100), 301 (22), 283 (20), 181 (12).

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REFERENCES

1. Rembold, H., in *Economic and Medicinal Plant Research*, Vol. 3, ed. H. Wagner, H. Hikino and N. R. Farnsworth. Academic Press, London, 1989, p. 57.
2. Klocke, J. A., in *Economic and Medicinal Plant Research*, Vol. 3, ed. H. Wagner, H. Hikino and N. R. Farnsworth. Academic Press, London, 1989, p. 104.
3. Chiu, S.-F., *Journal of Plant Disease Protection*, 1985, **92**, 310.
4. Mikolajczak, K. L. and Reed, D. K., *Journal of Chemistry and Ecology*, 1987, **13**, 99.
5. Champagne, D. E., Isman, M. B. and Towers, G. H. N., in *Insecticides of Plant Origin*, ed. J. T. Arnason, B. J. Philogene and P. Morand. ACS Symposium Series 387, American Chemical Society, Washington, DC, 1989, p. 95.
6. Janprasert, J., Satasook, C., Sukumalanand, P., Champagne, D. E., Isman, M. B., Wiriyachitra, P. and Towers, G. H. N., *Phytochemistry*, 1993, **32**, 67.
7. Ishibashi, F., Satasook, C., Isman, M. B. and Towers, G. H. N., *Phytochemistry*, 1993, **32**, 307.
8. Nugroho, B. W., Edrada, R. A., Güssregen, B., Wray, V., Witte, L. and Proksch, P., *Phytochemistry*, 1997, **44**, 1455.
9. Kokpol, U., Venaskulchai, B., Simpson, J. and Weavers, R. T., *Journal of the Chemical Society, Chemical Communications*, 1994, 773.
10. King, M. L., Chiang, C.-C., Ling, H.-C., Fujita, E., Ochiai, M. and McPhail, A. T., *Journal of the Chemical Society, Chemical Communications*, 1982, 1150.
11. Dumontet, V., Thoison, O., Omobuwajo, O. R., Martin, M.-T., Perromat, G., Chiaroni, A., Riche, C., Pais, M. and Sevenet, T., *Tetrahedron*, 1996, **52**, 6931.
12. Srivastava, R. P. and Proksch, P., *Entomology and Generics*, 1991, **15**, 265.
13. Trost, B. M., Greenspan, P. D., Yang, B. V. and Saulnier, M. G., *Journal of the American Chemical Society*, 1990, **112**, 9022.