

## 刺通草的化学成分及其肿瘤细胞毒活性研究

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**摘要:**对刺通草(*Trevesia palmate*)的化学成分及其肿瘤细胞毒活性进行研究。通过硅胶、Sephadex LH-20、Rp-C<sub>18</sub>和高效液相色谱反复层析纯化,从刺通草的甲醇提取物中分离得到14个化合物,并运用现代波谱学技术将它们的结构分别鉴定为3-O- $\alpha$ -L-鼠李糖-(1 $\rightarrow$ 2)- $\alpha$ -L-阿拉伯糖常春藤苷(1)、齐墩果酸(2)、熊果酸(3)、川续断皂苷B(4)、灰毡毛忍冬皂苷B(5)、常春藤皂苷C(6)、地肤子皂苷Ic(7)、阿魏酸(8)、水杨苷(9)、绿原酸(10)、芦丁(11)、腺苷(12)、 $\beta$ -谷甾醇(13)和棕榈酸(14)。化合物2~14为首次从该植物中分离得到。对分离得到的部分单体化合物进行抗肿瘤活性检测,发现化合物1和3对人肿瘤细胞株SMMC-7721、Hela、MCF-7均显示出较为明显的抑制活性,且化合物1对宫颈癌细胞Hela的抑制活性为首次报道。

**关键词:**刺通草;化学成分;肿瘤细胞毒活性

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Study on the chemical constituents from *Trevesia palmate* and their cytotoxicityCHEN Xue-lin<sup>1,2#</sup>, LU Zhi-yuan<sup>1,2#</sup>, GONGPAN Pian-chou<sup>1</sup>, ZHANG Yu-mei<sup>1\*</sup><sup>1</sup>Key Laboratory of Tropical Plant Resource and Sustainable Use Xishuangbanna Tropical Botanical Garden, Chinese Academy of Sciences, Kunming 650223, China; <sup>2</sup>University of Chinese Academy of Sciences, Beijing 100049, China

**Abstract:**To investigate the chemical components of *Trevesia palmate* and evaluate their cytotoxicity, the chemical constituents of the methanol extract of *T. palmate* were separated and purified by chromatographic techniques, including column chromatography of silica gel, Sephadex LH-20, Rp-C<sub>18</sub> and HPLC. Their structures were mainly elucidated by NMR and MS spectroscopic techniques. Fourteen compounds were isolated and purified. They were identified as hederagenin 3-O- $\alpha$ -L-rhamnopyranosyl-(1 $\rightarrow$ 2)- $\alpha$ -L-arabinopyranoside (1), oleanic acid (2), ursolic acid (3), dipsacoside B (4), macranthoidin B (5), hederacoside C (6), momordin Ic (7), ferulic acid (8), salicin (9), chlorogenic acid (10), rutin (11),  $\beta$ -adenosine (12),  $\beta$ -sitosterol (13) and palmitic acid (14). Compounds 2-14 were isolated from *T. palmate* for the first time. Some compounds were tested for their cytotoxicities against human tumor cell lines SMMC-7721, Hela and MCF-7, and compounds 1 and 3 exhibited inhibitory effects on all three cells. The cytotoxicity of compound 1 on Hela was reported for the first time.

**Key words:** *Trevesia palmate*; chemical constituents; cytotoxicity

五加科(Araliaceae)是药用植物资源非常丰富的一个科<sup>[1]</sup>,有很多著名的传统药材,如人参、三七等;还有很多民间常用的中草药,如鹅掌藤、白筋等。刺通草(*Trevesia palmate* (Roxb.) Vis. var. *palmata*)

为五加科(Araliaceae)刺通草属(*Trevesia*)植物,主要分布于云南南部、广西上林和贵州贞丰<sup>[2]</sup>。目前针对刺通草属的化学成分研究比较少,从中分离得到的化学成分主要是齐墩果酸型三萜皂苷化合物,对刺通草的生物活性主要集中在抗肿瘤、降血糖、抗炎和抗病毒等方面<sup>[3-7]</sup>。

刺通草作为传统傣药,傣族人民主要用其治疗“风寒湿痹证”,且 Nunziatina 等<sup>[4]</sup>从刺通草中分离得到的三萜皂苷及其次皂甙元具有抑制细胞增殖的活性,这为其深度开发利用提供了科学依据。为进

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一步明确刺通草的化学成分及其抗肿瘤活性药效物质基础,以期为其刺通草在抗肿瘤方面的开发利用提供一定的理论依据,本课题组以生长在中国云南省西双版纳地区的刺通草作为研究对象,对其化学成分及抗肿瘤活性进行研究。

## 1 仪器与材料

### 1.1 仪器和试剂

核磁共振谱用 Avance III-600 超导核磁共振仪测定, TMS 为内标; ESI-MS 用 Water Auto Spec Premier 双聚焦三扇形磁质谱仪测定; R-1001VN 型旋转蒸发器(郑州长城科工有限公司); DLSB-5L/25 型低温冷却液循环泵(巩义市予华仪器有限公司); YP5001N 型电子天平(2~5 000g)(上海舜宇恒平科学仪器有限公司); AL104 型电子天平(0.000 0~110 g)(梅特勒-托利多仪器(上海)有限公司); SK52008 型超声波清洗器(上海科导超声仪器有限公司); UV-1 型三用紫外仪(上海顾村电光仪器); 柱层析硅胶(80~100 目, 200~300 目)及薄板层析硅胶(GF-254)均为青岛海洋化工厂生产; Sephadex LH-20(美国 Pharmacia 公司); Rp-C<sub>18</sub>(德国 Merk 公司); 高效液相色谱仪(汉邦科技公司); 所用化学试剂均为工业重蒸试剂或分析纯。

### 1.2 材料

刺通草于 2015 年 10 月采于云南西双版纳,并由中国科学院西双版纳热带植物园肖春芬老师鉴定为 *Trevesia palmate* (Roxb.) Vis. var. *palmata*, 标本(NO. 20151006)存放在中国科学院西双版纳热带植物园创新药物研究组实验室。

## 2 实验方法

### 2.1 提取与分离

将刺通草枝叶晒干,粉碎,称重得 18 kg。用 90% 甲醇于室温分别提取 3 次(7 天、3 天、3 天)。合并提取液,减压浓缩,制成甲醇浸膏。甲醇浸膏用水搅拌溶解稀释后,依次用石油醚、乙酸乙酯、正丁醇进行萃取,每种溶剂萃取四次,减压回收溶剂后得到石油醚萃取物 503 g,乙酸乙酯萃取物 69.7 g,正丁醇萃取物 208 g。石油醚部分经硅胶柱(200~300 目, 5 kg),以石油醚-丙酮(V/V=9:1、8:2、7:3、6:4、1:1、0:1)梯度洗脱,得到 A1-A7 七个组分; A2 经反复重结晶得到化合物 13(203 mg); A5 经反复硅胶柱层析和 Sephadex LH-20 纯化,得到化合物 14(33 mg); 乙酸乙酯部分经硅胶柱(200~300 目, 1.5 kg),以氯仿-甲醇(V/V=20:1、10:1、5:1、2:1、1:1、

0:1)梯度洗脱,得到 B1-B6 六个组分; B2 经反复硅胶柱层析, MCI 和 Sephadex LH-20 纯化,得到化合物 1(93 mg); B3 经反复硅胶柱层析和 Sephadex LH-20 纯化,得到化合物 12(13 mg); B5 经反复硅胶柱层析, Rp-C<sub>18</sub> 和 Sephadex LH-20 纯化,得到化合物 3(22 mg); B6 经反复硅胶柱层析, Rp-C<sub>18</sub> 和 Sephadex LH-20 纯化,得到化合物 2(15 mg); B7 经反复硅胶柱层析, Rp-C<sub>18</sub> 和 Sephadex LH-20 纯化,得到化合物 8(17 mg); 正丁醇部分经硅胶柱(200~300 目, 1.5 kg),以氯仿-甲醇(V/V=50:1、20:1、10:1、5:1、2:1、1:1、0:1)梯度洗脱,洗脱得到 C1~C7 七个组分; C1 经反复硅胶柱层析和 Sephadex LH-20 纯化,得到化合物 9(13 mg); C2 经反复硅胶柱层析, Rp-C<sub>18</sub> 和 Sephadex LH-20 纯化,得到化合物 10(15 mg); C4 经反复硅胶柱层析和 Sephadex LH-20 纯化,得到化合物 11(22 mg); C5 经反复硅胶柱层析, MCI 和 Sephadex LH-20 纯化,得到化合物 7(5 mg); C6 经反复硅胶柱层析, MCI, Rp-C<sub>18</sub> 和 Sephadex LH-20 纯化,得到化合物 4(7 mg) 和 5(7 mg); C7 经反复硅胶柱层析, MCI 和 Sephadex LH-20 纯化,得到化合物 6(4 mg)。化合物 1~14 的化学结构见图 1。

### 2.2 抗肿瘤活性筛选

采用 MTS 法<sup>[8]</sup>测定部分单体化合物对人肿瘤细胞株 SMMC-7721、Hela、MCF-7 的体外肿瘤细胞毒活性。用含 10% 胎牛血清的培养液(DMEM 或者 RPMI1640)配成单个细胞悬液,以每孔 5 000 个细胞接种到 96 孔板,每孔体积 100  $\mu$ L,细胞提前 12~24 h 接种培养。加入待测化合物溶液(化合物用 DMSO 溶解,化合物以 100  $\mu$ g/mL 浓度初筛),每孔终体积 200  $\mu$ L,每种处理均设 3 个复孔。37  $^{\circ}$ C 培养 48 h 后,细胞弃孔内培养液,每孔加 MTS 溶液 20  $\mu$ L 以及培养液 100  $\mu$ L; 设 3 个空白复孔(MTS 溶液 20  $\mu$ L 和培养液 100  $\mu$ L 的混合液),继续孵育 2~4 h,使反应充分进行。多功能酶标仪(MULTISKAN FC)测定 492 nm 处的 OD 值,计算得出抗肿瘤活性的抑制率。每次实验均设顺铂(DDP)和紫杉醇(taxol)两个阳性化合物,以浓度为横坐标,细胞存活率为纵坐标绘制细胞生长曲线,应用两点法计算化合物的 IC<sub>50</sub> 值。

具有抑制率超 50% 的待测样品进行复筛,在测试浓度基础上向下稀释 5 个浓度,测定 OD 值,计算抑制率,求出相应的半数抑制浓度 IC<sub>50</sub>。

$$\text{抑制率} = (1 - \text{实验孔 OD}_{492 \text{ nm}} / \text{空白孔 OD}_{492 \text{ nm}}) \times 100\%$$

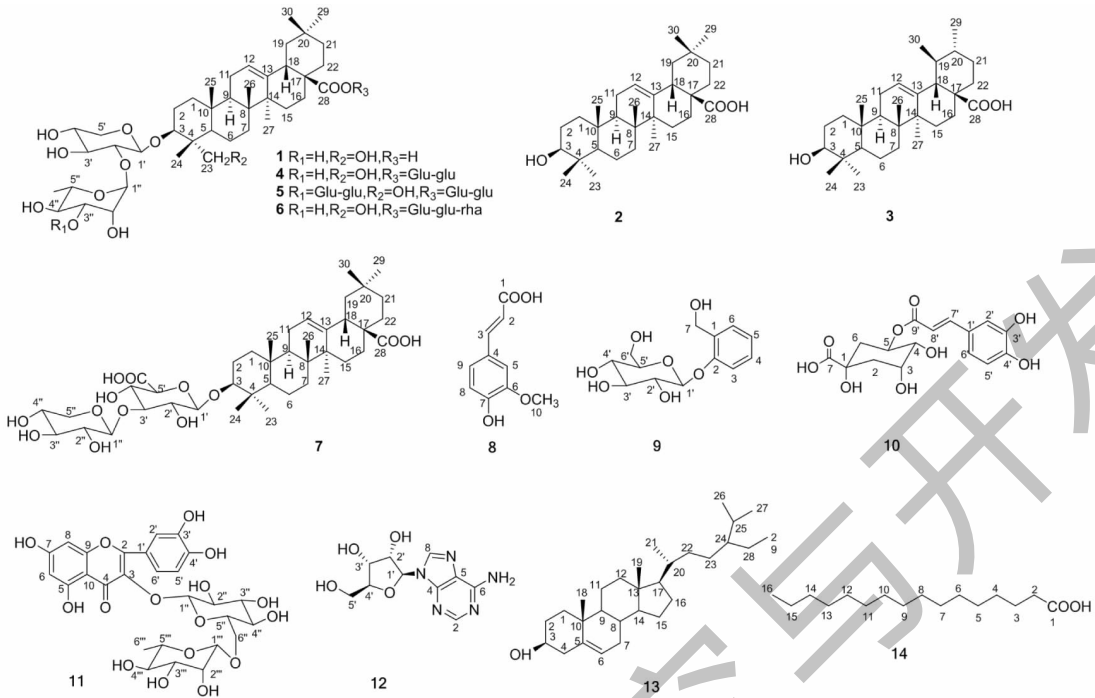


图1 化合物1~14的化学结构

Fig. 1 The chemical structures of compounds 1-14

$IC_{50}$  (50% concentration of inhibition) 按 Reed&Muench 法计算。

### 3 实验结果

#### 3.1 结构鉴定

**化合物 1** 白色粉末(甲醇);化学式为  $C_{41}H_{66}O_{12}$ ,ESI-MS:  $m/z$  749  $[M-H]^-$ ;  $^1H$  NMR (600 MHz,  $CD_3OD$ )  $\delta$ : 5.24 (1H, t,  $J = 3.6$  Hz, H-12), 5.16 (1H, d,  $J = 1.2$  Hz, H-1'), 4.55 (1H, d,  $J = 5.4$  Hz, H-1''), 3.38 (1H, dd,  $J = 11.0, 6.8$  Hz, H-3), 1.24 (3H, d,  $J = 6.0$  Hz, H-6''), 1.18 (3H, s, H-27), 0.98 (3H, s, H-24), 0.94 (3H, s, 26), 0.91 (3H, s, H-30), 0.82 (3H, s, H-25), 0.70 (3H, s, H-29);  $^{13}C$  NMR (150 MHz,  $CD_3OD$ )  $\delta$ : 39.8 (C-1), 26.7 (C-2), 82.4 (C-3), 44.1 (C-4), 48.2 (C-5), 18.1 (C-6), 34.0 (C-7), 40.7 (C-8), 48.4 (C-9), 37.8 (C-10), 24.7 (C-11), 123.8 (C-12), 145.4 (C-13), 43.1 (C-14), 29.0 (C-15), 24.1 (C-16), 47.8 (C-17), 42.9 (C-18), 47.4 (C-19), 31.8 (C-20), 35.0 (C-21), 33.5 (C-22), 64.7 (C-23), 13.9 (C-24), 16.5 (C-25), 17.9 (C-26), 26.6 (C-27), 182.1 (C-28), 33.7 (C-29), 24.2 (C-30), 104.5 (C-1'), 79.6 (C-2'), 76.8 (C-3'), 70.3 (C-4'), 65.0 (C-5'), 102.0 (C-1''), 72.2

(C-2''), 72.3 (C-3''), 74.1 (C-4''), 69.4 (C-5''), 19.0 (C-6'')。以上数据与文献<sup>[9]</sup>报道一致,鉴定为 3-O- $\alpha$ -L-鼠李糖-(1 $\rightarrow$ 2)- $\alpha$ -L-阿拉伯糖常春藤苷。

**化合物 2** 白色针状结晶(甲醇);化学式为  $C_{30}H_{48}O_3$ ,ESI-MS:  $m/z$  455  $[M-H]^-$ ;  $^1H$  NMR (600 MHz,  $CD_3OD$ )  $\delta$ : 5.22 (1H, t,  $J = 3.6$  Hz, H-12), 3.15 (1H, dd,  $J = 11.4, 4.2$  Hz, H-3), 1.16 (3H, s, H-27), 0.97 (3H, s, H-23), 0.94 (6H, s, H-24, H-29), 0.91 (3H, s, H-30), 0.82 (3H, s, H-25), 0.78 (3H, s, H-26);  $^{13}C$  NMR (150 MHz,  $CD_3OD$ )  $\delta$ : 38.6 (C-1), 27.4 (C-2), 79.2 (C-3), 39.0 (C-4), 55.4 (C-5), 18.5 (C-6), 32.8 (C-7), 39.4 (C-8), 47.8 (C-9), 37.3 (C-10), 23.2 (C-11), 122.9 (C-12), 143.8 (C-13), 41.8 (C-14), 27.9 (C-15), 23.6 (C-16), 46.7 (C-17), 41.3 (C-18), 46.1 (C-19), 30.9 (C-20), 34.0 (C-21), 32.6 (C-22), 28.3 (C-23), 15.8 (C-24), 15.5 (C-25), 17.3 (C-26), 26.1 (C-27), 181.6 (C-28), 33.3 (C-29), 23.8 (C-30)。以上数据与文献<sup>[10]</sup>报道基本一致,鉴定为齐墩果酸。

**化合物 3** 白色针状结晶(甲醇);化学式为  $C_{30}H_{48}O_3$ ,ESI-MS:  $m/z$  455  $[M-H]^-$ ;  $^1H$  NMR (600 MHz,  $CD_3OD$ )  $\delta$ : 5.23 (1H, t,  $J = 3.5$  Hz, H-12),

3.15(1H, dd,  $J = 11.6, 4.5$  Hz, H-3), 1.09(3H, s, H-27), 0.97(9H, overlapped, H-23, H-24, H-29), 0.89(3H, d,  $J = 6.4$  Hz, H-30), 0.85(3H, s, H-25), 0.77(3H, s, H-26);  $^{13}\text{C}$  NMR(150 MHz,  $\text{CD}_3\text{OD}$ )  $\delta$ : 40.6(C-1), 28.0(C-2), 79.8(C-3), 40.6(C-4), 56.9(C-5), 19.6(C-6), 34.5(C-7), 40.9(C-8), 48.1(C-9), 38.2(C-10), 24.5(C-11), 127.0(C-12), 139.8(C-13), 43.4(C-14), 29.3(C-15), 25.5(C-16), 48.1(C-17), 54.5(C-18), 40.1(C-19), 40.0(C-20), 31.9(C-21), 38.3(C-22), 28.9(C-23), 16.5(C-24), 16.2(C-25), 17.8(C-26), 24.2(C-27), 181.8(C-28), 17.9(C-29), 21.7(C-30)。以上数据与文献<sup>[11]</sup>报道一致, 鉴定为熊果酸。

**化合物 4** 白色粉末(甲醇); 化学式为  $\text{C}_{53}\text{H}_{86}\text{O}_{22}$ , ESI-MS:  $m/z$  1119  $[\text{M} + 2\text{Na} - \text{H}]^-$ , 749  $[\text{M} - 2\text{Glc} - \text{H}]^-$ ;  $^1\text{H}$  NMR(600 MHz,  $\text{CD}_3\text{OD}$ )  $\delta$ : 5.33(1H, d,  $J = 8.2$  Hz, H-1'''), 5.25(1H, brs, H-12), 5.16(1H, s, H-1''), 4.64(1H, s, H-1'''), 4.55(1H, d,  $J = 5.6$  Hz, H-1'), 3.25(1H, dd,  $J = 5.6, 1.9$  Hz, H-3), 1.17(3H, s, H-30), 0.98(3H, s, H-29), 0.94(3H, s, H-27), 0.91(3H, s, H-26), 0.80(3H, s, H-25), 0.70(3H, s, H-24);  $^{13}\text{C}$  NMR(150 MHz,  $\text{CD}_3\text{OD}$ )  $\delta$ : 39.9(C-1), 26.7(C-2), 82.4(C-3), 44.1(C-4), 48.3(C-5), 18.1(C-6), 33.5(C-7), 40.8(C-8), 49.7(C-9), 37.8(C-10), 24.2(C-11), 123.9(C-12), 145.1(C-13), 43.2(C-14), 29.1(C-15), 24.7(C-16), 48.2(C-17), 42.7(C-18), 47.4(C-19), 31.7(C-20), 35.0(C-21), 33.3(C-22), 64.7(C-23), 13.9(C-24), 16.7(C-25), 18.0(C-26), 26.5(C-27), 178.2(C-28), 33.7(C-29), 24.2(C-30), 104.5(C-1'), 76.8(C-2'), 74.1(C-3'), 70.3(C-4'), 65.0(C-5'), 102.0(C-1''), 72.1(C-2''), 72.2(C-3''), 74.0(C-4''), 69.4(C-5''), 19.0(C-6''), 95.9(C-1'''), 73.9(C-2'''), 78.1(C-3'''), 71.0(C-4'''), 77.9(C-5'''), 69.6(C-6'''), 104.8(C-1'''), 75.3(C-2'''), 78.3(C-3'''), 71.6(C-4'''), 78.1(C-5'''), 62.9(C-6''')。以上数据与文献<sup>[12]</sup>报道一致, 鉴定为川续断皂苷 B。

**化合物 5** 白色粉末(甲醇); 化学式为  $\text{C}_{65}\text{H}_{106}\text{O}_{32}$ , ESI-MS:  $m/z$  1073  $[\text{M} - 2\text{Glc} - \text{H}]^-$ ;  $^1\text{H}$  NMR(600 MHz,  $\text{CD}_3\text{OD}$ )  $\delta$ : 5.35(1H, d,  $J = 8.2$  Hz, H-1'''), 5.25(1H, br s, H-12), 5.16(1H, s, H-1'), 4.94(1H, overlapped, H-1'''), 4.64(1H, s, H-1''), 4.54(1H, d,  $J = 7.8$  Hz, H-1'''), 4.41(1H, d,  $J = 7.9$  Hz, H-1''),

3.38(1H, m, H-3), 1.26(3H, d,  $J = 6.2$  Hz, H-6''), 1.17(3H, s, H-25), 0.98(3H, s, H-24), 0.94(3H, s, H-27), 0.92(3H, s, H-26), 0.80(3H, s, H-30), 0.70(3H, s, H-29);  $^{13}\text{C}$  NMR(150 MHz,  $\text{CD}_3\text{OD}$ )  $\delta$ : 39.9(C-1), 26.8(C-2), 82.5(C-3), 44.1(C-4), 48.3(C-5), 18.3(C-6), 33.5(C-7), 40.8(C-8), 48.2(C-9), 37.8(C-10), 24.2(C-11), 123.9(C-12), 145.1(C-13), 43.2(C-14), 29.1(C-15), 24.7(C-16), 48.2(C-17), 42.7(C-18), 47.4(C-19), 31.7(C-20), 35.0(C-21), 33.4(C-22), 64.7(C-23), 13.9(C-24), 16.7(C-25), 18.0(C-26), 26.5(C-27), 178.2(C-28), 33.7(C-29), 24.2(C-30), 104.7(C-1'), 76.2(C-2'), 74.3(C-3'), 70.2(C-4'), 66.0(C-5'), 101.8(C-1''), 71.7(C-2''), 83.1(C-3''), 72.7(C-4''), 70.0(C-5''), 19.0(C-6''), 105.8(C-1'''), 75.3(C-2'''), 76.8(C-3'''), 80.2(C-4'''), 76.5(C-5'''), 61.7(C-6'''), 104.8(C-1'''), 75.0(C-2'''), 78.3(C-3'''), 71.5(C-4'''), 78.1(C-5'''), 62.7(C-6'''), 95.9(C-1'''), 74.0(C-2'''), 78.0(C-3'''), 71.0(C-4'''), 78.0(C-5'''), 69.6(C-6'''), 105.2(C-1'''), 75.2(C-2'''), 78.3(C-3'''), 71.0(C-4'''), 78.2(C-5'''), 62.5(C-6''')。以上数据与文献<sup>[13]</sup>报道一致, 鉴定为灰毡毛忍冬皂苷 B。

**化合物 6** 白色粉末(甲醇); 化学式为  $\text{C}_{59}\text{H}_{96}\text{O}_{26}$ , ESI-MS:  $m/z$  749  $[\text{M} - 2\text{Glc} - \text{Rha} - \text{H}]^-$ ;  $^1\text{H}$  NMR(600 MHz,  $\text{CD}_3\text{OD}$ )  $\delta$ : 5.33(1H, d,  $J = 7.8$  Hz, H-1'''), 5.25(1H, t,  $J = 3.4$  Hz, H-12), 5.16(1H, d,  $J = 1.2$  Hz, H-1''), 4.84(1H, d,  $J = 1.2$  Hz, H-1'''), 4.54(1H, d,  $J = 5.4$  Hz, H-1'''), 4.40(1H, d,  $J = 7.8$  Hz, H-1'), 3.23(1H, dd,  $J = 9.0, 8.4$  Hz, H-3), 1.27(3H, d,  $J = 6.0$  Hz, H-6''), 1.24(3H, d,  $J = 6.0$  Hz, H-6'''), 1.17(3H, s, H-30), 0.98(3H, s, H-29), 0.94(3H, s, H-27), 0.91(3H, s, H-26), 0.80(3H, s, H-25), 0.70(3H, s, H-2);  $^{13}\text{C}$  NMR(150 MHz,  $\text{CD}_3\text{OD}$ )  $\delta$ : 39.8(C-1), 26.7(C-2), 82.4(C-3), 43.1(C-4), 48.2(C-5), 18.0(C-6), 33.4(C-7), 40.8(C-8), 48.3(C-9), 37.8(C-10), 24.7(C-11), 123.9(C-12), 145.1(C-13), 42.7(C-14), 29.1(C-15), 24.2(C-16), 47.4(C-17), 41.7(C-18), 44.1(C-19), 31.7(C-20), 35.0(C-21), 33.4(C-22), 64.7(C-23), 13.9(C-24), 16.7(C-25), 18.0(C-26), 26.5(C-27), 178.3(C-28), 33.6(C-29), 24.3(C-30), 104.4(C-1'), 76.7(C-2'), 74.1(C-3'), 69.4(C-

4'), 65.1 (C-5'), 102.0 (C-1''), 72.2 (C-2''), 72.2 (C-3''), 74.0 (C-4''), 70.3 (C-5''), 18.1 (C-6''), 95.9 (C-1'''), 73.9 (C-2'''), 79.6 (C-3'''), 71.0 (C-4'''), 78.2 (C-5'''), 69.5 (C-6'''), 104.6 (C-1'''), 75.4 (C-2'''), 76.9 (C-3'''), 78.3 (C-4'''), 77.0 (C-5'''), 62.0 (C-6'''), 103.1 (C-1'''), 72.3 (C-2'''), 72.6 (C-3'''), 73.9 (C-4'''), 70.8 (C-5'''), 19.0 (C-6'''). 以上数据与文献<sup>[14]</sup>报道一致, 鉴定常春藤皂苷 C。

**化合物 7** 白色粉末(吡啶); 化学式为  $C_{41}H_{64}O_{13}$ , ESI-MS:  $m/z$  763 [M-H]<sup>-</sup>; <sup>1</sup>H NMR (600 MHz, Pyr)  $\delta$ : 5.37 (1H, overlapped, H-1''), 5.25 (1H, brs, H-12), 5.03 (1H, overlapped, H-1'), 3.30 (1H, d,  $J = 10.8$  Hz, H-3), 1.33 (3H, s, H-27), 1.32 (3H, s, H-23), 1.01 (3H, s, H-25), 0.99 (6H, s, H-24, H-29), 0.97 (3H, s, H-30), 0.79 (3H, s, H-26); <sup>13</sup>C NMR (150 MHz, Pyr)  $\delta$ : 39.0 (C-1), 26.7 (C-2), 89.6 (C-3), 40.0 (C-4), 56.1 (C-5), 20.0 (C-6), 33.8 (C-7), 40.2 (C-8), 48.4 (C-9), 37.4 (C-10), 24.2 (C-11), 123.0 (C-12), 145.3 (C-13), 42.6 (C-14), 28.5 (C-15), 24.1 (C-16), 47.1 (C-17), 42.4 (C-18), 46.9 (C-19), 31.4 (C-20), 34.7 (C-21), 33.6 (C-22), 28.8 (C-23), 17.8 (C-24), 17.4 (C-25), 18.9 (C-26), 27.0 (C-27), 180.9 (C-28), 33.7 (C-29), 24.2 (C-30), 107.2 (C-1'), 75.1 (C-2'), 86.7 (C-3'), 72.0 (C-4'), 80.3 (C-5'), 180.7 (C-6'), 106.6 (C-1''), 75.7 (C-2''), 78.6 (C-3''), 71.4 (C-4''), 67.9 (C-5''). 以上数据与文献<sup>[15]</sup>报道一致, 鉴定为地肤子皂苷 Ic。

**化合物 8** 白色粉末(甲醇); 化学式为  $C_{10}H_{10}O_4$ , EI-MS:  $m/z$  194 [M]<sup>+</sup>; <sup>1</sup>H NMR (600 MHz, CD<sub>3</sub>OD)  $\delta$ : 7.59 (1H, d,  $J = 16.2$  Hz, H-3), 7.17 (1H, d,  $J = 1.8$  Hz, H-5), 7.06 (1H, dd,  $J = 8.4, 1.8$  Hz, H-9), 6.81 (1H, d,  $J = 7.8$  Hz, H-8), 6.31 (1H, d,  $J = 15.6$  Hz, H-2), 3.89 (3H, s, H-10); <sup>13</sup>C NMR (150 MHz, CD<sub>3</sub>OD)  $\delta$ : 171.1 (C-1), 116.6 (C-2), 147.1 (C-3), 127.9 (C-4), 124.1 (C-5), 116.0 (C-6), 150.6 (C-7), 149.5 (C-8), 111.7 (C-9), 56.5 (C-10)。以上数据与文献<sup>[16]</sup>报道一致, 鉴定为阿魏酸。

**化合物 9** 白色粉末(DMSO); 化学式为  $C_{13}H_{18}O_7$ , EI-MS:  $m/z$  286 [M]<sup>+</sup>; <sup>1</sup>H NMR (600 MHz, DMSO-*d*<sub>6</sub>)  $\delta$ : 7.36 (1H, d,  $J = 7.2$  Hz, H-6), 7.20 (1H, m, H-4), 7.09 (1H, d,  $J = 7.9$  Hz, H-3), 7.00 (1H, m, H-5), 5.36 (1H, d,  $J = 4.2$  Hz, H-1'); <sup>13</sup>C NMR

(150 MHz, DMSO-*d*<sub>6</sub>)  $\delta$ : 131.5 (C-1), 154.7 (C-2), 114.7 (C-3), 127.7 (C-4), 121.7 (C-5), 127.1 (C-6), 58.2 (C-7), 101.4 (C-1'), 73.4 (C-2'), 77.1 (C-3'), 69.7 (C-4'), 76.5 (C-5'), 60.8 (C-6')。以上数据与文献<sup>[17]</sup>报道一致, 鉴定为水杨苷。

**化合物 10** 白色粉末(甲醇); 化学式为  $C_{16}H_{18}O_9$ , EI-MS:  $m/z$  354 [M]<sup>+</sup>; <sup>1</sup>H NMR (600 MHz, CD<sub>3</sub>OD)  $\delta$ : 7.56 (1H, d,  $J = 16.2$  Hz, H-7'), 7.05 (1H, d,  $J = 1.8$  Hz, H-2'), 6.95 (1H, dd,  $J = 8.4, 1.8$  Hz, H-6'), 6.78 (1H, d,  $J = 8.4$  Hz, H-5'), 6.26 (1H, d,  $J = 16.2$  Hz, H-8'), 5.33 (1H, td,  $J = 9.0, 4.4$  Hz, H-5), 4.16 (1H, m, H-3), 3.73 (1H, dd,  $J = 8.4, 3.0$  Hz, H-4), 2.21 (2H, ddd,  $J = 17.0, 13.6, 2.5$  Hz, H-2), 2.06 (2H, ddd,  $J = 14.1, 9.0, 6.7$  Hz, H-6); <sup>13</sup>C NMR (150 MHz, CD<sub>3</sub>OD)  $\delta$ : 76.2 (C-1), 38.3 (C-2), 71.4 (C-3), 73.5 (C-4), 72.1 (C-5), 38.9 (C-6), 177.1 (C-7), 127.9 (C-1'), 115.3 (C-2'), 146.9 (C-3'), 149.7 (C-4'), 116.6 (C-5'), 123.1 (C-6'), 147.2 (C-7'), 115.3 (C-8'), 168.8 (C-9')。以上数据与文献<sup>[18]</sup>报道一致, 鉴定为绿原酸。

**化合物 11** 黄色粉末(甲醇); 化学式为  $C_{27}H_{30}O_{16}$ , EI-MS:  $m/z$  610 [M]<sup>+</sup>; <sup>1</sup>H NMR (500 MHz, CD<sub>3</sub>OD)  $\delta$ : 7.66 (1H, t,  $J = 3.5$  Hz, H-2'), 7.62 (1H, dd,  $J = 10.2, 3.0$  Hz, H-6'), 6.86 (1H, d,  $J = 10.2$  Hz, H-5'), 6.39 (1H, d,  $J = 2.4$  Hz, H-8), 6.20 (1H, d,  $J = 2.4$  Hz, H-6), 5.10 (1H, d,  $J = 9.6$  Hz, H-1''), 4.51 (1H, d,  $J = 1.8$  Hz, H-1'''), 1.11 (3H, d,  $J = 7.8$  Hz, H-6'''); <sup>13</sup>C NMR (125 MHz, CD<sub>3</sub>OD)  $\delta$ : 158.5 (C-2), 135.6 (C-3), 179.4 (C-4), 163.0 (C-5), 99.9 (C-6), 166.0 (C-7), 94.8 (C-8), 159.3 (C-9), 105.6 (C-10), 123.1 (C-1'), 116.0 (C-2'), 149.8 (C-3'), 145.8 (C-4'), 117.7 (C-5'), 123.5 (C-6'), 104.7 (C-1''), 75.7 (C-2''), 77.2 (C-3''), 72.2 (C-4''), 78.2 (C-5''), 68.5 (C-6''), 102.4 (C-1'''), 72.1 (C-2'''), 71.4 (C-3'''), 73.9 (C-4'''), 69.7 (C-5'''), 17.9 (C-6''')。以上数据与文献<sup>[19]</sup>报道一致, 鉴定为芦丁。

**化合物 12** 白色粉末(DMSO); 化学式为  $C_{10}H_{13}N_5O_4$ , EI-MS:  $m/z$  267 [M]<sup>+</sup>; <sup>1</sup>H NMR (600 MHz, DMSO-*d*<sub>6</sub>)  $\delta$ : 8.35 (1H, s, H-8), 8.13 (1H, s, H-2), 5.87 (1H, d,  $J = 6.0$  Hz, H-1'), 5.22 (1H, d,  $J = 4.2$  Hz, OH-3'), 4.60 (1H, dd,  $J = 11.4, 6.0$  Hz, H-2'), 4.13 (1H, dd,  $J = 7.8, 4.8$  Hz, H-3'), 3.96 (1H, q,  $J$

= 3.6 Hz, H-4'), 3.59 (2H, m, H-5');  $^{13}\text{C}$  NMR (150 MHz, DMSO- $d_6$ )  $\delta$ : 152.4 (C-2), 149.1 (C-4), 119.4 (C-5), 156.2 (C-6), 140.0 (C-8), 87.9 (C-1'), 73.4 (C-2'), 70.7 (C-3'), 85.9 (C-4'), 61.7 (C-5')。以上数据与文献<sup>[20]</sup>报道一致, 鉴定为  $\beta$ -adenosine。

**化合物 13** 白色针状结晶; 与  $\beta$ -sitosterol 标准品对照, 经薄层色谱 (TLC) 检测, 其  $R_f$  值在三种不同溶剂体系中一致且显色相同, 故确定为  $\beta$ -谷甾醇。

**化合物 14** 白色粉末 (氯仿); 化学式为  $\text{C}_{16}\text{H}_{32}\text{O}_2$ , EI-MS:  $m/z$  256 [M]<sup>+</sup>;  $^1\text{H}$  NMR (600 MHz,  $\text{CDCl}_3$ )  $\delta$ : 2.35 (2H, t,  $J = 7.8$  Hz, H-2), 1.63 (2H, dt,  $J = 15.0, 7.2$  Hz, H-3), 0.88 (3H, t,  $J = 4.8$  Hz, H-16);  $^{13}\text{C}$  NMR (150 MHz,  $\text{CDCl}_3$ )  $\delta$ : 179.5 (C-1), 34.1 (C-2), 32.2 (C-3), 29.9 ~ 29.3 (C-4 ~ C-13), 24.9 (C-14), 22.9 (C-15), 14.4 (C-16)。以上数据与文献<sup>[21]</sup>报道一致, 鉴定为棕榈酸。

表 1 刺通草单体化合物对 SMMC-7721、Hela、MCF-7 细胞株的细胞毒活性 ( $\bar{x} \pm s, n = 2$ )

Table 1 Cytotoxicity of compounds on SMMC-7721, Hela and MCF-7 cell lines ( $\bar{x} \pm s, n = 2$ )

样品 Sample	浓度 Concentration ( $\mu\text{M}$ )	初筛 抑制率 Preliminary screening inhibition rate (%)		
		SMMC-7721	Hela	MCF-7
1	133.33	100.39 $\pm$ 0.38	99.64 $\pm$ 0.43	99.71 $\pm$ 0.25
2	219.30	18.43 $\pm$ 1.99	31.32 $\pm$ 1.21	32.57 $\pm$ 4.66
3	219.30	87.47 $\pm$ 1.18	96.68 $\pm$ 0.69	93.46 $\pm$ 1.39
4	93.11	12.43 $\pm$ 3.66	8.13 $\pm$ 2.03	2.13 $\pm$ 2.85
5	71.53	11.86 $\pm$ 1.66	2.34 $\pm$ 1.46	5.74 $\pm$ 3.65
6	81.97	11.33 $\pm$ 0.74	0.00 $\pm$ 0.31	9.02 $\pm$ 1.27
8	515.46	18.66 $\pm$ 1.69	14.29 $\pm$ 1.73	14.57 $\pm$ 2.19
9	349.65	2.53 $\pm$ 1.10	12.34 $\pm$ 1.02	16.61 $\pm$ 4.94
10	282.48	15.40 $\pm$ 2.13	11.04 $\pm$ 2.65	6.11 $\pm$ 0.14
11	163.93	19.99 $\pm$ 3.53	16.53 $\pm$ 0.82	0.04 $\pm$ 0.24

表 2 化合物 1 和化合物 3 的细胞毒活性 ( $\bar{x} \pm s, n = 2$ )

Table 2 Cytotoxicity of compound 1 and compound 3 ( $\bar{x} \pm s, n = 2$ )

样品 Sample	复筛 $\text{IC}_{50}$ Re-screening $\text{IC}_{50}$ ( $\mu\text{M}$ )		
	SMMC-7721	Hela	MCF-7
1	10.37 $\pm$ 0.19	28.57 $\pm$ 0.93	4.92 $\pm$ 0.49
3	17.46 $\pm$ 0.19	51.80 $\pm$ 4.38	6.75 $\pm$ 0.18
顺铂 DDP*	38.79 $\pm$ 2.97	42.59 $\pm$ 4.23	39.86 $\pm$ 2.10
紫杉醇 Taxol*	< 0.009	< 0.009	< 0.009

注: \* 阳性对照。

Note: \* Positive control.

## 4 结论

本研究从刺通草中分离得到 14 个化合物,其中化合物 **2** ~ **14** 为首次从刺通草中分离得到。对人肿瘤细胞株 SMMC-7721、Hela、MCF-7 的细胞毒活性筛选结果显示,化合物 **1** 和 **3** 对 3 种人肿瘤细胞株均显示出较为明显的细胞毒活性,且化合物 **1** 对人肿瘤细胞株 SMMC-7721、Hela 和 MCF-7 的细胞毒活性(其对三种人肿瘤细胞株的  $IC_{50}$  值分别为  $10.37 \pm 0.19$ 、 $28.57 \pm 0.93$  和  $4.92 \pm 0.49 \mu\text{M}$ ),均优于阳性药物顺铂 DDP(其对三种人肿瘤细胞株的  $IC_{50}$  值分别为  $38.79 \pm 2.97$ 、 $42.59 \pm 4.23$  和  $39.86 \pm 2.10 \mu\text{M}$ );而化合物 **3** 对人肿瘤细胞株 SMMC-7721 和 MCF-7 的细胞毒活性(其对人肿瘤细胞株 SMMC-7721 和 MCF-7 的  $IC_{50}$  值分别为  $17.46 \pm 0.19$  和  $6.75 \pm 0.18 \mu\text{M}$ )也优于阳性药物顺铂 DDP。其中化合物 **1** 对宫颈癌细胞 Hela 的细胞毒活性为首次报道,具有一定的抗肿瘤药物开发潜力。本研究通过对刺通草化学成分和肿瘤细胞毒活性的研究,进一步明确了刺通草的抗肿瘤活性药效物质基础,为刺通草在抗肿瘤方面的开发利用提供了一定的理论依据。

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