# Two New Neolignans from the Stems of *Syringa pinnatifolia* HEMSL. var. *alashanensis*

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Two new neolignans, syripinnalignins A and B (**1** and **2**, resp.), were isolated from the 95% EtOH extract of the stem of *Syringa pinnatifolia* HEMSL. var. *alashanensis*. The structures of **1** and **2** were elucidated by spectroscopic methods, including UV, IR, HR-ESI-MS, and extensive 1D- and 2D-NMR techniques.

**Introduction.** – *Syringa pinnatifolia* HEMSL. var. *alashanensis* MA et S.Q.ZHOU (*Syringa pinnatifolia* HEMSL.) is a member of the family Oleaceae, genus *Syringa*, and found predominantly in the spinney and scrub in the upland of Helan Mountain, Inner Mongolia. The stem of *S. pinnatifolia* is one of the best-known traditional herbal medicines frequently used to treat cardiovascular symptoms in Mongolian medicine [1–3]. It is widely used in Mongolia as a substitute of the precious materia medica, *Lignum Aquilariae Resinatum*, which is used in the treatment of asthma, cardiopalmus, and angina pectoris. However, there are few reported phytochemical studies to support these claimed therapeutic and medicinal effects. In our previous work, some lignans were isolated from this plant [4]. As a part of our search for bioactive materials, the phytochemical study of the AcOEt fraction of *S. pinnatifolia* led to the isolation of two new neolignans, syripinnalignins A and B[1]) (**1** and **2**, resp. *Fig. 1*). In this article, we report the structural characterization of the two new compounds.

**Results and Discussion.** – The 95% EtOH extract of *S. pinnatifolia* was suspended in $H_2O$, then partitioned with petroleum ether, $CHCl_3$, AcOEt, and BuOH. The AcOEt-soluble fraction was separated by chromatography and affored the two new neolignans **1** and **2**.

Compound **1** was obtained as white needles. The molecular formula was determined to be $C_{39}H_{36}O_{11}$ by HR-ESI-MS at *m/z* 679.2168 ($[M-H]^-$). The $^1$H-NMR spectrum of **1** (*Table*) exhibited downfield signals of 12 aromatic H-atoms at $\delta$(H) 6.73 (*d*, *J* = 1.2 Hz, 1 H), 6.72 (*d*, *J* = 7.8 Hz, 1 H), 6.68 (*dd*, *J* = 7.8, 1.2 Hz, 1 H), 6.62 (*d*, *J* = 1.2 Hz, 1 H), 6.71 (*d*, *J* = 7.8 Hz, 1 H), 6.51 (*dd*, *J* = 7.8, 1.2 Hz, 1 H), 6.52 (*d*, *J* = 1.2 Hz, 1 H), 6.70 (*d*, *J* = 7.8 Hz, 1 H), 6.59 (*dd*, *J* = 7.8, 1.2 Hz, 1 H), 6.57 (*d*, *J* = 1.2 Hz, 1 H), 6.70 (*d*, *J* = 7.8 Hz, 1 H), and 6.55 (*dd*, *J* = 7.8, 1.2 Hz, 1 H), forming

[1]) Trivial atom numbering; for systematic names, see *Exper. Part.*

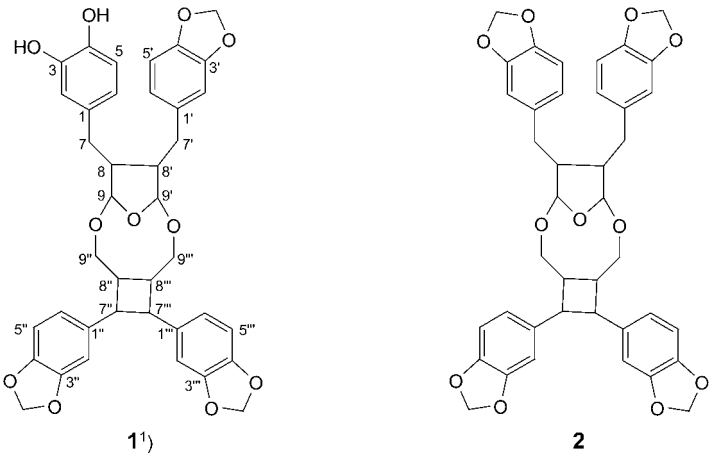


Fig. 1. *Compouds* **1** *and* **2**, *isolated from* Syringa pinnatifolia

four *ABX* systems. The $^{13}$C-NMR, DEPT, and HSQC spectra showed the signals of 39 C-atoms, corresponding to four aromatic rings ($\delta$(C) 108.1 – 148.2), two $CH_2$ ($\delta$(C) 33.6 and 38.9), six CH ($\delta$(C) 53.1, 52.0, 42.9, 45.9, 38.4, and 39.2), two oxigenated $CH_2$ ($\delta$(C) 72.2 and 72.6), two OCHO ($\delta$(C) 103.3 and 103.1), and three $OCH_2O$ groups ($\delta$(C) 100.8). Comparing with literature values [5 – 12], the $^{13}$H-NMR data and the signals at $\delta$(C) 134.5, 109.3, 148.2, 146.1, 108.2, 121.6, 33.6, 42.9 and 103.3, as well as 133.3, 108.9, 147.6, 145.9, 108.2, 121.4, 38.9, 45.9, and 103.1, and $\delta$(C) 133.9, 109.1, 147.5, 145.8, 108.1, 121.3, 38.4, 53.1, and 72.2, as well as 134.1, 109.2, 147.5, 145.8, 108.1, 121.7, 39.2, 52.0, and 72.6 suggested the presence of a monoepoxy lignan moiety and a cyclobutane lignan moiety in compound **1**. Comparison of the $^{13}$C-NMR data of the monoepoxy lignan moiety with those of the monoepoxy lignans reported in [5 – 8], the main differences were downfield shifts of C(9) ($\delta$(C) 103.3) and C(9′) ($\delta$(C) 103.1), explained by the effect of the two oxy groups at both C(9) and C(9′). The $^{13}$C-NMR spectrum of the cyclobutane lignan moiety, compared with those reported in [9 – 12], exhibited downfield shifts of C(9″) ($\delta$(C) 72.2) and C(9‴) ($\delta$(C) 72.6), providing evidence for the linkage of two lignan units through C(9)–O–C(9″) and C(9′)–O–C(9‴). The HMBC spectrum confirmed the structure of **1**, in which the correlations $OCH_2O$ ($\delta$(H) 5.91 (*s*, 6 H))/C(3′) ($\delta$(C) 147.6), C(4′) ($\delta$(C) 149.5), C(3″) ($\delta$(C) 147.5), C(4″) ($\delta$(C) 145.8), C(3‴) ($\delta$(C) 147.5), and C(4‴) ($\delta$(C) 145.8) indicated that the three $OCH_2O$ groups were located at C(3′) and C(4′), C(3″) and C(4″), and C(3‴) and C(4‴) (*Fig. 2*). The correlations H–C(7)/C(2) ($\delta$(C) 109.3), C(6) (121.6), C(9) (103.3), and C(8′) (45.9), together with the correlations H–C(7′)/C(2′) ($\delta$(C) 108.9), C(6′) (121.4), C(9′) (103.1), and C(8) (42.9), confirmed that **1** certainly contained a monoepoxy lignan moiety. In addition, the correlations of H–C(7″)/C(2″) ($\delta$(C) 109.1), C(6″) (121.3), C(9″) (72.2), and C(8‴) (52.0), together with the correlations H–C(7‴)/C(2‴) ($\delta$(C) 109.2), C(6‴) (121.7), C(9‴) (72.6), and C(8″) (53.1), implied that the other part of **1** could be a cyclobutane lignan moiety. Finally, the correlations H–C(9)/C(9″) and H–C(9′)/C(9‴) provided further evidence for the linkage of the two lignan units through

Table. *$^1$H- and $^{13}$C-NMR Data* (600 and 150 MHz, resp.; ($D_6$)DMSO) *of Compounds* **1** *and* **2**[1]). $\delta$ in ppm, $J$ in Hz.

| Position | **1** | | **2** | |
|---|---|---|---|---|
| | $\delta$(H) | $\delta$(C) | $\delta$(H) | $\delta$(C) |
| C(1) | | 134.5 | | 134.8 |
| H–C(2) | 6.73 (*d*, *J* = 1.2) | 109.3 | 6.61 (*d*, *J* = 1.2) | 109.1 |
| C(3) | | 148.2 | | 147.3 |
| C(4) | | 146.1 | | 145.4 |
| H–C(5) | 6.72 (*d*, *J* = 7.8) | 108.2 | 6.70 (*d*, *J* = 7.8) | 108.9 |
| H–C(6) | 6.68 (*dd*, *J* = 7.8, 1.2) | 121.6 | 6.56 (*dd*, *J* = 7.8, 1.2) | 121.3 |
| $CH_2$(7) | 2.78–2.76, 2.63–2.62 (2*m*) | 33.6 | 2.77–2.72, 2.61–2.59 (2*m*) | 33.9 |
| H–C(8) | 2.45–2.42 (*m*) | 42.9 | 2.49–2.46 (*m*) | 42.7 |
| H–C(9) | 5.20 (*d*, *J* = 13.2) | 103.3 | 5.19 (*d*, *J* = 13.2) | 103.1 |
| C(1′) | | 133.3 | | 134.8 |
| H–C(2′) | 6.62 (*d*, *J* = 1.2) | 108.9 | 6.61 (*d*, *J* = 1.2) | 109.1 |
| C(3′) | | 147.6 | | 147.3 |
| C(4′) | | 145.9 | | 145.4 |
| H–C(5′) | 6.71 (*d*, *J* = 7.8) | 108.2 | 6.70 (*d*, *J* = 7.8) | 108.9 |
| H–C(6′) | 6.51 (*dd*, *J* = 7.8, 1.2) | 121.4 | 6.56 (*dd*, *J* = 7.8, 1.2) | 121.3 |
| $CH_2$(7′) | 2.76–2.74, 2.44–2.40 (2*m*) | 38.9 | 2.77–2.72, 2.61–2.59 (2*m*) | 33.9 |
| H–C(8′) | 2.16–2.12 (*m*) | 45.9 | 2.49–2.46 (*m*) | 42.7 |
| H–C(9′) | 5.20 (*d*, *J* = 13.2) | 103.1 | 5.19 (*d*, *J* = 13.2) | 103.1 |
| C(1″) | | 133.9 | | 133.9 |
| H–C(2″) | 6.52 (*d*, *J* = 1.2) | 109.1 | 6.55 (*d*, *J* = 1.2) | 109.4 |
| C(3″) | | 147.5 | | 147.5 |
| C(4″) | | 145.8 | | 145.2 |
| H–C(5″) | 6.70 (*d*, *J* = 7.8) | 108.1 | 6.69 (*d*, *J* = 7.8) | 108.4 |
| H–C(6″) | 6.59 (*dd*, *J* = 7.8, 1.2) | 121.3 | 6.60 (*dd*, *J* = 7.8, 1.2) | 121.5 |
| H–C(7″) | 2.64 (*dd*, *J* = 13.8, 6.0) | 38.4 | 2.63 (*dd*, *J* = 13.2, 6.6) | 38.9 |
| H–C(8″) | 2.16–2.12 (*m*) | 53.1 | 2.11–2.09 (*m*) | 52.8 |
| $CH_2$(9″) | 4.00, 3.79 (2*dd*, *J* = 7.8, 7.2) | 72.2 | 3.97, 3.79 (2*dd*, *J* = 8.4, 7.2) | 72.7 |
| C(1‴) | | 134.1 | | 133.9 |
| H–C(2‴) | 6.57 (*d*, *J* = 1.2) | 109.2 | 6.55 (*d*, *J* = 1.2) | 109.4 |
| C(3‴) | | 147.5 | | 147.5 |
| C(4‴) | | 145.8 | | 145.2 |
| H–C(5‴) | 6.70 (*d*, *J* = 7.8) | 108.1 | 6.69 (*d*, *J* = 7.8) | 108.4 |
| H–C(6‴) | 6.55 (*dd*, *J* = 7.8, 1.2) | 121.7 | 6.60 (*dd*, *J* = 7.8, 1.2) | 121.5 |
| H–C(7‴) | 2.60 (*dd*, *J* = 13.2, 6.0) | 39.2 | 2.63 (*dd*, *J* = 13.2, 6.6) | 38.9 |
| H–C(8‴) | 2.01–1.99 (*m*) | 52.0 | 2.11–2.09 (*m*) | 52.8 |
| $CH_2$(9‴) | 4.09, 3.57 (2*dd*, *J* = 8.4, 7.2) | 72.6 | 3.97, 3.79 (*dd*, *J* = 8.4, 7.2) | 72.7 |
| $OCH_2O$ | 5.91 (*s*, 6 H) | 100.8 | 5.91 (*s*, 8 H) | 100.8 |

C(9)–O–C(9″) and C(9′)–O–C(9‴). The relative configuration at the stereogenic centers of **1** was supported by $^1$H,$^1$H-coupling constants and the NOESY experiment (*Fig. 3*). The typical coupling constants of H–C(9) and H–C(9′) ($\delta$(H) 5.20 (*d*, *J* = 13.2 Hz)), H–C(7″) ($\delta$(H) 2.64 (*dd*, *J* = 13.8, 6.0 Hz)), and H–C(7‴) ($\delta$(H) 2.60 (*dd*, *J* = 13.2, 6.0 Hz)) suggested that the relationships between H–C(8) and H–C(9), H–C(8′) and H–C(9′), H–C(7″) and H–C(8″), and H–C(7‴) and H–C(8‴) were all *trans*. The NOESY interactions H–C(8)/H–C(8′), H–C(8″), and H–C(8‴), H–C(8)/

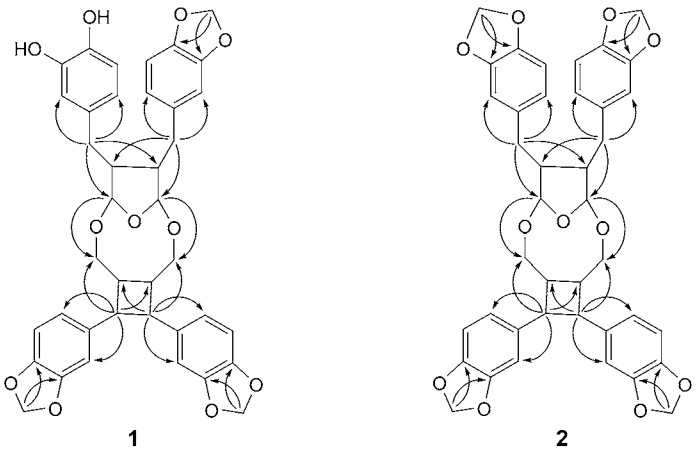


Fig. 2. *Some key HMBCs* (H → C) *of* **1** *and* **2**

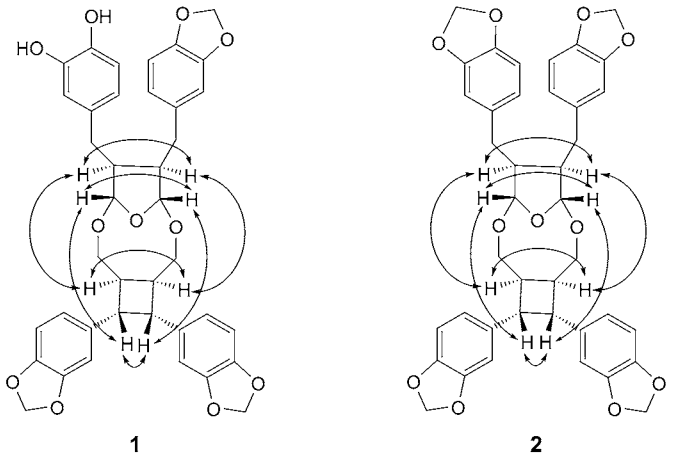


Fig. 3. *NOESY* (H ↔ H) *Correlations of* **1** *and* **2**

$H_\alpha$–C(7) ($\delta$(H) 2.63 – 2.62), H–C(8′)/$H_\alpha$–C(7′) ($\delta$(H) 2.44 – 2.40), H–C(8″)/$H_\alpha$–C(9″) ($\delta$(H) 3.79), H–C(8‴)/$H_\alpha$–C(9‴) ($\delta$(H) 3.57) indicated that H–C(8), H–C(8′), H–C(8″), and H–C(8‴) were all $\alpha$-oriented. In addition, the NOESY interactions H–C(9)/H–C(9′), H–C(7″), and H–C(7‴) suggested the $\beta$-orientation of these H-atoms. Thus, the structure of compound **1** was elucidated and named syripinnalignin A.

Compound **2** was also obtained as white needles. The molecular formula was determined to be $C_{40}H_{36}O_{11}$ by HR-ESI-MS (*m*/*z* 691.2170 ([$M - H$]$^-$)). The $^1$H- and $^{13}$C-NMR spectra of **2** (*Table*) were similar to those of **1**, except for the appearance of one additional $OCH_2O$ group at $\delta$(C) 100.8 and eight instead of six corresponding H-atoms at $\delta$(H) 5.91. The HMBC cross-peaks $OCH_2O$ ($\delta$(H) 5.91 (*s*, 8 H))/C(3) ($\delta$(C) 147.3), C(4) (145.4), C(3′) (147.3), C(4′) (145.4), C(3″) (147.5), C(4″) (145.2), C(3‴)

(147.5), and C(4‴) (145.2) indicated that the $OCH_2O$ groups were located at C(3) and C(4), C(3′) and C(4′), C(3″) and C(4″), and C(3‴) and C(4‴) (*Fig. 2*). The relative configuration at the stereogenic centers of **2** was identified by the NOESY experiment similar to that of **1** (*Fig. 3*). Based on the above evidence, the structure of compound **2** was elucidated and named syripinnalignin B.

## Experimental Part

*General.* Semi-prep. HPLC: Japanese liquid chromatograph (*Shimadzu Corporation*, Japan); *Zorbax-SB-C$_{18}$* column. Column chromatography (CC): silica gel ($SiO_2$; 200–300 mesh; *Marine Chemical Factory*, Qingdao, China) and *Sephadex LH-20* (*Pharmacia*, Uppsala, Sweden). TLC: $SiO_2$ *GF$_{254}$* (10–40 μm; *Marine Chemical Factory*, Qingdao, China); visualization by heating the plates sprayed with 10% $H_2SO_4$ in EtOH. Optical rotations: *Perkin-Elmer-241* polarimeter; in MeOH at 25°. UV Spectra: *Shimadzu-UV-2201* spectrometer (*Shimadzu Corporation*, Japan); $\lambda_{max}$ (log $\varepsilon$) in nm. IR Spectra: *Thermo-Nicolet-200* double-beam spectrophotometer (*Shimadzu Corporation*, Japan); KBr discs; $\tilde{\nu}$ in $cm^{-1}$. NMR Spectra: *Bruker-ARX-600* NMR spectrometer (*Bruker Daltonics Inc.*, USA); $\delta$ in ppm rel. to $Me_4Si$ as internal standard, *J* in Hz. HR-ESI-MS: *Bruker-Daltonics Micro-TOF-Q* instrument (*Bruker Daltonics Inc.*, USA); in *m*/*z*.

*Plant Material.* The stem of *Syringa pinnatifolia* HEMSL., used as experimental material, was collected from Alashan Meng, Inner Mongolia of China, in July 2010, and identified by Prof. *Buhebateer* (Inner Mongolia University for Nationalities). A voucher (No. 20100726) has been deposited with the School of Traditional Mongolian Medicine of the Inner Mongolia University for Nationalities.

*Extraction and Isolation.* The stem of *S. pinnatifolia* (3 kg) was crushed and extracted twice with 95% EtOH under reflux. The combined extract was concentrated and the obtained EtOH extract partitioned with petroleum ether, $CHCl_3$, AcOEt, and BuOH. The $CHCl_3$-soluble fraction (20.0 g) was subjected to CC ($SiO_2$, gradient petroleum ether/acetone 80:1 → 5:1): *Fractions 1–10*. *Fr. 6* (600 mg; petroleum ether/acetone 30:1 eluate) was subjected to CC ($SiO_2$, petroleum ether/acetone 40:1 → 10:1): *Frs. 6.1–6.4*. *Fr. 6.3* (60 mg) was subjected to CC (*Sephadex LH-20*), $CHCl_3$/MeOH 1:1) and then separated by semi-prep. HPLC (MeOH/$H_2O$ 59:41): **1** (20 mg) and **2** (23 mg).

*Syripinnalignin A* (= rel-*4-{[(1*R*,4*S*,5*R*,6*S*,7*R*,10*S*,11*S*,12*R*)-5,6-Bis(1,3-benzodioxol-5-yl)-12-(1,3-benzodioxol-5-ylmethyl)-2,9,13-trioxatricyclo[8.2.1.0$^{4,7}$]tridec-11-yl]methyl}benzene-1,2-diol*; **1**): White needles. M.p. 256–257°. $[\alpha]_D^{25} = +14.5$ ($c = 0.1$, MeOH). UV (MeOH): 219 (4.64), 267 (3.98), 314 (3.10). IR (KBr): 3334, 2944, 2821, 1613, 1594, 1485, 1341, 1258. $^1$H- and $^{13}$C-NMR: *Table.* HR-ESI-MS: 679.2168 ($[M-H]^-$, $C_{39}H_{36}O_{11}^-$; calc. 679.2173).

*Syripinnalignin B* (= rel-*4-{[(1*R*,4*S*,5*R*,6*S*,7*R*,10*S*,11*S*,12*R*)-5,6-Bis(1,3-benzodioxol-5-yl)-11,12-bis(1,3-benzodioxol-5-ylmethyl)-2,9,13-trioxatricyclo[8.2.1.0$^{4,7}$]tridecane*; **2**): White needles. M.p. 256–257°. $[\alpha]_D^{25} = +13.2$ ($c = 0.1$, MeOH). UV (MeOH): 219 (4.33), 267 (4.01), 314 (3.32). IR (KBr): 3304, 2924, 2823, 1610, 1598, 1487, 1329, 1232. $^1$H- and $^{13}$C-NMR: *Table.* HR-ESI-MS: 691.2170 ($[M-H]^-$, $C_{40}H_{36}O_{11}^-$; calc. 691.2174).

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