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ANTIMALARIAL COMPOUNDS FROM DENDROBIUM VENUSTUM

Miss Prapapun Sukphan

A Thesis Submitted in Partial Fulfillment of the Requirements
for the Degree of Master of Science in Pharmacy Program in Pharmacognosy
Department of Pharmacognosy and Pharmaceutical Botany
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Thesis Title	ANTIMALARIAL COMPOUNDS FROM DENDROBIUM VENUSTUM
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ประภาพรรณ สุขพรรณ์ : สารที่มีฤทธิ์ต้านมาลาเรียจากเอื้องดอกมะขาม. (ANTIMALARIAL COMPOUNDS FROM DENDROBIUM VENUSTUM) อ.ที่ปรึกษาวิทยานิพนธ์หลัก: รศ. ภก. ดร.บุญชู ศรีตุลารักษ์, อ.ที่ปรึกษาวิทยานิพนธ์ร่วม: ศ. ภก. ดร.กิตติศักดิ์ ลิขิตวิทยาวุฒิ, , หน้า.

การศึกษาทางฤทธิ์ชีวภาพของสารสกัดหยาบด้วยเมทานอลจากต้นเอื้องดอกมะขาม (วงศ์กล้วยไม้) สามารถแยกสารบริสุทธิ์ที่เคยมีรายงานมาแล้ว ได้แก่ กลุ่ม bibenzyl 2 ชนิด (gigantol, batatasin III) และกลุ่ม phenanthrene 5 ชนิด (flavanthrinin, densiflorol B, lusianthridin, phoyunanin C, E) สารทั้งหมดนั้นสามารถพิสูจน์โครงสร้างทางเคมี โดยการวิเคราะห์ข้อมูลสเปกโตรสโคปี (UV, IR, MS, NMR) ร่วมกับการเปรียบเทียบข้อมูลที่มีรายงานมาแล้ว จากการศึกษาฤทธิ์ในการต้านมาลาเรีย พบว่า gigantol, batatasin III, densiflorol B, phoyunanin C และ E มีฤทธิ์ต้านมาลาเรีย โดยมีค่าความเข้มข้นที่สามารถต้านมาลาเรีย 50% (IC50) คือ 0.012, 0.039, 0.001, 0.006 และ 0.001 ไมโครโมลาร์ ตามลำดับซึ่งมีชุดควบคุมผลบวกคือ dihydroartemisinine และ mefloquine มีค่าความเข้มข้นที่สามารถต้านมาลาเรียได้ 50% (IC50) = 0.0018 และ 0.0314 ไมโครโมลาร์ ตามลำดับ นอกจากนี้ในการศึกษาความเป็นพิษต่อเซลล์ผิวหนังของมนุษย์ซึ่งเป็นตัวแทนของเซลล์มนุษย์พบว่าไม่เป็นพิษ 3 ชนิดคือ gigantol, batatasin III และ densiflorol B

ภาควิชา	เภสัชเวทและเภสัชพฤกษศาสตร์	ลายมือชื่อนิสิต .....
สาขาวิชา	เภสัชเวท	ลายมือชื่อ อ.ที่ปรึกษาวิทยานิพนธ์หลัก .....
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PRAPAPUN SUKPHAN: ANTIMALARIAL COMPOUNDS FROM DENDROBIUM VENUSTUM. ADVISOR: ASSOC. PROF. BOONCHOO SRITULARAK, Ph.D., CO-ADVISOR: PROF. KITTISAK LIKHITWITAYAWUID, Ph.D., pp.

Bioactivity guided isolation of a methanol extract prepared from Dendrobium venustum to the isolation of two bibenzyls (gigantol, batatasin III) and five phenanthrenes (pherenanthrene, lusi, phoyunanin C, E). Their structures were determinated by analysis of spectroscopic methods and bioactivity. Antimalaria activity of gigantol, batatasin III, densifloral B, phoyunnanin C and E have IC50 values of 0.012, 0.039, 0.001, 0.006, 0.001 μM respectively. Dihydroartemisinin and mefloquine were used as positive controls with IC50 values of 0.0018, and 0.0314 μM respectively. In addition, they were evaluated for cytotoxicity assay (dermal skin fibroblast cell lines). Gigantol, batatasin III, and densifloral B were not cytotoxic to dermal skin fibroblast cell lines .

Department:	Pharmacognosy and Pharmaceutical Botany	Student's Signature .....
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CHAPTER I

INTRODUCTION

Malaria is an intraerythrocytic information caused by protozoa of the genus *Plasmodium*. It is transmitted by the bite of an infective female Anopheles mosquito, which serves as the vector and definitive host. Typically, four species of *Plasmodium* cause clinical disease in humans: *Plasmodium falciparum*, *P. vivax*, *P. malariae*, and *P. ovale* (Bope and Killerman, 2013). In Thailand, malaria is mainly caused by *P. falciparum* and *P. vivax*. Endemic areas of malaria in Thailand are in the border provinces, especially in mountainous regions, thick forests, and areas with water resources which can be breeding grounds of such mosquitoes. Malaria is widely in these provinces: Mae Hong Son, Tak, Trat, and Ranong. Malaria paroxysms of chills, high fevers, and then sweats are produced when infected red blood cells rupture and release mero zoites. Other symptoms include headache, febrile seizures, rigors, cough, chest pain, diarinclude nausea, vomiting, myalgias and abdominal pain. The first drug for malaria treatment was obtained from cinchona bark, and it was named quinine, and used for inhibiting replication of parasite. Currently, chloroquine, mefloquine, doxycycline, proguanil, artemisinin are used for malaria treatment (บุษบัน ศิริธัญญาลักษณ์, 2540, นิมิตร มรกต, 2554).

Plants in genus *Dendrobium* is represented by more than 1,100 species widely distributed throughout Asia including India, China, Japan, Malaysia, Phillipines, and Thailand. There are about 150 species of *Dendrobium* in Thailand (นันทิยา วรรธนะภูติ, 2555). The stems of *Dendrobium* spp. have been used in traditional medicine to treat fever, stomach diseases, dry mouth and hyperglycemia (Bulpitt *et al*., 2007).

The Phytochemical constituents of *Dendrobium* spp. are mainly classified as phenanthrenes, flavonoids, alkaloids, bibenzyls, sterols, sesquiterpenes and fluorenones. There are several reports of biological activities of *Dendrobium* plants, for example, anticancer compounds from *D. loddigesii* (Ho and Chen, 2003), antitumor compounds from *D. nobile* (You *et al*., 1995), antiplatelet aggregating agents from *D. loddigesii* (Chen *et al*., 1994) and *D. densifiorum* (Fan *et al*., 2001) and antioxidants from *D. nobile* (Zhang *et al*., 2008a).

The plants of Genus *Dendrobium* in Thailand as listed in Smitinand (2001) are as follows:

Dendrobium acerosum Lindl.	กล้วยไม้มือนาง Kluai mai mue nang (Chumphon)
D. acinaciforme Roxb.	เอื้องยอดสร้อย Ueang yot soi (Northern)
D. albosanguineum Lindl.	เอื้องตางัว Ueang ta ngua (Mae Hong Son)
D. aloifolium (Blume) Rchb.f.	เอื้องมณี Ueang mani (Bangkok)
D. anosmum Lindl.	เอื้องสาย Ueang sai (Chiang Mai, Peninsular)
D. aphyllum (Roxb.) C.E.C.Fisch.	เอื้องงวงช้าง Ueang nguang chang (Mae Hong Son)
D. bellatulum Rolfe	เอื้องแซะภู Ueng sae phu
D. bicameratum Lindl.	เอื้องเข็ม Ueang khem (Northern)
D. bilobulatum Seidenf.	กล้วยไม้ก้างปลา Kluai mai kang pla (General)
D. binoculare Rchb.f.	เอื้องคำสาย Ueang kham sai (Northern)
D. brymerianum Rchb.f.	เอื้องคำฝอย Ueang kham foi (Northern)
D. capillipes Rchb.f.	เอื้องคำกิ่ว Ueang kham kio (Lampang, Phrae)
D. cariniferum Rchb.f.	เอื้องกาจก Ueang kachok (Chiang Mai)
D. christyanum Rchb.f.	เอื้องแซะภูกระดึง Ueang sae phu kradueng (Loei)
D. chrysanthum Lindl.	เอื้องสายมรกต Ueang sai morakot (Bangkok)
D. chrysotoxum Lindl.	เอื้องคำ Ueang kham (Northern)
D. compactum Rolfe ex Hackett	เอื้องข้าวตอก Ueang khao tok (Northern)
D. concinnum Miq.	หางเปีย Hang pia (Narathiwat)
D. crepidatum Lindl. & Paxton	เอื้องสายน้ำเขียว Ueang sai nam khiao (General)
D. crocatum Hook.f.	เอื้องนางนวล Ueang nang nuan (Peninsular)
D. cruentum Rchb.f.	เอื้องนกแก้ว Ueang nok kaeo (Bangkok)
D. crumenatum Sw.	หวายตะมอย Wai tamoi (Central, Peninsular)
D. crystallinum Rchb.f.	เอื้องนางฟ่อน Ueang nang fon (Chiang Mai)
D. cumulatum Lindl.	เอื้องสายสี่ดอก Ueang sai si dok (Northern, Southeastern)
D. dantaniense Guillaumin	เอื้องเข็ม Ueang khem (Chiang Mai)

D. densiflorum Lindl.	เอื้องมอนไข่ Ueang mon khai (Northern)
D. devonianum Paxton	เอื้องเมี่ยง Ueang miang (Chiang Mai)
D. dickasonii L.O. Williams	เอื้องเคี้ยะ Ueang khia (Chiang Mai)
D. discolor Lindl.	หวายกลัก Wai klak (Bangkok)
D. dixanthum Rchb.f.	เอื้องเทียน Ueang thian (Northern)
D. draconis Rchb.f.	เอื้องเงิน Ueang ngoen (Northern)
D. ellipsophyllum Tang & Wang	เอื้องทอง Ueang thong (General)
D. exile Schltr.	เอื้องเสี้ยน Ueang sian (General)
D. falconeri Hook.	เอื้องสายวิสูตร Ueang sai wisut (Bangkok)
D. farmeri Paxton	เอื้องมัจฉาณุ Ueang mat chanu (Bangkok)
D. fimbriatum Hook.	เอื้องคำน้อย Ueang kham noi (Chiang Mai)
*D. findlayanu*m Parish & Rchb.f.	พวงหยก Phuang yok (Bangkok)
D. formosum Roxb. ex Lindl.	เอื้องเงินหลวง Ueang ngoen luang (Chiang Mai)
D. friedericksianum Rchb.f.	เอื้องเหลืองจันทบูร Ueang Lueang chantabun (Bangkok)
D. fuerstenbergianum Schltr.	เอื้องแซะภูกระดึง Ueang sae phukradueng (Loei)
D. gibsonii Lindl.	เอื้องคำสาย Ueang kham sai (Northern)
D. grande Hook.f	เอื้องแผงใบใหญ่ Ueang pheang bai yai (Peninsular)
D. gratiosissimum Rchb.f.	เอื้องกิ่งดำ Ueang king dam (Bangkok)
D. gregulus Seidenf.	เอื้องมะต่อม Ueang matom (Chiang Mai)
D.griffithianum Lindl.	เอื้องมัจฉาณุ Ueang matchanu (Bangkok)
D. harveyanum Rchb.f.	เอื้องคำฝอย Ueang kham foi (Chiang Mai)
D. hendersonii Hawkes & Heller	หวายตะมอยน้อย Wai tamoi noi (Peninsular)
D. hercoglossum Rchb.f.	เอื้องดอกมะเขือ Ueang dok ma kuea (Bangkok)
D. heterocarpum Lindl.	เอื้องสีตาล Ueang si tan (Chiang Mai)
D. indivisum (Blume) Miq. var. *indivisum*	ตานเสี้ยนไม้ Tan sian mai (Chumphon)
D. indivisum (Blume) Miq.	ก้างปลา Kang pla (General)

var. *pallidum* Seidenf.

D. infundibulum Lindl.	เอื้องตาเหิน Ueang ta hoen (General)
D. intricatum Gagnep.	เอื้องชมพู Ueang chom phu (Chanthaburi)
D. jenkinsii Wall. ex Lindl.	เอื้องผึ้งน้อย Ueang phueng noi(Chiang Mai)
D. kanburiense Seidenf.	หวายเมืองกาญจน์ Wai muang kan (Kanchanaburi)
D. leonis (Lindl.) Rchb.f.	เอื้องตะขาบใหญ่ Ueang ta khap yai (General)
D. lindleyi Steud.	เอื้องผึ้ง Ueang phueng (Northern)
D. lituiflorum Lindl.	เอื้องสายม่วง Ueang sai muang (Bangkok, Northern)
D. moschatum (Buch.-Ham.) Sw.	เอื้องจำปา Ueang champa (Northern)
D. nathanielis Rchb.f.	เกล็ดนิ่ม Klet nim (Chantaburi)
D. nobile Lindl.	เอื้องเค้ากิ่ว Ueang khao kio (Northern)
D. ochreatum Lindl.	เอื้องตะขาบ Ueang ta khap (Chiang Mai)
D. oligophyllum Gagnep.	ข้าวตอกปราจีน Khao tok prachin (General)
D. pachyglossum C.S.P.Parish & Rchb.f	เอื้องขนหมู Ueang khon mu (Mae Hong Son)
D. pachyphyllum (Kuntze) Bakh.f.	เอื้องน้อย Ueang noi (General)
D. palpebrae Lindl.	เอื้องมัจฉา Ueang mat cha, เอื้องมัจฉาณุ Ueang mat chanu (Bangkok)
D. parcum Rchb.f.	เอื้องก้านกิ่ว Ueang kan kio (Bangkok)
D. parishii Rchb.f.	เอื้องครั่ง Ueang khrang (Northern)
D. pendulum Roxb.	เอื้องไม้เท้าฤาษี Ueang mai thao ruesi (Bangkok, Chiang Mai)
D. pensile Ridl.	หวาย Wai (Narathiwat)
D. porphyrophyllum Guillaumin	เอื้องลิ้น Ueang lin (Lampang)
D. primulinum Lindl.	เอื้องสายประสาท Ueang sai prasat (Bangkok)
D. pulchellum Roxb. ex Lindl.	เอื้องคำตาควาย Ueang kham ta khwai (Mae Hong Son)
D. pychnostachyum Lindl.	เศวตสอดสี Sawet sot si (Chiang Mai)

D. salaccense (Blume) Lindl.	เอื้องใบไผ่ Ueang bai phai (Chiang Mai)
D. scabrilingue Lindl.	เอื้องแซะ Ueang sae (Mae Hong Son)
D. secundum (Blume) Lindl.	เอื้องแปรงสีฟัน Ueang preang si fan (Bangkok)
D. seidenfadenii Rchb.f.	เอื้องเกี๊ยะ Ueang kia (Chiang Mai)
D. senile Parish & Rchb.f.	เอื้องชะนี Ueang chani (Bangkok)
D. signatum Rchb.f.	เอื้องเค้ากิ่ว Ueang khao kio (Chiang Mai)
D. stuposum Lindl.	เอื้องสาย Ueang sai (Chiang Mai)
D. sulcatum Lindl.	เอื้องจำปาน่าน Ueang champa nan (Bangkok)
D. superbiens Rchb.f.	หวายคิง Wai khing (Bangkok)
D. sutepense Rolfe ex Downie	เอื้องมะลิ Ueang mali (Chiang Mai)
D. terminale Parish & Rchb.f	เอื้องแผงโสภา Ueang phaeng sopha (Peninsular)
D. thyrsiflorum Rchb.f	เอื้องมอนไข่ใบมน Ueang mon khai bai mon (Northern)
D. tortile Lindl.	เอื้องไม้ตึง Ueang mai tueng (Mae Hong Son)
D. trigonopus Rchb.f.	เอื้องคำเหลี่ยม Ueang kham liam (Chiang Mai)
D. trinervium Ridl.	เทียนลิง Thian ling (Chumphon)
D. unicum Seidenf.	เอื้องครั่งแสด Ueang krang saet (General)
D. uniflorum Griff.	เอื้องทอง Ueang thong (Pattani)
D. venustum Teijsm. & Binn	เอื้องดอกมะขาม Ueang dokmakham, ข้าวเหนียวลิง Kawneawling (Prae)
D. villosulum Lindl.	กล้วยหญ้านา Kluai ya na (Bangkok)
D. virgineum Rchb.f.	เอื้องเงินวิลาศ Ueang ngoen wilat (Northern)
D. wardianum Warner	เอื้องมณีไตรรงค์ Ueang mani trai rong (Northern)
D. wattii (Hook.f.) Rchb.f.	เอื้องแซะ Ueang sae (Northern)
D. ypsilon Seidenf.	เอื้องแบนปากตัด Ueang baen pak tat (General)

Dendrobium venustum is known in Thai as Ueang dokmakham. The fleshy stems are long about 7-10 cm, diameter 1 cm. The colour of flowers are yellow, the number of flowers are 10-20 with 2 cm wide. It has 5-9 leaves. This species is widely found in Thailand, Myanmar, Cambodia and Laos (นันทิยา วรรธนะภูติ, 2555).

The chemical constituents and bioactivities of *D. venustum* have never been studied. In this investigation, the methanol extract of this plant was found to possess antimalarial activity (IC_{50} = 3.27 ± 0.083 µg/ml). The chemical and biological study of this plant may give useful information for the development of new antimalarial drugs, as well as the chemotaxonomic study of plants in this genus.

The main objectives of this research are as follows.

1. Extraction and isolation of pure compounds from *Dendrobium venustum.*
2. Structure determination of isolated compounds.
3. Evaluation of isolated compounds for antimalarial activity.

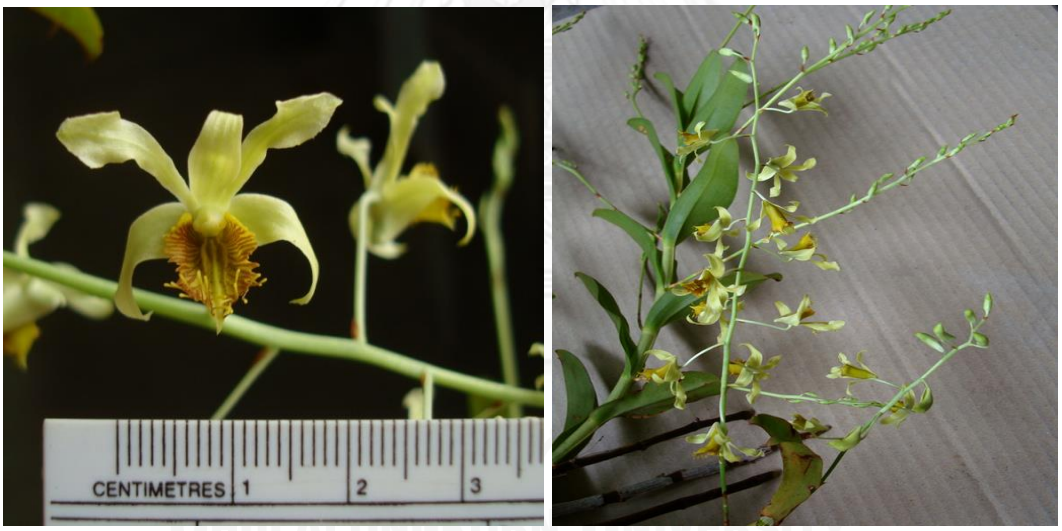


Figure 1 *Dendrobium venustum*

CHAPTER II

HISTORICAL

1. Chemical constituents of genus *Dendrobium*.

According to previous studies, the chemical constituents found in plants of the genus *Dendrobium* can be categorized into several classes, including bibenzyls (dihydrostilbenes), phenanthrenes, dihydrophenanthrenes, flavonoids, alkaloids, and miscellaneous compounds (Table 1).

Table 1 Distribution of chemical constituents in the genus *Dendrobium*

Catergory and Compound	Plant	Plant part	Reference*
Aliphatic acid			
Aliphalic acids [1]	*D. clavatum* var. *aurantiacum*	Stem	(Chang, Lin, and Chen, 2001)
Malic acid [2]	*D. huoshanense*	Aerial part	(Chang *et al*., 2010)
Shikimic acid [3]	*D. huoshanense*	Aerial part	Chang *et al*., 2010
(-)-Shikimic acid [3]	*D. fuscescens*	Whole plant	(Talapatra, Das, and Talapatra, 1989)
	D. pulchellum	Stem	Chanvorachote *et al*., 2013
(3*S*,4*S*,5*R*)-3,4,5-trihydroxy-1-cyclohexene carboxylic acid (Shikimic acid) [3]	*D. longicornu*	Stem	(Hu *et al*., 2008a)
Aliphatic alcohols [4]	*D. clavatum* var. *aurantiacum*	Stem	Chang *et al*., 2001
Aliphatic ester			
Dimethyl malate [5]	*D. huoshanense*	Aerial part	Chang *et al*., 2010
Isopentyl butyrate [6]	*D. huoshanense*	Aerial part	Chang *et al*., 2010

Table 1 (continued)

Catergory and Compound	Plant	Plant part	Reference*
Anthracene			
3,6,9-Trihydroxy-3,4-dihydroanthracen-1-(2*H*)-one [7]	*D. chrysotoxum*	Stem	(Hu *et al*., 2012)
	D. polyanthum	Stem	(Hu *et al*., 2009)
Anthraquinone			
Chrysophanol [8]	*D. thyrsiforum*	Stem	Zhang *et al*., 2005
Emodin [9]	*D. thyrsiforum*	Stem	Zhang *et al*., 2005
Physcion [10]	*D. thyrsiforum*	Stem	Zhang *et al*., 2005
Aromatic compound			
N-phenylacetamide [11]	*D. huoshanense*	Aerial part	Chang *et al*., 2010
Benzoic acid derivative			
Gallic acid [12]	*D. longicornu*	Whole plant	(Li *et al*., 2009d)
3-Hydroxy-2-methoxy-5,6-dimethylbenzoic acid [13]	*D. crystallinum*	Stem	(Wang *et al*., 2009)
Salicylic acid [14]	*D. huoshanense*	Aerial part	Chang *et al*., 2010
Syringic acid [15]	*D. crystallinum*	Stem	Wang *et al.*, 2009
Vanillic acid [16]	*D. crystallinum*	Stem	Wang *et al.*, 2009
Vanilloside [17]	*D. denneanum*	Stem	(Pan *et al*., 2012)
Benzoic acid ester			
Bis (2-ethylhexyl) phthalate [18]	D. longicornu	Whole plant	Li *et al*, 2009d

Table 1 (continued)

Catergory and Compound	Plant	Plant part	Reference*
Dibutyl phthalate [19]	*D. aphyllum*	Whole plant	Chen *et al.*, 2008a
	D. longicornu	Whole plant	Li *et al*, 2009d
Diisobutyl phthalate [20]	*D. aphyllum*	Whole plant	Chen *et al.*, 2008a
Benzoquinone			
2,6-Dimethoxy	*D. chryseum*	Stem	(Ma *et al*., 1998)
benzoquinone [21]			
Bibenzyl			
Aloifol I [22]	*D. longicornu*	Stem	Hu *et al*., 2008a
Amoenylin [23]	*D. amoenum*	Whole plant	(Majumder, Guha, and Pal, 1999)
Betatasin [24]	*D. longicornu*	Stem	Hu *et al*., 2008a
	D. plicatile	Stem	(Yamaki and Honda, 1996)
	D. polyanthum	Stem	Hu *et al*., 2009
Batatasin III [25]	*D. aphyllum*	Whole plant	Chen *et al.*, 2008a
	D. cariniferum	Stem	(Chen *et al*., 2008c)
	D. chrysotoxum	Whole plant	(Li *et al*., 2009c)
	D. cariniferum	Stem	(Chen *et al*., 2008c)
	D. chrysotoxum	Whole plant	Li et al., 2009c

Table 1 (continued)

Catergory and Compound	Plant	Plant part	Reference*
	D. draconis	Stem	(Sritularak, Anuwat, and Likhitwitayawuid, 2011a)
	D. gratiosissimum	Stem	(Zhang *et al*., 2008a)
	D. loddigesii	Whole plant	(Ito *et al*., 2010)
	D. rotundatum	Whole plant	(Majumder and Pal, 1992)
Brittonin A [26]	*D. secundum*	Stem	Sritularak *et al*., 2011b
Chrysotobibenzyl [27]	*D. aurantiacum* var.*denneanum*	Stem	(Yang, Wang, and Xu, 2006a)
	D. capillipes	Stem	Phechrmeekha *et al*., 2012
	D. chrysanthum	Stem	(Yang *et al*., 2006b)
	D. chryseum	Stem	Ma *et al*., 1998
	D. chrysotoxum	Stem	Hu *et al*., 2012
	D. nobile	Stem	(Zhang *et al*., 2007a)
	D. pulchellum	Stem	Chanvorachote *et al*., 2013

Table 1 (continued)

Catergory and Compound	Plant	Plant part	Reference*
Chrysotoxine [28]	*D. aurantiacum* var.*denneanum*	Stem	Yang *et al.*, 2006a
	D. capillipes	Stem	Phechrmeekha *et al*., 2012
	D. chrysanthum	Stem	Yang *et al*., 2006b
	D. chryseum	Stem	Ma *et al*., 1998
	D. nobile	Stem	Zhang *et al*., 2007a
	D. pulchellum	Stem	Chanvorachote *et al*., 2013
Crepidatin [29]	*D. aurantiacum* var.*denneanum*	Whole plant	(Liu *et al*., 2009a)
	D. capillipes	Stem	Phechrmeekha *et al*., 2012
	D. chrysanthum	Stem	Yang *et al*., 2006b
	D. crepidatum	Whole plant	(Majumder and Chatterjee, 1989)
	D. nobile	Stem	Zhang *et al*., 2007a
	D. pulchellum	Stem	Chanvorachote *et al*., 2013
Cumulatin [30]	*D. cumulatum*	Whole plant	(Majumder and Pal, 1993)
Dendrocandin A [31]	*D. candidum*	Stem	(Li *et al*., 2008)
Dendrocandin B [32]	*D. candidum*	Stem	Li et al., 2008

Table 1 (continued)

Catergory and Compound	Plant	Plant part	Reference*
Dendrocandin C [33]	*D. candidum*	Stem	(Li *et al*., 2009a)
Dendrocandin D [34]	*D. candidum*	Stem	Li *et al.,* 2009a
Dendrocandin E [35]	*D. candidum*	Stem	Li *et al.,* 2009a
Dendrocandin F [36]	*D. candidum*	Stem	(Li *et al*., 2009b)
Dendrocandin G [37]	*D. candidum*	Stem	Li *et al.,* 2009b
Dendrocandin H [38]	*D. candidum*	Stem	Li *et al.,* 2009b
Dendrocandin I [39]	*D. candidum*	Stem	Li *et al.,* 2009b
Dendrobin A [40]	*D. nobile*	Stem	(Wang, Zhao, and Che, 1985; Ye and Zhao, 2002a)
Dendrophenol [41]	*D. candidum*	Stem	Li *et al.,* 2008
Densiflorol A [42]	*D. densiflorum*	Stem	(Fan *et al*., 2001)
3,4-Dihydroxy-5,4′-dimethoxybibenzyl [43]	*D. candidum*	Stem	Li *et al.,* 2008
	D. gratiosissimum	Stem	Zhang *et al.*, 2008a
	D. moniliforme	Stem	(Bi, Wang, and Xu, 2004)
3,4′-Dihydroxy-5-methoxybibenzyl [44]	*D. amoenum*	Whole plant	Majumder *et al*., 1999
	D. gratiosissimum	Stem	Zhang *et al.*, 2008a
4,4′-Dihydroxy-3,5-dimethoxybibenzyl [45]	*D. candidum*	Stem	Li *et al.,* 2008

Table 1 (continued)

Catergory and Compound	Plant	Plant part	Reference*
3,4′-Dihydroxy-5,5′-dimethoxydihydro stilbene [46]	*D. nobile*	Stem	Hwang *et al*., 2010
4,5-Dihydroxy-3,3′-dimethoxybibenzyl (Dendrobin A) [47]	*D. nobile*	Stem	Ye and Zhao *et al.*, 2002a
Erianin [48]	*D. chrysotoxum*	Stem	Hu *et al*., 2012
Gigantol [49]	*D. aphyllum*	Whole plant	Chen *et al*., 2008a
	D. aurantiacum var.denneanum	Whole plant	Liu *et al*., 2009a
	D. candidum	Stem	Li *et al*., 2008
	D. capillipes	Stem	Phechrmeekha *et al*., 2012
	D. cariniferum	Stem	Chen *et al*., 2008c
	D. chrysanthum	Stem	Yang *et al*., 2006b
	D. chrysotoxum	Whole plant	Li *et al*., 2009c
	D. densiflorum	Stem	Fan *et al.*, 2001
	D. draconis	Stem	Sritularak *et al*., 2011a
	D. gratiosissimum	Stem	Zhang *et al.*, 2008a
	D. loddigesii	Whole plant	Ito *et al.*, 2010
	D. longicornu	Stem	Hu *et al*., 2008a

Table 1 (continued)

Catergory and Compound	Plant	Plant part	Reference*
	D. nobile	Stem	Zhang *et al*., 2007a
	D. polyanthum	Stem	Hu *et al.*, 2009
	D. trigonopus	Stem	(Hu *et al*., 2008b)
4-Hydroxy-3,5,3′-trimethoxybibenzyl [50]	*D. nobile*	Stem	Ye and Zhao *et al.*, 2002a
4-[2-(3-Hydroxyphenol)-1-methoxyethyl]-2,6-dimethoxy phenol [51]	*D. longicornu*	Stem	Hu *et al*., 2008a
5-Hydroxy-3,4,3′,4′,5′-pentamethoxybibenzyl [52]	*D. secundum*	Stem	Phechrmeekha *et al*., 2012
Isoamoenylin [53]	*D. amoenum*	Whole plant	Majumder *et al.*, 1999
Loddigesiinol C [54]	*D. loddigesii*	Whole plant	Ito *et al.*, 2010
Loddigesiinol D [55]	*D. loddigesii*	Whole plant	Ito *et al.*, 2010
Longicornuol A [56]	*D. longicornu*	Stem	Hu *et al*., 2008a
3-*O*-Methylgigantol [57]	*D. candidum*	Stem	Li *et al.,* 2008
	D. plicatile	Stem	Yamaki and Honda, 1996
Moscatilin [58]	*D. amoenum*	Whole plant	Majumder *et al.*, 1999
	D. aurantiacum var. *denneanum*	Stem	Yang *et al.,* 2006a

Table 1 (continued)

Catergory and Compound	Plant	Plant part	Reference*
	D. capillipes	Stem	Phechrmeekha *et al*., 2012
	D. chrysanthum	Stem	Yang *et al.,* 2006b
	D. densiflorum	Stem	Fan *et al.*, 2001
	D. gratiosissimum	Stem	Zhang *et al.*, 2008a
	D. loddigesii	Whole plant	Chen *et al.*, 1994 ; Ito *et al.*, 2010
	D. longicornu	Stem	Hu *et al*., 2008a
	D. moscatum	Whole plant	(Majumder and Sen, 1987)
	D. nobile	Stem	(Yang, Sung, and Kim, 2007)
	D. polyanthum	Stem	Hu *et al.*, 2009
	D. pulchellum	Stem	Chanvorachote *et al*., 2013
	D. secundum	Stem	Sritularak *et al.*, 2011b
Nobilin A [59]	*D. nobile*	Stem	(Zhang *et al*., 2006)
Nobilin B [60]	*D. nobile*	Stem	Zhang *et al*., 2006
Nobilin C [61]	*D. nobile*	Stem	Zhang *et al*., 2006
Nobilin D [62]	*D. nobile*	Stem	Zhang *et al*., 2007a
Trigonopol A [63]	*D. trigonopus*	Stem	Hu *et al.*, 2008b
Trigonopol B [64]	*D. chrysotoxum*	Stem	Hu *et al.*, 2012

Table 1 (continued)

Catergory and Compound	Plant	Plant part	Reference*
	D. trigonopus	Stem	Hu *et al.*, 2008b
3,3′,4-Trihydroxy bibenzyl [65]	*D. longicornu*	Stem	Hu *et al*., 2008a
3,3′,5-Trihydroxy bibenzyl [66]	*D. cariniferum*	Whole plant	(Liu *et al*., 2009b)
3,5,4′-Trihydroxy bibenzyl [67]	*D. gratiosissimum*	Stem	Zhang *et al.*, 2008a
4,5,4′-Trihydroxy-3,3′-dimethoxy bibenzyl [68]	*D. secundum*	Stem	Sritularak *et al.*, 2011b
Tristin [69]	*D. chrysotoxum*	Stem	Hu *et al.*, 2012
	D. densiflorum	Stem	Fan *et al.*, 2001
	D. gratiosissimum	Stem	Zhang *et al.*, 2008a
	D. longicornu	Stem	Hu *et al*., 2008a
	D. trigonopus	Stem	Hu *et al.*, 2008b
Bibenzyl glycoside			
Dendromoniliside E [70]	*D. moniliforme*	Stem	Zhao *et al*., 2003
Bisbibenzyl			
Dencryol A [71]	*D. crystallinum*	Stem	Wang *et al.*, 2009
Dencryol B [72]	*D. crystallinum*	Stem	Wang *et al.*, 2009
Dendrofalconerol A [73]	*D. falconeri*	Stem	Sritularak and Likhitwitayawuid, 2009
Dendrofalconerol B [74]	*D. falconeri*	Stem	Sritularak and Likhitwitayawuid, 2009

Table 1 (continued)

Catergory and Compound	Plant	Plant part	Reference*
Dengraol A [75]	*D. gratiosissimum*	Stem	Zhang *et al.*, 2008a
Dengraol B [76]	*D. gratiosissimum*	Stem	Zhang *et al.*, 2008a
Nobilin E [77]	*D. nobile*	Stem	Zhang *et al*., 2007a
Biphenanthrene			
2,2′-Dihydroxy-3,3′,4,4′,7,7-hexamethoxy-9,9′,10,10′-tetrahydro-1,1′-biphenanthrene [78]	*D. nobile*	Stem	Yang *et al*., 2007
2,2′-Dimethoxy-4,4′,7,7′-tetrahydroxy-9′,10,10′-tetrahydro-1,1′-biphenanthrene [79]	*D. plicatile*	Stem	Yamaki and Honda, 1996
Denthyrsinol [80]	*D. thyrsiforum*	Stem	Zhang *et al*., 2005
Denthyrsinone [81]	*D. thyrsiforum*	Stem	Zhang *et al*., 2005
Flavanthrin [82]	*D. aphyllum*	Whole plant	Chen *et al.*, 2008a
Coumarin			
Ayapin [83]	*D. densiflorum*	Stem	Fan *et al.*, 2001
Coumarin [84]	*D. aurantiacum var.denneanum*	Stem	Yang *et al.,* 2006a
	D. clavatum var. *aurantiacum*	Stem	Chang *et al.*, 2001
Denthyrsin [85]	*D. thyrsiforum*	Stem	Zhang *et al.*, 2005
Scoparone [86]	*D. densiflorum*	Stem	Fan *et al.*, 2001
	D. thyrsiforum	Stem	Zhang *et al.*, 2005
Scopoletin [87]	*D. densiflorum*	Stem	Fan *et al.*, 2001

Table 1 (continued)

Catergory and Compound	Plant	Plant part	Reference*
Flavanone			
(2*S*)-Homoeriodictyol [88]	*D. densiflorum*	Stem	Fan *et al.*, 2001
Naringenin [89]	*D. aurantiacum var.denneanum*	Stem	Yang *et al.,* 2006a
	D. densiflorum	Stem	Fan *et al.*, 2001
	D. longicornu	Stem	Hu *et al*., 2008a
	D. trigonopus	Stem	Hu *et al*., 2008b
Flavone			
Apigenin [90]	*D. crystallinum*	Stem	Wang *et al.*, 2009
5,6-Dihydroxy-4′-methoxy-flavone [91]	*D. chrysotoxum*	Stem	Hu *et al*., 2012
Luteolin [92]	*D. aurantiacum* var.*denneanum*	Whole plant	Liu *et al.*, 2009a
Flavone glycoside			
6-*C*-(α-Arabino pyranosyl)-8-*C*-[(2-*O*-α-rhamnopyranosyl) -β-galactopyranosyl] apigenin [93]	*D. huoshanense*	Aerial part	Chang *et al*., 2010
6-*C*-(α-Arabino pyranosyl)-8-*C*-[(2-*O*-α-rhamnopyranosyl) -β-glucopyranosyl] apigenin [94]	*D. huoshanense*	Aerial part	Chang *et al*., 2010
6‴-Glucosyl-vitexin [95]	*D. crystallinum*	Stem	Wang *et al.*, 2009
Isoschaftoside [96]	*D. huoshanense*	Aerial part	Chang *et al*., 2010
Isoviolanthin [97]	*D. crystallinum*	Stem	Wang *et al.*, 2009

Table 1 (continued)

Catergory and Compound	Plant	Plant part	Reference*
6-C-[(2-O- α-Rhamno pyranosyl)- β-gluco pyranosyl]-8-C-(α-arabinopyranosyl) apigenin [98]	*D. huoshanense*	Aerial part	Chang *et al*., 2010
6-*C*-(β-Xylopyranosyl)-8-*C*-[(2-*O*-α-rhamnopyranosyl)-β -glucopyranosyl] apigenin [99]	*D. huoshanense*	Aerial part	Chang *et al*., 2010
Vicenin-2 [100]	*D. aurantiacum* var. *denneanum*	Stem	(Xiong *et al*., 2013)
Flavonol			
Kaempferol [101]	*D. aurantiacum* var. *denneanum*	Stem	Yang *et al.,* 2006a
Flavonol glycoside			
Kaempferol-3-*O*-α-L-rhamnopyranoside [102]	*D. secundum*	Stem	Phechrmeekha *et al*., 2012
Kaempferol-3,7-*O*-di-α-L-rhamnopyranoside [103]	*D. secundum*	Stem	Phechrmeekha *et al*., 2012
Kaempferol-3-*O*-α-L-rhamnopyranosyl-(1⟶2)-β -D-gluco pyranoside [104]	*D. capillipes*	Stem	Phechrmeekha *et al*., 2012
Kaempferol-3-O-α-L-rhamnopyranosyl-(1⟶2)-β -D-xylo pyranoside [105]	*D. capillipes*	Stem	Phechrmeekha *et al*., 2012
Quercetin-3-*O*-L-rhamnopyranoside [106]	*D. secundum*	Stem	Phechrmeekha *et al*., 2012

Table 1 (continued)

Catergory and Compound	Plant	Plant part	Reference*
Quercetin-3-*O*-*α*-L-rhamnopyranosyl-(1→2)-β-D-xylopyranoside [107]	*D. capillipes*	Stem	Phechrmeekha *et al*., 2012
Fluorenone			
Dencrysan A [108]	*D. chrysotoxum*	Whole plant	Li *et al.*, 2009c
Dencrysan B [109]	*D. chrysotoxum*	Whole plant	(Chen *et al*., 2008b)
Dendroflorin [110]	*D. aurantiacum* var. *denneanum*	Stem	Yang *et al.,* 2006a
	D. chrysotoxum	Whole plant	Chen *et al.*, 2008b
	D. nobile	Stem	Zhang *et al*., 2007a
Dengibsin [111]	*D. aurantiacum* var. *denneanum*	Stem	Yang *et al.,* 2006a
	D. chrysanthum	Stem	Yang *et al*., 2006b
	D. chrysotoxum	Whole plant	Li *et al.*, 2009c
	D. densiflorum	Stem	Fan *et al.*, 2001
Nobilone [112]	*D. nobile*	Stem	Zhang *et al*., 2007a
1,4,5-Trihydroxy-7-methoxy-9*H*-fluoren-9-one [113]	*D. chrysotoxum*	Whole plant	Chen *et al.*, 2008b
2,4,7-Trihydroxy-5-methoxy-9-fluorenone [114]	*D. chrysotoxum*	Stem	(Yang *et al*., 2004)
2,4,7-Trihydroxy-1,5-dimethoxy-9-fluorenone [115]	*D. chrysotoxum*	Stem	Yang *et al*., 2004
Ketone			
Dehydrovomifoliol [116]	*D. loddigesii*	Whole plant	Ito *et al.*, 2010
Lignan			

Table 1 (continued)

Catergory and Compound	Plant	Plant part	Reference*
7-7′-Bis-(4-hydroxy-3,5-dimethoxyphenyl)-8-8′-dihydroxy methyltetra hydrofuran-4-β-D-glucoside [117]	*D. chrysanthum*	Stem	(Ye, Zhao, and Qin, 2004)
Dehydrodiconiferyl alcohol-4-β-D-glucoside [118]	*D. chrysanthum*	Stem	Ye *et al*., 2004
Episyringaresinol [119]	*D. chrysotoxum*	Stem	Hu *et al*., 2012
	D. longicornu	Stem	Hu *et al*., 2008a
	D. nobile	Stem	(Zhang *et al*., 2008b)
(-)-(7S,8R,7′E)-4-Hydroxy-3,3',5,5'-tetramethoxy-8,4′-Oxyneolign-7′-ene-7,9′-triol-7,9′-bis-*O*-β-D-glucopyranoside [120]	*D. aurantiacum* var. *denneanum*	Stem	Xiong *et al*., 2013
Lyoniresinol [121]	*D. chrysanthum*	Stem	Ye *et al*., 2004
(-)-Medioresinol [122]	*D. loddigesii*	Whole plant	Ito *et al*., 2010
(-)-Pinoresinol [123]	*D. loddigesii*	Whole plant	Ito *et al*., 2010
Pinoresinol [124]	*D. nobile*	Stem	Zhang *et al*., 2008b
Syringaresinol [125]	*D. nobile*	Stem	Zhang *et al*., 2008b
	D. secundum	Stem	Sritularak *et al*., 2011b
(-)-Syringaresinol-4,4′-bis-*O*-β-D glucopyranoside [126]	*D. aurantiacum* var. *denneanum*	Stem	Xiong *et al*., 2013
Syringaresinol-4-*O*-D-monoglucopyranoside [127]	*D. aurantiacum* var. *denneanum*	Stem	Xiong *et al*., 2013

Table 1 (continued)

Catergory and Compound	Plant	Plant part	Reference*
Lignan glycoside			
Acanthoside B [128]	*D. chrysanthum*	Stem	Ye *et al*., 2004
Episyringaresinol 4″-O-β-D-glucopyranoside [129]	*D. moniliforme*	Stem	Zhao *et al*, 2003
Erythro-1-(4-*O*-β-D-glucopyranosyl-3-methoxyphenyl)-2-[4-(3-hydroxypropyl)-2,6-dimethoxyphenoxy]-1,3-propanediol [130]	*D. longicornu*	Stem	Hu *et al*., 2008a
Liriodendrin [131]	*D. pulchellum*	Stem	Chanvorachote *et al*., 2013
Long chain hydrocarbon			
n-Nonacosane [132]	*D. moniliforme*	Stem	Bi *et al.*, 2004
Naphthalene			
Palmarumycin JC2 [133]	*D. crystallinum*	Stem	Wang *et al*., 2009
Neolignan glucoside			
Denchryside B [134]	*D. chrysanthum*	Stem	Ye *et al*., 2004
Phenanthrene			
Amoenumin [135]	*D. amoenum*	Whole plant	(Veerraju *et al*., 1989)
Bulbophyllanthrin [136]	*D. nobile*	Stem	Yang *et al.*, 2007
Coelonin [137]	*D. aphyllum*	Whole plant	Chen *et al.*, 2008a
	D. nobile	Stem	Yang *et al.*, 2007
Confusarin [138]	*D. chryseum*	Stem	Ma *et al*., 1998
	D. chrysotoxum	Stem	Hu *et al*., 2012
	D. nobile	Stem	Zhang *et al.*, 2008b
Chrysotoxol A [139]	*D. chrysotoxum*	Stem	Hu *et al*., 2012

Table 1 (continued)

Catergory and Compound	Plant	Plant part	Reference*
Chrysotoxol B [140]	*D. chrysotoxum*	Stem	Hu *et al*., 2012
Crystalltone [141]	*D. chrysotoxum*	Stem	Hu *et al*., 2012
	D. crystallinum	Stem	Wang *et al.*, 2009
Cypripedin [142]	*D. densiflorum*	Stem	Fan *et al.,* 2001
Denbinobin [143]	*D. moniliforme*	Stem	(Lin *et al*., 2001)
	D. nobile	Stem	Yang *et al.*, 2007
Dendrochrysanene [144]	*D. chrysanthum*	Stem	Yang *et al*., 2006b
Dendronone [145]	*D. chrysanthum*	Stem	Yang *et al*., 2006b
	D. longicornu	Stem	Hu *et al.*, 2008a
Densiflorol B [146]	*D. densiflorum*	Stem	Fan *et al.,* 2001
Denthyrsinin [147]	*D. thyrsiforum*	Stem	Zhang *et al.*, 2005
9,10-Dihydromoscatin [148]	*D. polyanthum*	Stem	Hu *et al.*, 2009
9,10-Dihydrophenan threne-2,4,7-triol [149]	*D. polyanthum*	Stem	Hu *et al*., 2009
4,5-Dihydroxy-2,3-dimethoxy-9,10-dihydrophenanthrene [150]	*D. sinense*	Whole plant	(Chen *et al*., 2013)
4,5-Dihydroxy-2,6-dimethoxy-9,10-dihydrophenanthrene [151]	*D. chrysotoxum*	Stem	Hu *et al.*, 2012
4,5-Dihydroxy-3,7-dimethoxy-9,10-dihydrophenanthrene [152]	*D. nobile*	Stem	Ye and Zhao *et al.*, 2002a
2,5-Dihydroxy-3,4-dimethoxyphenanthrene [153]	*D. nobile*	Stem	Yang *et al.*, 2007

Table 1 (continued)

Catergory and Compound	Plant	Plant part	Reference*
2,5-Dihydroxy-4,9-dimethoxyphenanthrene [154]	*D. nobile*	Stem	Zhang *et al.*, 2008b
	D. chrysotoxum	Whole plant	Li *et al.*, 2009c
3,7-Dihydroxy-2,4-di methoxyphenanthrene [155]	*D. chrysotoxum*	Whole plant	Li *et al.*, 2009c
4,5-Dihydroxy-2-methoxy-9,10-dihydrophenanthrene [156]	*D. nobile*	Stem	Zhang *et al*., 2008b
Lusianthridin [157]	*D. nobile*	Stem	Yang *et al.*, 2007
2,7-Dihydroxy-3,4,6-trimethoxy-9,10-dihydrophenanthrene [158]			
2,8-Dihydroxy-3,4,7-trimethoxy-9,10-dihydrophenanthrene [159]	*D. densifloru*	Stem	Fan *et al.,* 2001
4,7-Dihydroxy-2,3,6-trimethoxy-9,10-dihydrophenanthrene [160]	*D. rotundatum*	Whole plant	Majumder and Pal, 1992
2,6-Dihydroxy-1,5,7-trimethoxyphenanthrene [161]	*D. densiflorum*	Stem	Fan *et al*., 2001

Table 1 (continued)

Catergory and Compound	Plant	Plant part	Reference*
2,8-Dihydroxy-3,4,7-trimethoxyphenanthrene [163]	*D. nobile*	Stem	Yang *et al.*, 2007
5,7-Dimethoxy phenanthrene-2,6-diol [164]	*D. nobile*	Stem	Hwang *et al.*, 2010
Ephemeranthol A [165]	*D. nobile*	Stem	Yang *et al.*, 2007; Hwang *et al.*, 2010
Ephemeranthol C [166]	*D. nobile*	Stem	Yang *et al.*, 2007; Hwang *et al.*, 2010
Ephemeranthoquinone [167]	*D. plicatile*	Stem	Yamaki and Honda, 1996
Epheranthol B [168]	*D. chrysotoxum*	Stem	Hu *et al.*, 2012
	D. plicatile	Stem	Yamaki and Honda, 1996
Erianthridin [169]	*D. nobile*	Stem	Hwang *et al.*, 2010
Fimbriatone [170]	*D. nobile*	Stem	Zhang *et al.*, 2008b
	D. pulchellum	Stem	Chanvorachote *et al.*, 2013
Fimbriol B [171]	*D. nobile*	Stem	Yang *et al.*, 2007; Hwang *et al.*, 2010
Flaccidin (Amoenumin) [172]	*D. amoenum*	Whole plant	Majumder *et al.*, 1999
Flavanthridin [173]	*D. nobile*	Stem	Hwang *et al.*, 2010
Flavanthrinin [174]	*D. nobile*	Stem	Zhang *et al.*, 2008b
Hircinol [175]	*D. draconis*	Stem	Sritularak *et al.*, 2011a

Table 1 (continued)

Catergory and Compound	Plant	Plant part	Reference*
2-Hydroxy-4,7-dimethoxy-9,10-dihydrophenanthrene [176]	*D. nobile*	Stem	Yang *et al.*, 2007
5-Hydroxy-2,4-dimethoxyphenanthrene [177]	*D. loddigesii*	Whole plant	Ito *et al.*, 2010
2-Hydroxy-3,4,7-trimethoxy-9,10-dihydrophenanthrene [178]	*D. nobile*	Stem	Yang *et al.*, 2007
3-Hydroxy-2,4,7-trimethoxy-9,10-dihydrophenanthrene [179]	*D. nobile*	Stem	Yang *et al.*, 2007
3-Hydroxy-2,4,7-trimethoxyphenanthrene [180]	*D. nobile*	Stem	Yang *et al.*, 2007
Loddigesiinol A [181]	*D. loddigesii*	Whole plant	Ito *et al.*, 2010
Loddigesiinol B [182]	*D. loddigesii*	Whole plant	Ito *et al.*, 2010
7-Methoxy-9,10-dihydrophenanthrene-2,4,5-triol [183]	*D. draconis*	Stem	Sritularak *et al.*, 2011a
5-Methoxy-7-hydroxy-9,10-dihydro-1,4-phenanthrenequinone [184]	*D. draconis*	Stem	Sritularak *et al.*, 2011a
Moniliformin [185]	*D. moniliforme*	Stem	Lin *et al.*, 2001
Moscatin [186]	*D. aphyllum*	Whole plant	Chen *et al.*, 2008a

Table 1 (continued)

Catergory and Compound	Plant	Plant part	Reference*
	D. chrysanthum	Stem	Yang *et al*., 2006b
	D. chrysotoxum	Whole plant	Li *et al.*, 2009c
	D. densiflorum	Stem	Fan *et al.,* 2001
	D. polyanthum	Stem	Hu *et al.*, 2009
Nudol [182]	*D. nobile*	Stem	Yang *et al.*, 2007
	D. rotundatum	Whole plant	Majumder and Pal, 1992
Plicatol A [188]	*D. nobile*	Stem	Yang *et al.*, 2007
	D. plicatile	Stem	(Honda and Yamaki, 2000)
Plicatol B [189]	*D. plicatile*	Stem	Honda and Yamaki, 2000
Plicatol C [190]	*D. plicatile*	Stem	Honda and Yamaki, 2000
Rotundatin [191]	*D. rotundatum*	Whole plant	Majumder and Pal, 1992
2,3,5-Trihydroxy-4,9-dimethoxyphenanthrene [192]	*D. nobile*	Stem	Yang *et al.*, 2007
3,4,8-Trimethoxy phenanthrene-2,5-diol [193]	*D. nobile*	Stem	Hwang *et al.*, 2010
Phenolic compound			
Antiarol [194]	*D. chrysotoxum*	Stem	Hu *et al*., 2012
Ethylhaematommate [195]	*D. longicornu*	Whole plant	Li *et al.*, 2009d

Table 1 (continued)

Catergory and Compound	Plant	Plant part	Reference*
p-Hydroxybenzaldehyde [196]	*D. falconeri*	Stem	Sritularak and Likhitwitayawuid, 2009
Methyl β -orsellinate [197]	*D. longicornu*	Stem	Hu *et al.*, 2008a
Protocatechuic acid [198]	*D. nobile*	Stem	Ye and Zhao *et al.*, 2002a
Tachioside [199]	*D. denneanum*	Stem	Pan *et al*., 2012
Phenylpropanoid			
Alkyl4′-hydroxy-transcinnamates [200]	*D. clavatum* var. *aurantiacum*	Stem	Chang *et al*., 2001
Alkyl *trans*-ferulates [201]	*D. clavatum* var. *aurantiacum*	Stem	Chang *et al*., 2001
Defuscin [202]	*D. aurantiacum var. denneanum*	Stem	Yang *et al.,* 2006a
n-Docosyl *trans*-ferulate [203]	*D. longicornu*	Whole plant	Li *et al*., 2009d
Ferulaldehyde [204]	*D. longicornu*	Whole plant	Li *et al*., 2009d
Ferulic acid [205]	*D. secundum*	Stem	Sritularak *et al.*, 2011b
2-(*p*-Hydroxyphenyl) ethyl *p*-coumarate [206]	*D. falconeri*	Stem	Sritularak and Likhitwitayawuid, 2009
1-[4-(β-D-lucopyranosyloxy)-3,5-dimethoxyphenyl]-1-propanone [207]	*D. aurantiacum* var. *denneanum*	Stem	Xiong *et al*., 2013

Table 1 (continued)

Catergory and Compound	Plant	Plant part	Reference*
3-(4-Hydroxy-3-methoxyphenyl)-2-propen-1-ol [208]	*D. trigonopus*	Stem	Hu *et al*., 2008b
p-Hydroxyphenyl propionic methyl ester [209]	*D. aphyllum*	Whole plant	Chen *et al.*, 2008a
3-(3-Methoxy,4-hydroxyphenyl)-1-propanol [210]	*D. longicornu*	Stem	Hu *et al*., 2008a
n-Octacosyl ferulate [211]	*D. aurantiacum* var. *denneanum*	Stem	Yang *et al.,* 2006a
	D. moniliforme	Stem	Bi *et al.*, 2004
Phloretic acid [212]	*D. candidum*	Whole plant	(Li *et al*., 2010)
Salidrosol [213]	*D. chrysotoxum*	Stem	Hu *et al*., 2012
Shashenoside I [214]	*D. aurantiacum* var. *denneanum*	Stem	Xiong *et al*., 2013
Syringin [215]	*D. aurantiacum* var. *denneanum*	Stem	Xiong *et al*., 2013
Tetracosyl(*Z*)-*p*-coumarate [216]	*D. falconeri*	Stem	Sritularak and Likhitwitayawuid, 2009
n-Triacontyl *p*-hydroxy-*cis*-cinnamate [217]	*D. moniliforme*	Stem	Bi *et al*., 2004
Purine			
9-β-D-Allofuranul syguanine [218]	*D. denneanum*	Stem	Pan *et al*., 2012

Table 1 (continued)

Catergory and Compound	Plant	Plant part	Reference*
Guanosine [219]	*D. denneanum*	Stem	Pan *et al*., 2012
Purine nucleotide			
9-β-D-Ribofuranosyl-9*H*-purin-6-amine [220]	*D. denneanum*	Stem	Pan *et al*., 2012
Sesquiterpene			
Aduncin [221]	*D. longicornu*	Stem	Hu *et al*., 2008a
Amoenin [222]	*D. aduncum*	Whole plant	(Gawell and Leander, 1976)
Amotin [223]	*D. amoenum*	Whole plant	Majumder *et al.*, 1999
α -Dihydropicrotoxinin [224]	*D. amoenum*	Whole plant	Majumder *et al.*, 1999
Dendrobane A [225]	*D. moniliforme*	Stem	Bi *et al.*, 2004
	D. nobile	Stem	Zhang *et al*., 2007a
Dendronobilin A [226]	*D. wardianum*	Stem	(Fan *et al*., 2013)
Dendronobilin B [227]	*D. nobile*	Stem	(Zhang *et al*., 2007b)
	D. crystallium	Stem	Wang *et al.*, 2009
Dendronobilin C [228]	*D. nobile*	Stem	Zhang *et al*., 2007b
Dendronobilin D [229]	*D. nobile*	Stem	Zhang *et al*., 2007b
Dendronobilin E [230]	*D. nobile*	Stem	Zhang *et al*., 2007b
Dendronobilin F [231]	*D. nobile*	Stem	Zhang *et al*., 2007b
Dendronobilin G [232]	*D. nobile*	Stem	Zhang *et al*., 2007b
Dendronobilin H [233]	*D. nobile*	Stem	Zhang *et al*., 2007b
Dendronobilin I [234]	*D. nobile*	Stem	Zhang *et al*., 2007b

Table 1 (continued)

Catergory and Compound	Plant	Plant part	Reference*
Dendronobilin J [235]	*D. wardianum*	Stem	Fan *et al*., 2013
Dendronobilin K [236]	*D. nobile*	Stem	Zhang *et al*., 2007b
Dendronobilin L [237]	*D. nobile*	Stem	(Zhang *et al*., 2008c)
Dendronobilin M [238]	*D. nobile*	Stem	Zhang *et al*., 2008c
Dendronobilin N [239]	*D. nobile*	Stem	Zhang *et al*., 2008c
Dendrowarnol A [240]	*D. nobile*	Stem	Zhang *et al*., 2008c
Dendrowarnol B [241]	*D. wardianum*	Stem	Fan *et al*., 2013
Dendrowarnol C [242]	*D. wardianum*	Stem	Fan *et al*., 2013
Corchoionoside C [243]	*D. wardianum*	Stem	Fan *et al*., 2013
Crystallinin [244]	*D. polyanthum*	Stem	Hu *et al*., 2009
Findlayanin [245]	*D. findlayanum*	Whole plant	(Qin *et al*., 2011)
Sesquiterpene alkaloid			
Dendrobine [246]	*D. nobile*	Stem	Zhang *et al*., 2007b
3-Hydroxy-2-oxodendrobine [247]	*D. nobile*	Stem	Wang *et al*.,1985
Sesquiterpene glycoside			
Dendromoniliside A [248]	*D. moniliforme*	Stem	Zhao *et al*, 2003
Dendromoniliside B [249]	*D. moniliforme*	Stem	Zhao *et al*, 2003
Dendromoniliside C [250]	*D. moniliforme*	Stem	Zhao *et al*, 2003
Dendromoniliside D [251]	*D. moniliforme*	Stem	Zhao *et al*, 2003
Dendronobiloside A [252]	*D. nobile*	Stem	Zhao *et al*., 2001; Ye and Zhao *et al*., 2002a
Dendronobiloside B [253]	*D. nobile*	Stem	Zhao *et al*., 2001; Ye and Zhao *et al*., 2002a

Table 1 (continued)

Catergory and Compound	Plant	Plant part	Reference*
Dendronobiloside C [254]	*D. nobile*	Stem	Zhao *et al*., 2001; Ye and Zhao *et al*., 2002a
Dendronobiloside D [255]	*D. nobile*	Stem	Zhao *et al*., 2001; Ye and Zhao *et al*., 2002a
Dendronobiloside E [256]	*D. nobile*	Stem	Zhao *et al*., 2001; Ye and Zhao *et al*., 2002a
Dendroside A [257]	*D. moniliforme*	Stem	Zhao *et al,* 2003
	D. nobile	Stem	Zhao *et al*., 2001; Ye and Zhao *et al*., 2002a
Dendroside B [258]	*D. nobile*	Stem	Ye and Zhao *et al*., 2002a
Dendroside C [259]	*D. moniliforme*	Stem	Zhao *et al,* 2003
	D. nobile	Stem	Ye and Zhao *et al*., 2002a
Dendroside D [260]	*D. nobile*	Stem	(Ye, Qin, and Zhao, 2002b)
Dendroside E [261]	*D. nobile*	Stem	Ye *et al*., 2002b
Dendroside F [262]	*D. moniliforme*	Stem	Zhao *et al*, 2003
	D. nobile	Stem	Ye *et al*., 2002b
Dendroside G [263]	*D. nobile*	Stem	Ye *et al*., 2002b

Table 1 (continued)

Catergory and Compound	Plant	Plant part	Reference*
7,12-Dihydroxy-5-hydroxymethyl-11-isopropyl-6-methyl-9-oxatricyclo [6.2.1.02,6]undecan-10-one-15-O- β-D-glucopyranoside (Dendromoniliside D) [264]	*D. nobile*	Stem	Shu, Zhang, and Guo, 2004)
Triterpene			
Taraxerol [265]	*D. aurantiacum*	Stem	Yang *et al.,* 2006a

* The meaning of word "(Author name, Year)" refers to the author's name citations at the first appearance in this thesis.

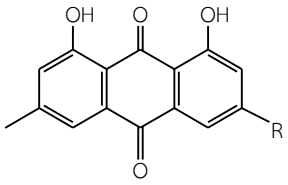
CH_3-$(CH_2)_n$-CH_2-R

[1] Aliphatic acids:

R = COOH, n = 19-31

[4] Aliphatic alcohol:

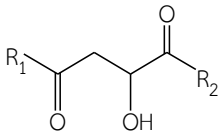
R= OH, n = 22-32



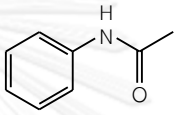
[8] Chrysophanol: R = H

[9] Emodin: R = OH

[10] Physcion: R= OMe

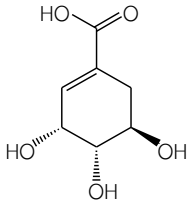


[2] Malic acid: R_1 = R_2 = OH

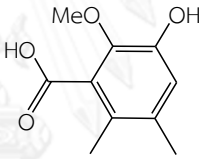


[11] *N*-Phenylacetamide

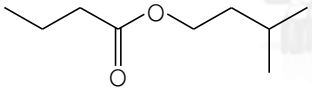
[5] Dimethyl malate: R_1 = R_2 = OMe



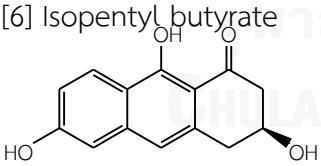
[3] (-)-Shikimic acid



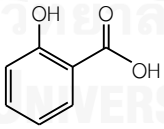
[13] 3-Hydroxy-2-methoxy-5,6-dimethylbenzoic acid



[6] Isopentyl butyrate

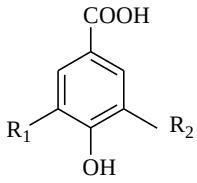


[7] 3,6,9-Trihydroxy-3,4-dihydro anthracen-1-(2*H*)-one



[14] Salicylic acid

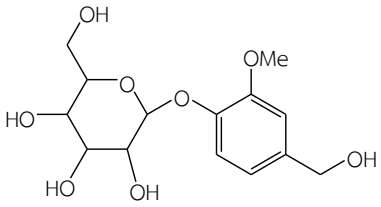
Figure 2 Structures of compounds previously isolated from *Dendrobium* species



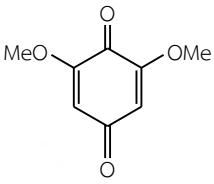
[12] Gallic acid: R_1 = OH, R_2 = OH

[15] Syringic acid: R_1 = OMe, R_2 = OMe

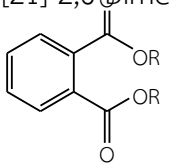
[16] Vanillic acid: R_1 = OMe, R_2 = OH



[17] Vanilloside



[21] 2,6-Dimethoxybenzoquinone

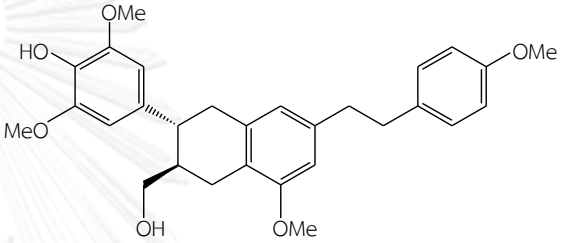


[18] Bis(2-ethylhexyl)phthalate:

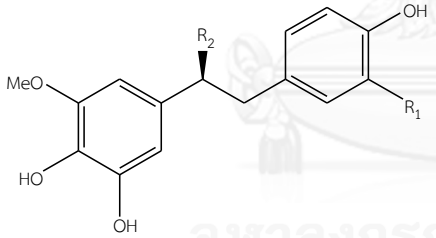
R = $CH_2CH(C_2H_5)(CH_2)_3CH_3$

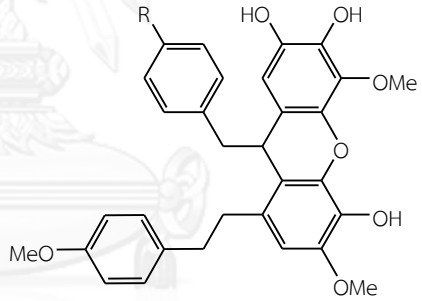
[19] Dibutylphthalate: R = $(CH_2)_3CH_3$

[20] Diisobutylphthalate: R = $CH_2CH(CH_3)_2$



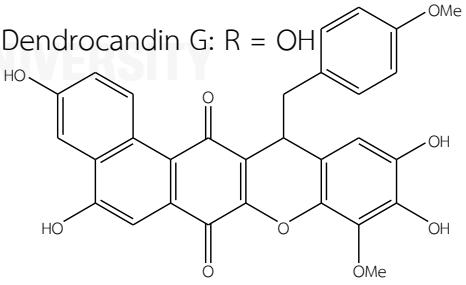
[32] Dendrocandin B





[36] Dendrocandin F: R = OMe

[37] Dendrocandin G: R = OH



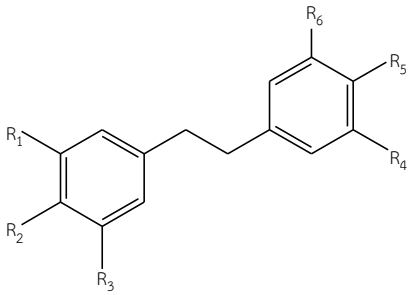
[33] Dendrocandin C: R_1 = H, R_2 = OMe

[34] Dendrocandin D: R_1 = H, R_2 = OCH_2CH_3

[35] Dendrocandin E: R_1 = OH, R_2 = H

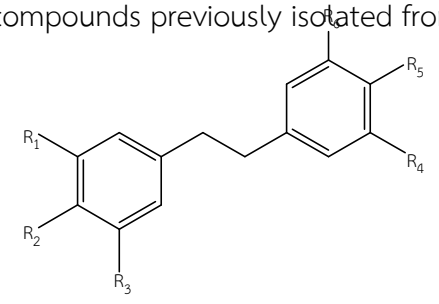
[38] Dendrocandin H

Figure 2 Structures of compounds previously isolated from *Dendrobium* species (continued)



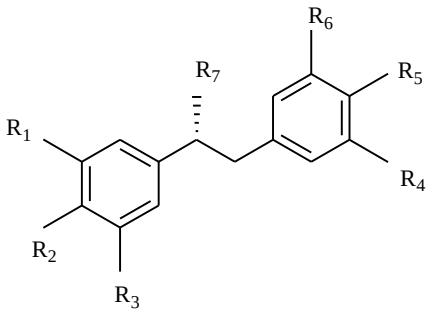
	R_1	R_2	R_3	R_4	R_5	R_6
[22] Aloifol I	OMe	OH	OMe	OH	H	H
[23] Amoenylin	OMe	OH	OMe	H	OMe	H
[24] Betatasin	OMe	H	H	OH	H	OH
[25] Betatasin III	OH	H	OMe	H	H	OH
[26] Brittonin A	OMe	OMe	OMe	OMe	OMe	OMe
[27] Chrysotobibenzyl	OMe	OMe	OMe	OMe	OMe	H
[28] Chrysotoxine	OMe	OH	OMe	OMe	OMe	H
[29] Crepidatin	OMe	OMe	OMe	OMe	OH	H
[30] Cumulatin	OMe	OMe	OH	OH	OMe	OMe
[40] Dendrobin A	OH	OH	OMe	H	H	OMe
[44] 3,4′-Dihydroxy-5-methoxybibenzyl	OH	H	OMe	H	OH	H
[46] 3,4′-Dihydroxy-5,5-dimethoxy dihydrostilbene	OH	H	OMe	OMe	OH	H

Figure 2 Structures of compounds previously isolated from *Dendrobium* species (continued)

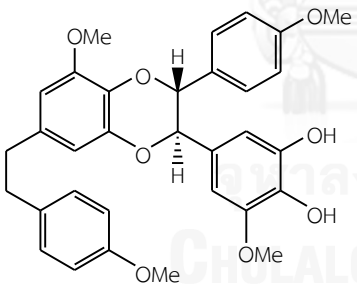


	R_1	R_2	R_3	R_4	R_5	R_6
[47] 4,5-Dihydroxy-3,3′-dimethoxybibenzyl (Dendrobin A)	OMe	OH	OH	H	H	OMe
[49] Gigantol	OMe	H	H	H	OH	OMe
[50] 4-Hydroxy-3,5,3′ trimethoxybibenzyl	OMe	OH	OMe	H	H	OMe
[52] 5-Hydroxy-3,4,3′,4′,5′ pentamethoxybibenzyl	OMe	OMe	OH	OMe	OMe	OMe
[53] Isoamoenylin	OMe	OMe	OMe	H	H	OH
[58] Moscatilin	OMe	OH	OMe	H	OH	OMe
[65] 3,3′,4-Trihydroxybibenzyl	OH	OH	H	H	H	OH
[66] 3,3′,5-Trihydroxybibenzyl	OH	H	OH	H	H	OH
[67] 3,5,4′-Trihydroxybibenzyl	OH	H	OH	H	OH	H
[68] 4,5,4′-Trihydroxy-3-3′-dimethoxybibenzyl	OMe	OH	OH	H	OH	OMe
[69] Tristin	OH	H	OH	H	OH	OMe
[70] Dendromoniliside	OGlc	OGlc	OMe	H	OMe	H

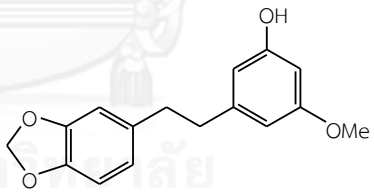
Figure 2 Structures of compounds previously isolated from *Dendrobium* species (continued)



	R_1	R_2	R_3	R_4	R_5	R_6	R_7
[31] Dendrocandin A	OMe	OH	OH	H	H	H	OMe
[41] Dendrophenol	OMe	OH	OMe	OH	OH	H	H
[43] 3,4-Dihydroxy-5,4′-dimethoxybibenzyl	OH	OH	OMe	H	OMe	H	H
[45] 4,4′-Dihydroxy-3,5-dimethoxybibenzyl	OMe	OH	OMe	H	OH	H	H
[54] Loddigesiinol C	OMe	OH	OMe	H	OH	OMe	OMe
[57] 3-*O*-Methylgigantol	OMe	H	OH	OMe	OMe	H	H

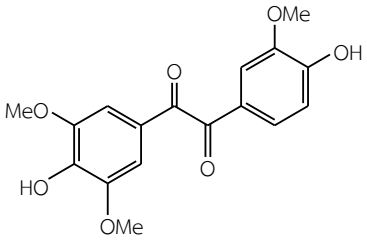


[39] Dendrocandin I

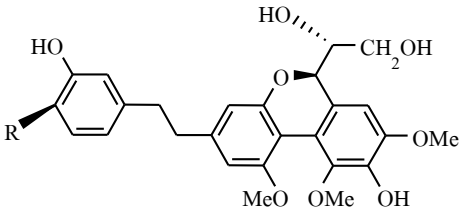


[42] Densiflorol A

Figure 2 Structures of compounds previously isolated from *Dendrobium* species (continued)

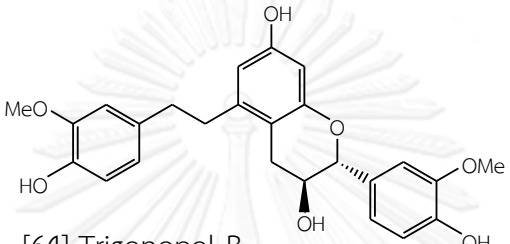


[55] Loddigesiinol D

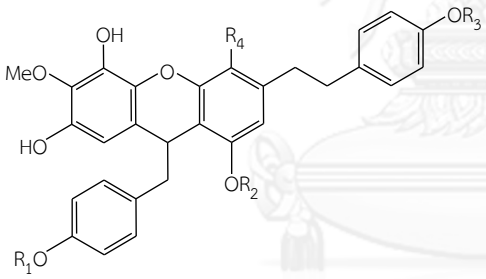


[56] Longicornuol A, R = H

[63] Trigonopol A, R = OMe



[64] Trigonopol B

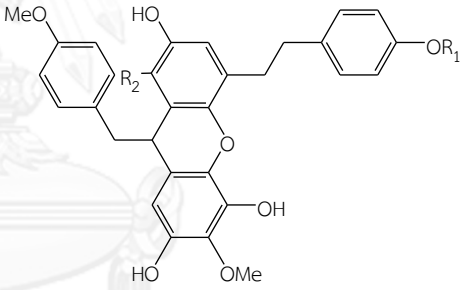


[71] Dencryol A:

R_1 = Me, R_2 = R_3 = R_4 = H

[72] Dencryol B:

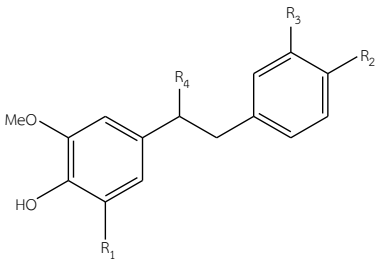
R_1 = H, R_2 = R_3 = Me, R_4 = OH



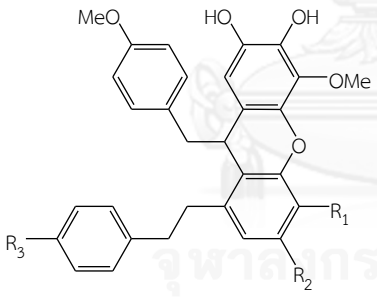
[75] Dengraol A: R_1 = R_2 =H

[76] Dengraol B: R_1 = Me, R_2 = OMe

Figure 2 Structures of compounds previously isolated from *Dendrobium* species (continued)



	R_1	R_2	R_3	R_4
[51] 4-[2-(3-Hydroxyphenol)-1-methoxyethyl]-2,6-dimethoxyphenol	OMe	H	OH	OMe
[59] Nobilin A	OH	H	OMe	OMe
[60] Nobilin B	OMe	OH	OMe	OMe
[61] Nobilin C	OMe	OMe	OMe	OMe
[62] Nobilin D	OMe	OH	OMe	OH

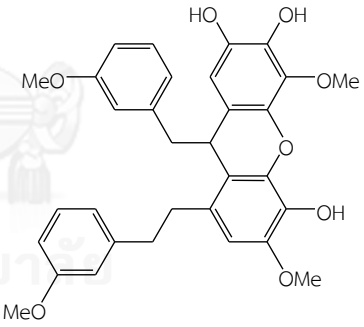


[73] Dendrofalconerol A:

R_1 = OH, R_2 = R_3 = OMe

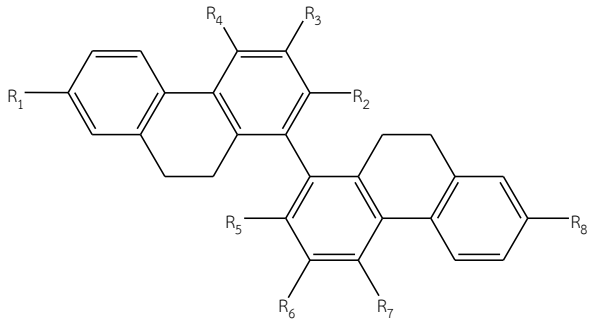
[74] Dendrofalconerol B:

R_1 = H, R_2 = R_3 = OH

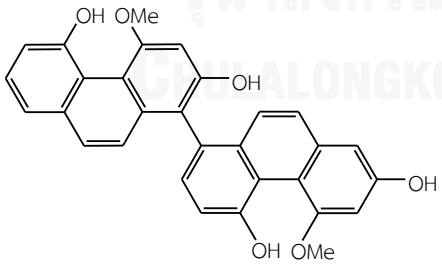


[77] Nobilin E

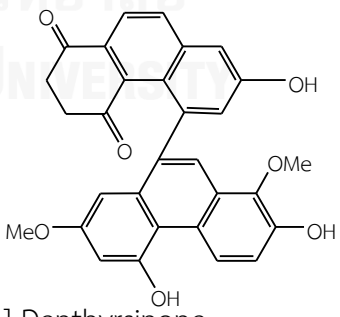
Figure 2 Structures of compounds previously isolated from *Dendrobium* species (continued)



	R_1	R_2	R_3	R_4	R_5	R_6	R_7	R_8
[78] 2,2′-Dihydroxy-3,3′,4,4′, 7,7′-hexamethoxy -9,9′, 10,10′-tetrahydro-1,1′ -biphenanthrene	OMe	OH	OMe	OMe	OH	OMe	OMe	OMe
[79] 2,2′-Dimethoxy-4,4′,7,7′-tetrahydroxy-9,9′,10,10′-tetrahydro-1,1′-biphenanthrene	OH	OMe	H	OH	OMe	H	OH	OH
[82] Flavanthrin	OH	OH	H	OMe	OH	H	OMe	OH

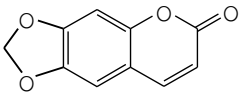


[80] Denthyrsinol

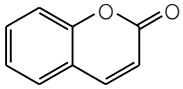


[81] Denthyrsinone

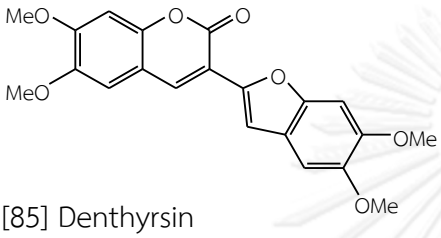
Figure 2 Structures of compounds previously isolated from *Dendrobium* species (continued)



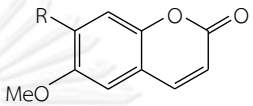
[83] Ayapin



[84] Coumarin

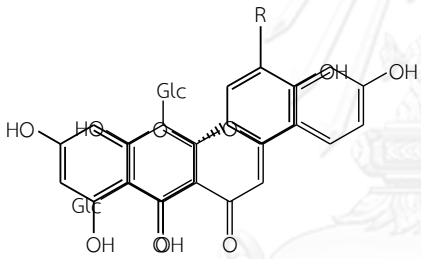


[85] Denthyrsin



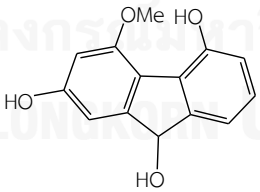
[86] Scoparone: R = OMe

[87] Scopoletin: R = OH



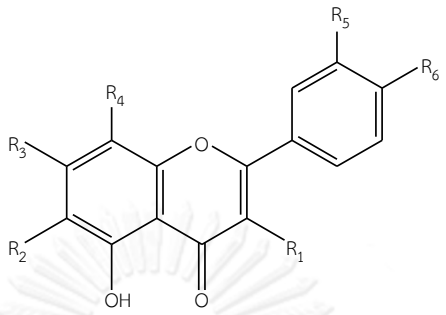
[88] (2*S*)-Homoeriodictyol: R = OMe

[89] Naringenin: R = H



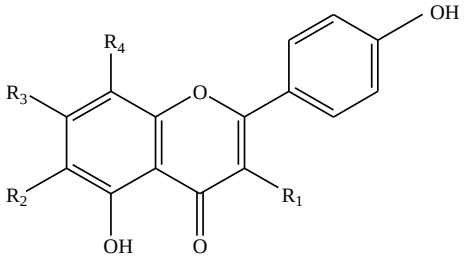
[109] Denchrysan B

Figure 2 Structures of compounds previously isolated from *Dendrobium* species (continued)



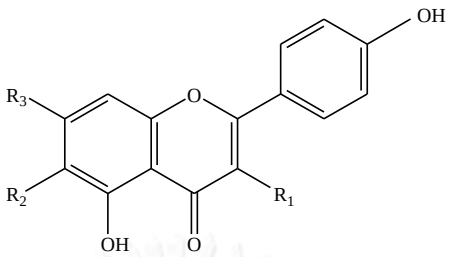
	R_1	R_2	R_3	R_4	R_5	R_6
[90] Apigenin	H	H	OH	H	H	OH
[91] 5,6-Dihydroxy-4′-methoxy-flavone	H	OH	H	H	H	OMe
[92] Luteolin	H	H	OH	H	OH	OH
[93] 6-*C*-(α-Arabinopyranosyl)-8-*C*-[(2-*O*- α-rhamnopyranosyl) -β-galactopyranosyl] apigenin	H	-Ara	OH	-Gal-O-Rha	H	OH
[94] 6-*C*-(α-Arabinopyranosyl)-8-*C*-[(2-*O*- α-rhamnopyranosyl) -β-glucopyranosyl] apigenin	H	-Ara	OH	-Glc-O-Rha	H	OH

Figure 2 Structures of compounds previously isolated from *Dendrobium* species (continued)



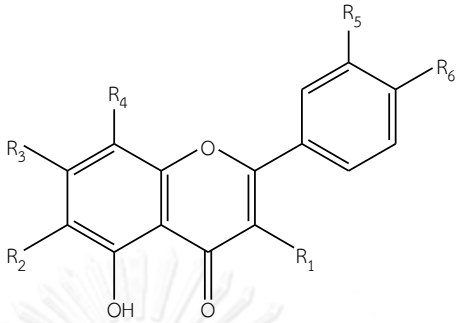
	R_1	R_2	R_3	R_4
[95] 6‴-Glucosyl-vitexin	H	H	OH	Glc
[96] Isoschaftoside	H	-Ara	OH	-Glc
[97] Isoviolanthin	H	-Rha	OH	-Glc
[98] 6-*C*-[(2-*O*- α-Rhamnopyranosyl)-β-glucopyranosyl]-8-*C*-(α-arabinopyranosyl) apigenin	H	-Glc-Rha	OH	-Ara
[99] 6-*C*-(β-Xylopyranosyl)-8-*C*-[(2-*O*- α-rhamnosepyranosyl) -β-glucosepyranosyl] apigenin	H	-Xyl	OH	-Glc-Rha
[101] Kaempferol	OH	H	OH	H

Figure 2 Structures of compounds previously isolated from *Dendrobium species (continued)*



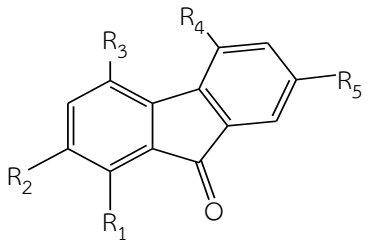
	R_1	R_2	R_3
[102] Kaempferol-3-*O*- α-L-rhamnopyranoside	O-Rha	H	OH
[103] Kaempferol-3,7-*O*-di- α-L-rhamnopyranoside	O-Rha	H	O-Rha
[104] Kaempferol-3-*O*- α-L-rhamnopyranosyl-(1⟶2)-β-D-glucopyranoside	O-Glc-Rha	H	OH
[105] Kaempferol-3-*O*- α -L-rhamnopyranosyl-(1⟶2)-β-D-xylopyranoside	O-Xyl-Rha	H	OH

Figure 2 Structures of compounds previously isolated from *Dendrobium* species (continued)

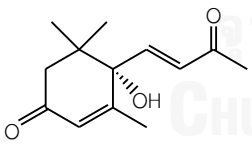


	R_1	R_2	R_3	R_4	R_5	R_6
[106] Quercetin-3-*O*- α-L-rhamnopyranoside	O-Rha	H	OH	H	OH	OH
[107] Quercetin-3-*O*- α-L-rhamnopyranosyl-(1$\rightarrow$2)-β-D-xylopyranoside	O -Xyl-Rha	H	OH	H	OH	OH

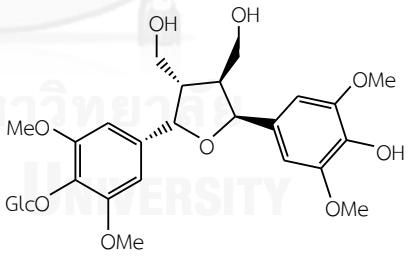
Figure 2 Structures of compounds previously isolated from *Dendrobium* species (continued)



	R_1	R_2	R_3	R_4	R_5
[108] Denchrysan A	H	OH	OH	OMe	OH
[110] Dendroflorin	OH	H	OH	OMe	OH
[111] Dengibsin	H	OH	OMe	OH	H
[112] Nobilone	H	OH	H	OMe	OH
[113] 1,4,5-Trihydroxy-7-methoxy-9H-fluoren-9-one	OH	H	OH	OH	OMe
[114] 2,4,7-Trihydroxy-5-methoxy-9-fluorenone	H	OH	OH	OMe	OH
[115] 2,4,7-Trihydroxy-1,5-dimethoxy -9-fluorenone	OMe	OH	OH	OMe	OH

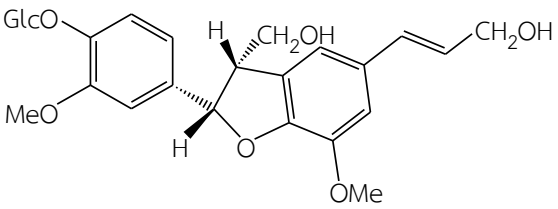


[116] Dehydrovomifoliol

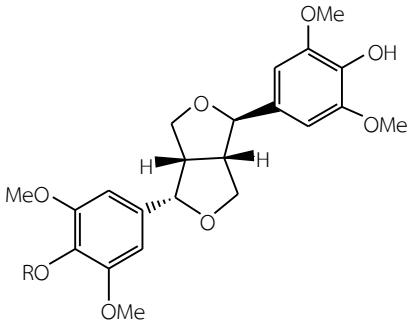


[117] 7,7′-bis-(4-hydroxy-3,5-dimethoxyphenyl)-8,8′dihydroxymethyltetrahydrofuran-4-β-D-glucoside

Figure 2 Structures of compounds previously isolated from *Dendrobium* species (continued)

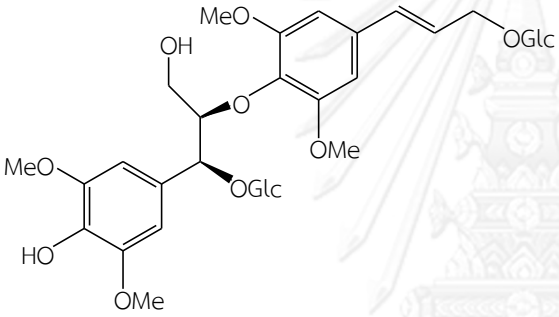


[118] Dehydrodiconiferyl alcohol-4-β-D-glucoside

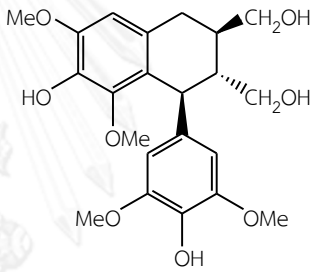


[119] Episyringaresinol: R = H

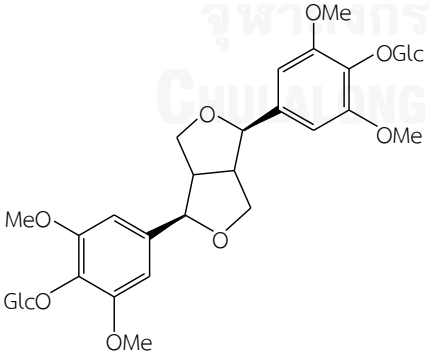
[129] Episyringaresinol 4′′-*O*-β-D-glucopyranoside: R = β-D-Glucose



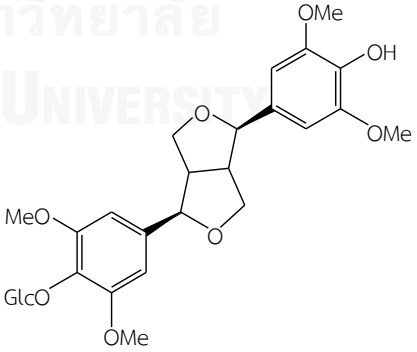
[120] (-)-(7S,8R,7′E)-4-hydroxy-3,3′,5,5′-tetramethoxy-8,4′-oxyneolign-7′-ene-7,9,9′-triol-7,9′-bis-*O*-β-D-glucopyranoside



[121] Lyoniresinol

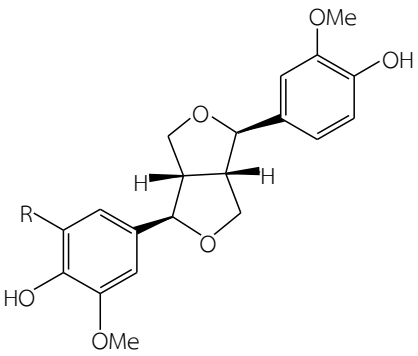


[126] (-)-Syringaresinol-4,4′-bis-*O*-β-D-glucopyranoside



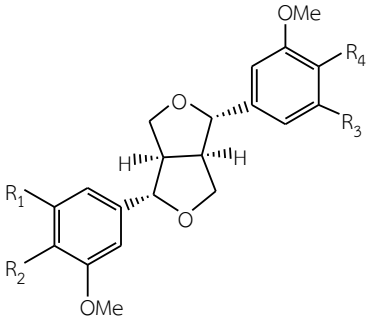
[127] Syringaresinol-4-*O*-D monoglucopyranoside

Figure 2 Structures of compounds previously isolated from *Dendrobium* species (continued)



[122] (-)-Medioresinol: R = OMe

[123] (-)-Pinoresinol: R = H



[124] Pinoresinol:

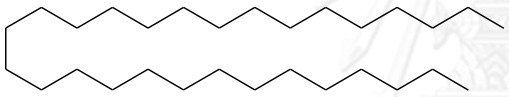
R_1 = H, R_2 = OH, R_3 = H, R_4 = OH

[125] Syringaresinol:

R_1 = OMe, R_2 = OH, R_3 = OMe, R_4 = OH

[128] Acanthoside B:

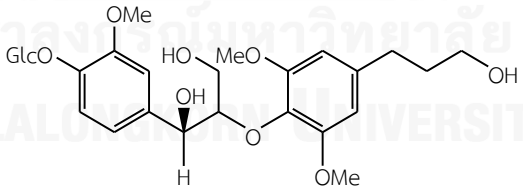
R_1 = OMe, R_2 = OGlc, R_3 = OMe, R_4 = OH



[132] *n*-Nonacosane

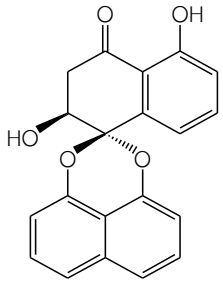
[131] Liriodendrin:

R_1 = OMe, R_2 = OGlc, R_3 = OMe, R_4 = OGlc

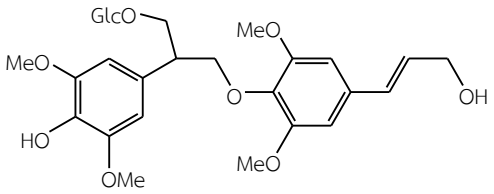


[130] Erythro-1-(4-*O*-β-D-glucopyranosyl-3-methoxyphenyl)-2-[4-(3-hydroxypropyl)-2,6-dimethoxyphenoxy]-1,3-propanediol

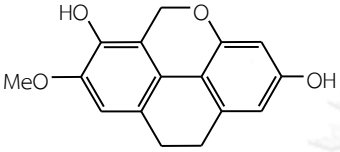
Figure 2 Structures of compounds previously isolated from *Dendrobium* species (continued)



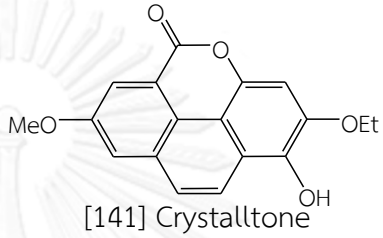
[133] Palmarumycin JC2



[134] Denchryside B

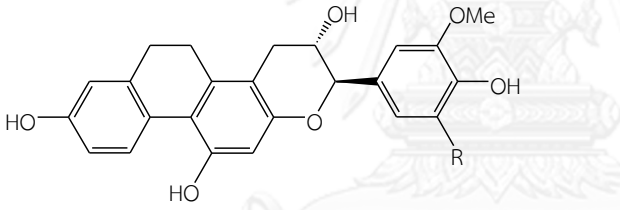


[135] Amoenumin



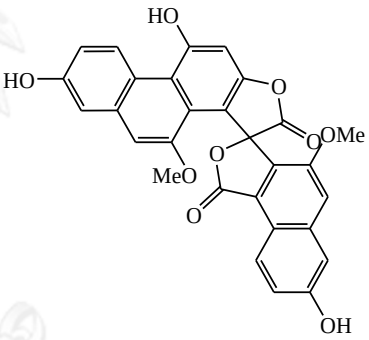
[141] Crystalltone

[172] Flaccidin

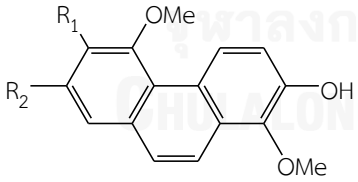


[139] Chrysotoxol A: R = H

[140] Chrysotoxol B: R = OMe

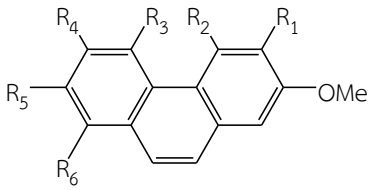


[144] Dendrochrysanene

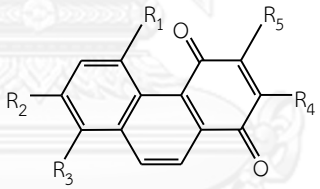


	R_1	R_2
[138] Confusarin	OMe	OH
[161] 2,6-Dihydroxy-1,5,7-trimethoxyphenanthrene	OH	OMe

Figure 2 Structures of compounds previously isolated from *Dendrobium* species (continued)

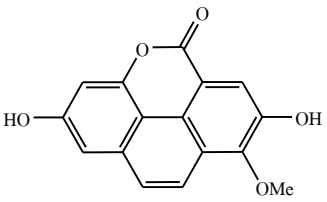


	R_1	R_2	R_3	R_4	R_5	R_6
[136] Bulbophyllanthrin	OH	OMe	OH	H	H	H
[147] Denthyrsinin	OH	OMe	H	H	OH	OMe
[177] 5-Hydroxy-2,4-dimethoxy phenanthrene	H	OMe	OH	H	H	H
[180] 3-Hydroxy-2,4,7-trimethoxy Phenanthrene	OH	OMe	H	H	OMe	H

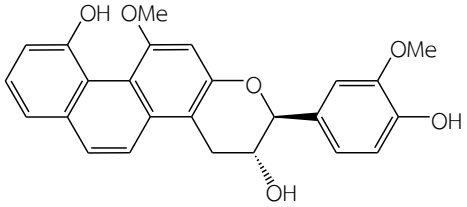


	R_1	R_2	R_3	R_4	R_5
[142] Cypripedin	H	OH	OMe	OMe	H
[146] Densiflorol B	H	OH	H	OMe	H
[143] Denbinobin	OH	OMe	H	H	OMe

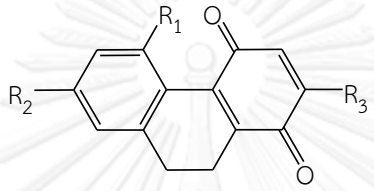
Figure 2 Structures of compounds previously isolated from *Dendrobium* species (continued)



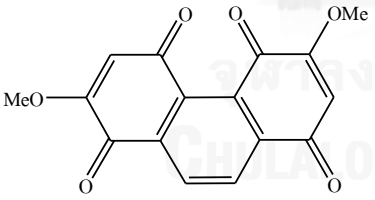
[170] Fimbriatone



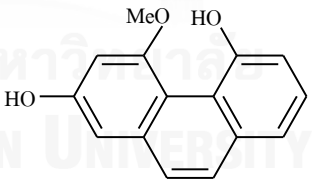
[182] Loddigesiinol B



	R_1	R_2	R_3
[145] Dendronone	OH	OMe	H
[167] Ephemeranthoquinone	H	OH	OMe
[184] 5-Methoxy-7-hydroxy-9,10-dihydro-1,4 phenanthrenequinone	OMe	OH	H

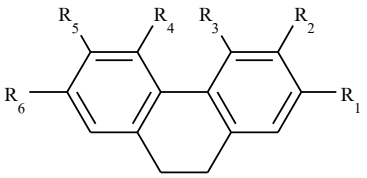


[185] Moniliformin



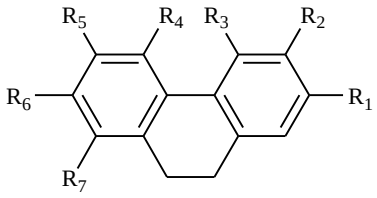
[186] Moscatin

Figure 2 Structures of compounds previously isolated from *Dendrobium* species (continued)



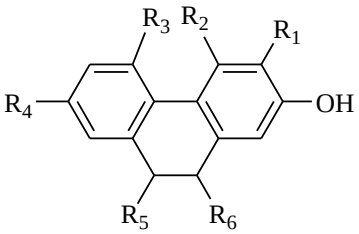
	R_1	R_2	R_3	R_4	R_5	R_6
[137] Coelonin	OH	H	OMe	H	H	OH
[148] 9,10-Dihydromoscatin	H	H	OH	OMe	H	OH
[149] 9,10-Dihydrophenanthrene-2,4,7-triol	OH	H	OH	H	H	OH
[150] 4,5-Dihydroxy-2,3-dimethoxy-9,10-dihydrophenanthrene	OMe	OMe	OH	OH	H	H
[151] 4,5-Dihydroxy-2,6-dimethoxy-9,10-dihydrophenanthrene	OMe	H	OH	OH	OMe	H
[152] 4,5-Dihydroxy-3,7-dimethoxy-9,10-dihydrophenanthrene	H	OMe	OH	OH	H	OMe
[156] 4,5-Dihydroxy-2-methoxy-9,10-dihydrophenanthrene	OMe	H	OH	OH	H	H

Figure 2 Structures of compounds previously isolated from *Dendrobium* species (continued)



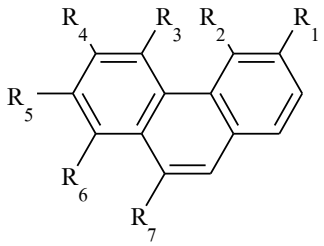
	R_1	R_2	R_3	R_4	R_5	R_6	R_7
[158] 2,7-Dihydroxy-3,4,6-trimethoxy-9,10-dihydro phenanthrene	OH	OMe	OMe	H	OMe	OH	H
[159] 2,8-Dihydroxy-3,4,7-trimethoxy-9,10-dihydro phenanthrene	OH	OMe	OMe	H	H	OMe	OH
[160] 4,7-Dihydroxy-2,3,6-trimethoxy-9,10-dihydro phenanthrene	OMe	OMe	OH	H	OMe	OH	H
[165] Ephemeranthol A	OH	H	H	OH	OMe	OMe	H
[166] Ephemeranthol C	OH	OH	OMe	OH	H	H	H
[169] Erianthridin	OH	OMe	OMe	H	H	OH	H
[173] Flavanthridin	OH	H	H	OMe	OH	OMe	H
[175] Hircinol	OH	H	OMe	OH	H	H	H
[179] 3-Hydroxy-2,4,7-trimethoxy-9,10-dihydro phenanthrene	OMe	OH	OMe	H	H	OMe	H

Figure 2 Structures of compounds previously isolated from *Dendrobium* species (continued)



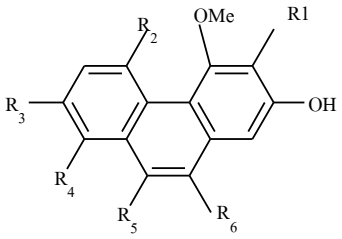
	R_1	R_2	R_3	R_4	R_5	R_6
[176] 2-Hydroxy-4,7-dimethoxy-9,10-dihydro phenanthrene	H	OMe	H	OMe	H	H
[183] 7-Methoxy-9,10-dihydrophenanthrene-2,4,5-triol	H	OH	OH	OMe	H	H
[190] Plicatol C	H	OMe	OH	H	OMe	OMe
[191] Rotundatin	H	OMe	OH	H	OH	OH

Figure 2 Structures of compounds previously isolated from *Dendrobium* species (continued)

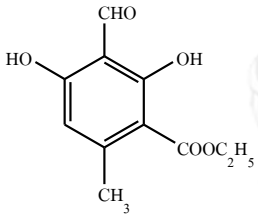


	R_1	R_2	R_3	R_4	R_5	R_6	R_7
[153] 2,5-Dihydroxy-3,4-dimethoxyphenanthrene	OMe	OMe	OH	H	H	H	H
[154] 2,5-Dihydroxy-4,9-dimethoxyphenanthrene	H	OMe	OH	H	H	H	OMe
[155] 3,7-Dihydroxy-2,4-dimethoxyphenanthrene	H	H	OMe	OH	OMe	H	H
[162] 2,7-Dihydroxy-3,4,6-trimethoxyphenanthrene	OMe	OMe	H	OMe	OH	H	H
[163] 2,8-Dihydroxy-3,4,7-trimethoxyphenanthrene	OMe	OMe	H	H	OMe	OH	H
[164] 5,7-Dimethoxy phenanthrene-2,6-diol	H	H	OMe	OH	OMe	H	H
[168] Epheranthol B	H	H	OMe	OH	OMe	H	H
[171] Fimbriol B	OH	OMe	OH	H	H	H	H
[174] Flavanthrinin	H	H	OMe	H	OH	H	H

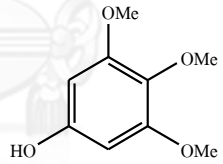
Figure 2 Structures of compounds previously isolated from *Dendrobium* species (continued)



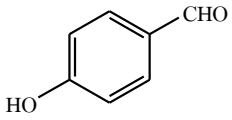
	R_1	R_2	R_3	R_4	R_5	R_6
[181] Loddigesiinol A	H	OMe	H	H	OH	H
[187] Nudol	OMe	H	OH	H	H	H
[188] Plicatol A	H	OH	H	H	OMe	OMe
[189] Plicatol B	H	OH	H	H	H	H
[192] 2,3,5-Trihydroxy -4,9-dimethoxyphenanthrene	OH	OH	H	H	OMe	H
[193] 3,4,8-Trimethoxy phenanthrene- 2,5-diol	OMe	OH	H	OMe	H	H



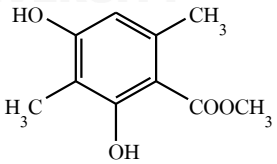
[194] Antiarol



[195] Ethylhaematommate

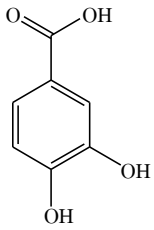


[196] *p*- Hydroxybenzaldehyde

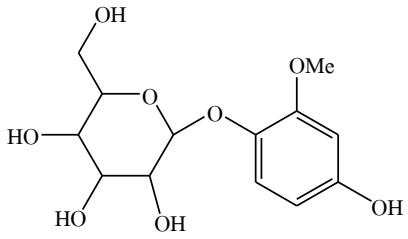


[197] Methyl β-orsellinate

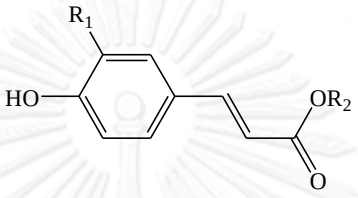
Figure 2 Structures of compounds previously isolated from *Dendrobium* species (continued)



[198] Protocatechuic acid



[199] Tachioside



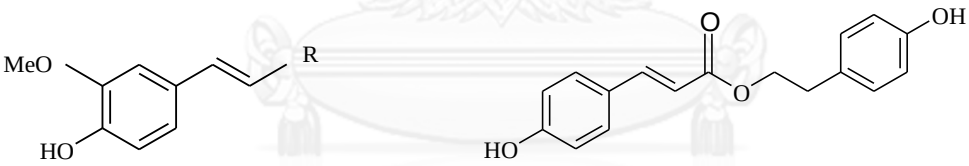
[200] Alkyl 4′-hydroxy-*trans*-cinnamates: R_1 = H, R_2 = C_nH_{2n+1}, n = 22-32

[201] Alkyl *trans*-ferulates: R_1 = OMe, R_2 = C_nH_{2n+1}, n = 18-28, 30

[202] Defuscin: R_1 = OMe, R_2 = $(CH_2)_{27}CH_3$

[211] *n*-Octacosyl ferulate : R_1 = OMe, R_2 = $(CH_2)_{28}CH_3$

[217] *n*-Triacontyl *p*-hydroxy-*cis*-cinnamate: R_1 = H, R_2 = C_nH_{2n+1}, n = 30



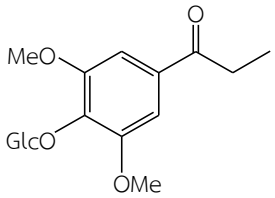
[203] *n*-Docosyl *trans*-ferulate: R = $COOCH_2(CH_2)_{20}CH_3$coumarate

[206] 2-(*p*-Hydroxyphenyl) ethyl *p*

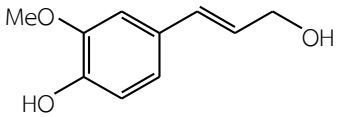
[204] Ferulaldehyde: R = CHO

[205] Ferulic acid: R = COOH

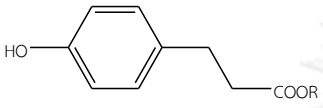
Figure 2 Structures of compounds previously isolated from *Dendrobium* species (continued)



[207] 1-[4-(β-D-glucopyranosyloxy)-3,5-dimethoxyphenyl]-1-propanone

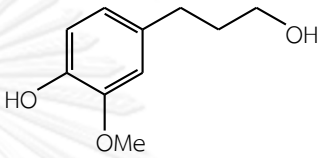


[208] 3-(4-Hydroxy-3-methoxyphenyl)-2-propen-1-ol

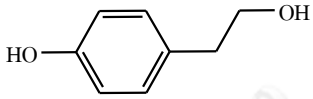


[209] *p*-Hydroxyphenyl propionic methyl ester: R = CH_3

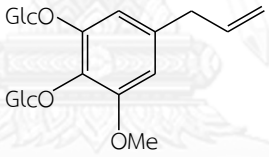
[212] Phloretic acid: R = OH



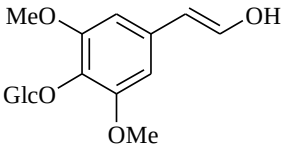
[210] 3-(3-Methoxy,4-hydroxyphenyl)-1-propanol



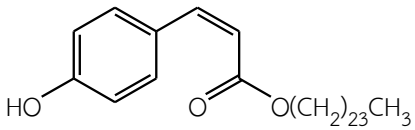
[213] Salidrosol



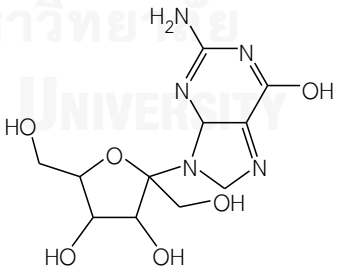
[214] Shashenoside I



[215] Syringin

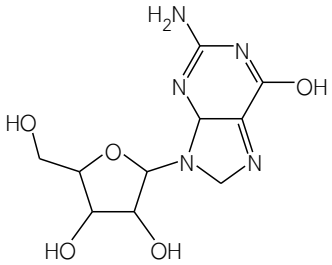


[216] Tetracosyl (*Z*)-*p*-coumarate

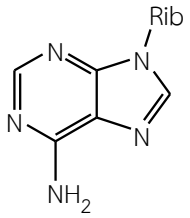


[218] 9-β-D-allofurannoseguanine

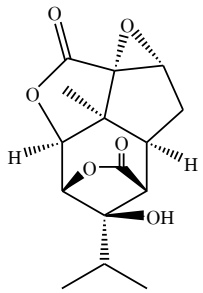
Figure 2 Structures of compounds previously isolated from *Dendrobium* species (continued)



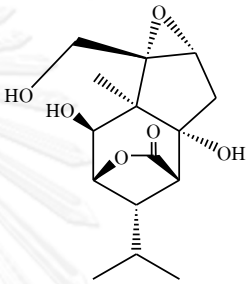
[219] Guanosine



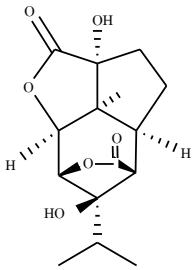
[220] 9-β-D-Ribofuranosyl-9*H*-purin-6-amine



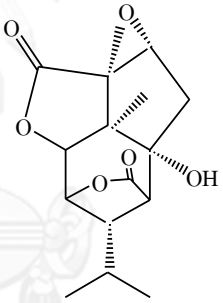
[221] Aduncin



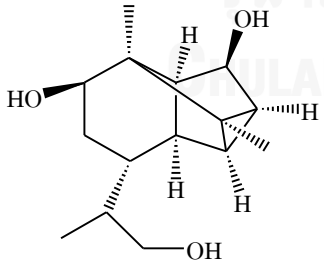
[222] Amoenin



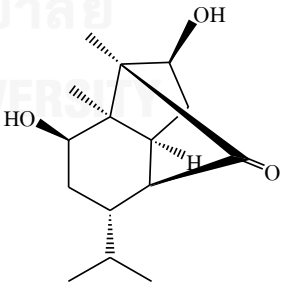
[223] Amotin



[224] α-Dihydropicrotoxinin

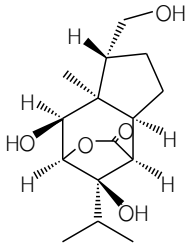


[225] Dendrobane A

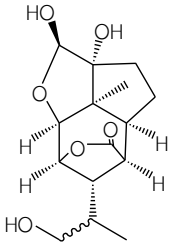


[226] Dendronobilin A

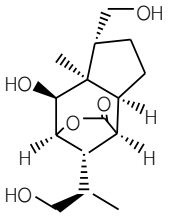
Figure 2 Structures of compounds previously isolated from *Dendrobium* species (continued)



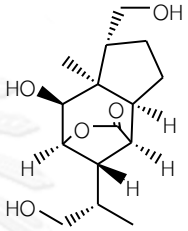
[227] Dendronobilin B



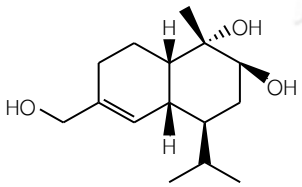
[228] Dendronobilin C



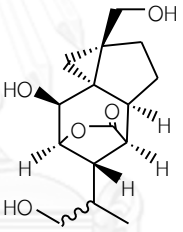
[229] Dendronobilin D



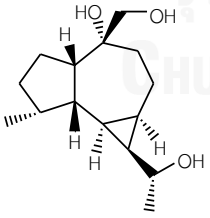
[230] Dendronobilin E



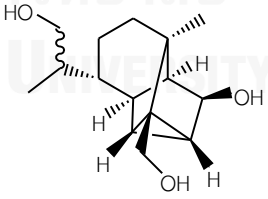
[231] Dendronobilin F



[232] Dendronobilin G

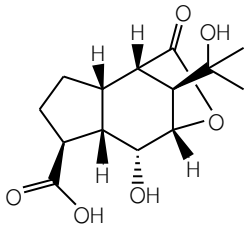


[233] Dendronobilin H

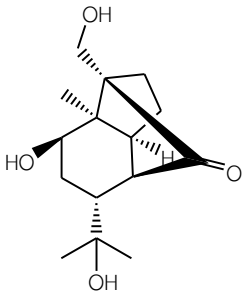


[234] Dendronobilin I

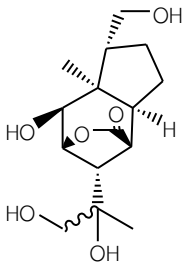
Figure 2 Structures of compounds previously isolated from *Dendrobium* species (continued)



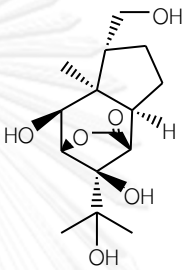
[235] Dendronobilin J



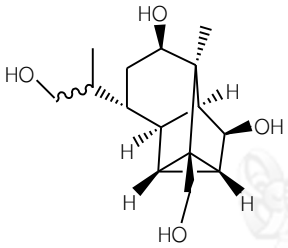
[236] Dendronobilin K



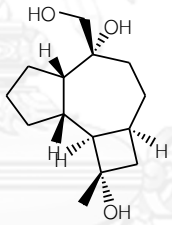
[237] Dendronobilin L



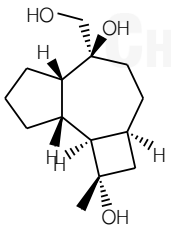
[238] Dendronobilin M



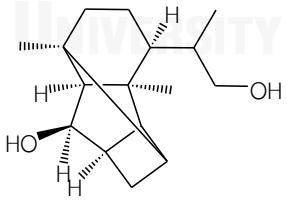
[239] Dendronobilin N



[240] Dendrowardol A

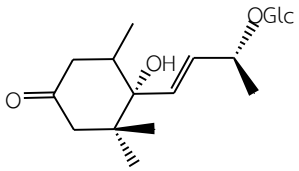


[241] Dendrowardol B

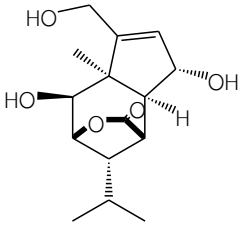


[242] Dendrowardol C

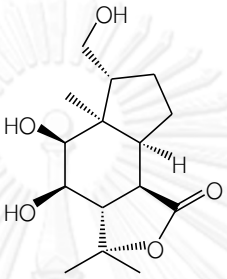
Figure 2 Structures of compounds previously isolated from *Dendrobium* species (continued)



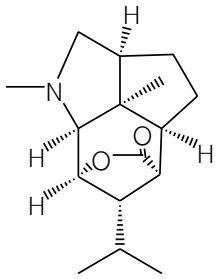
[243] Corchoionoside C



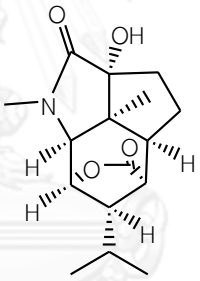
[244] Crystallinin



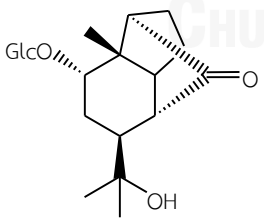
[245] Findlayanin



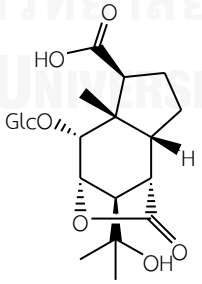
[246] Dendrobine



[247] 3-Hydroxy-2-oxodendrobine

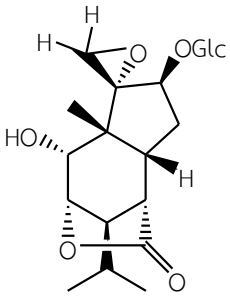


[248] Dendromoniliside A

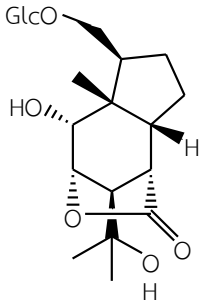


[249] Dendromoniliside B

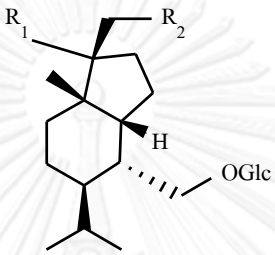
Figure 2 Structures of compounds previously isolated from *Dendrobium* species (continued)



[250] Dendromoniliside C

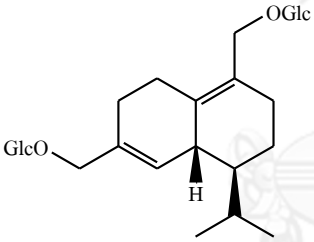


[251] Dendromoniliside D

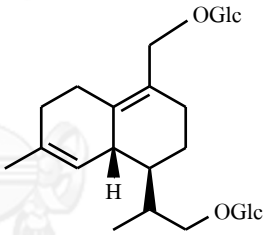


[252] Dendronobiloside A, R_1 = H, R_2 = OGlc

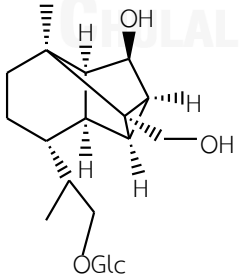
[253] Dendronobiloside B, R_1 = OH, R_2 = OH



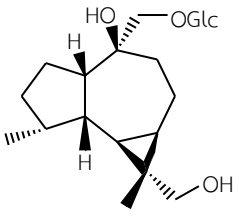
[254] Dendronobiloside C



[255] Dendronobiloside D

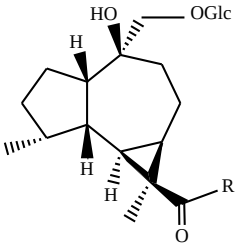


[256] Dendronobiloside E



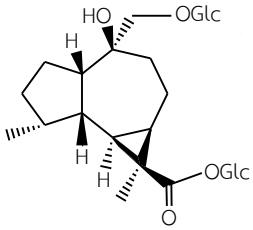
[257] Dendroside A

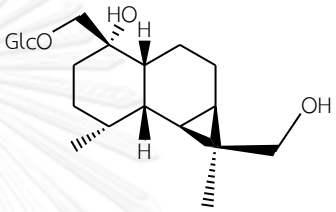
Figure 2 Structures of compounds previously isolated from *Dendrobium* species (continued)



[258] Dendroside B, R = OGlc

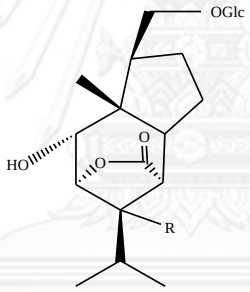
[259] Dendroside C, R = OH





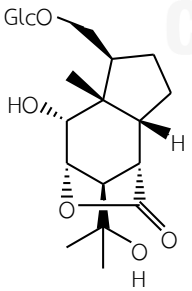
\[260] Dendroside D

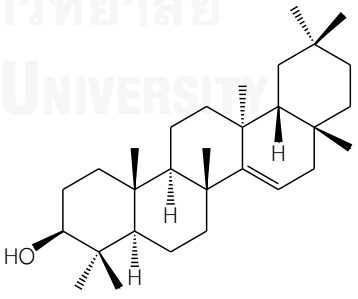
[261] Dendroside E



[262] Dendroside F, R= H

[263] Dendroside G, R = OH





[264] Dendromoniliside D

[265] Taraxerol

Figure 2 Structures of compounds previously isolated from *Dendrobium* species (continued)

2. Traditional uses and biological activities of Dendrobium species.

In China, several plants of the genus Dendrobium have been used in traditional medicine. They are used to treat kidney, lung and stomach diseases, swelling, dry mouth, fever and hyperglycemia (Hossain, 2011). For example, "Shi-Hu" (Herba Dendrobii) is used as a Yin tonic to promote the production of body fluid, supply the stomach and reduce fever (Bensky and Gamble, 1993).

Chemical constituents including dihydrostilbenes (bibenzyls), phenanthrenes, dihydrophenanthrenes, flavonoids and their glycosides, alkaloids, terpenoids, lignans, fluorenones and coumarins have been previously isolated from Dendrobium species (Bensky and Gamble, 1993). In addition, plants in this genus have been reported to posses antioxidant, anti-inflammatory, cytotoxic, antiplatelet aggregation and immunomodulatory activities.

The bibenzyl derivatives separated from Dendrobium nobile, including chrysotoxin [28], moscatilin [58], nobilin D [62] and nobilin E [77], showed antioxidant activity in DPPH assay with IC_{50} values of 14.0, 14.5, 19.9, and 21.0 μM, respectively (Zhang *et al*., 2007a; 2008b). Furthermore, in DPPH scavenging and ORAC assays, moscatilin [58] and chrysotoxin [28] exhibited stronger activity than, or equivalent to, vitamin C (Ono *et al*.,1995).

In an antiinflammatory study, ephemeranthol A [165], ephemeranthol C [166] and lusianthridin [157] isolated from *Dendrobium nobile* exhibited inhibitory effect on the lipopolysaccharide-induced nitric oxide production from macrophage cells (RAW 264.7) with IC_{50} values of 12.0, 17.6, and 9.6 μM, respectively (Hwang *et al*., 2010).

In cytotoxic studies, it was found that denthyrsin [85] from *Dendrobium thyrsiflorum* exhibited cytotoxicity against several cancer cell lines such as Hela, K-562 and MCF-7 (Zhang *et al*., 2005). Denbinobin [143] from *Dendrobium nobile* could inhibit the proliferation of hepatic stellate cells (HSCs-T6) (Yang *et al*., 2007). In addition, moscatilin [58], a bibenzyl found in several plants of this genus, exhibited potent cytotoxic effects against lung and stomach cancer cells (Ho and Chen, 2003). Furthermore, this compound induced apoptosis in human colorectal cancer cells through tubulin depolymerization and DNA damage. It could activate of C-Jun NH2-terminal protein kinase (JNK) and mitochondria- involved intrinsic apoptosis pathways (Chen *et al*., 2008a). Additionally, it suppressed tumor angiogenesis and growth in vitro and in vivo (Tsai *et al*., 2010). Three fluorenones isolated from *Dendrobium*

chrysotoxum, including dendroflorin [110], denchrysan A [108] and 1,4,5-trihydroxy-7-methoxy-9H-fluoren-9-one [113], demonstrated cytotoxicity against human hepatoma (BEL-7402) cell line, with IC_{50} values of 0.97, 1.38 and 14.9 μg/ml, respectively (Chen *et al*., 2008b).

In antiplatelet aggregation studies, the compounds isolated from *Dendrobium densiflorum*, including moscatilin [58] and gigantol [49], were found to exhibit antiplatelet aggregation activity on rat platelets *in vitro* (Fan *et al*., 2001). In addition, moscatilin [58] and moscatin [186] strongly inhibited both arachidonic acid and collagen-induced platelet aggregation (Chen *et al*., 1994).

The sesquiterpene glycosides separated from *Dendrobium nobile*, including dendrosides A [257], D-G [260, 261, 262, 263], were found to significantly stimulate the generation of mouse T and B lymphocytes *in vitro* (Zhao *et al*., 2001; Ye and Zhao 2002).

CHAPTER III

EXPERIMENTAL

1. Source of plant materials

The whole plants of Dendrobium venustum were purchased from Jatujak market, Bangkok, in May 2012. Authentication was performed by comparison with voucher specimens of the Department of National Parks, Wildlife and Plant Conservation, Ministry of National Resource and Enviroment, Bangkok, Thailand. A voucher specimen (BS-DV-05255) was deposited at the herbarium of the Department of Pharmacognosy and Pharmaceutical Botany, Faculty of Pharmaceutical Sciences, Chulalongkorn University.

2. General technique

2.1 Analytical thin-layer chromatography (TLC)

Technique	:	One dimension, ascending
Absorbent	:	Silica gel 60 F254 (E. Merck) precoated plate
Layer thickness	:	0.2 mm
Distance	:	6.5 cm
Temperature	:	Laboratory temperature (30-35oC)
Detection	:	1. Ultraviolet light at wavelengths of 254 and 365 nm 2. Spraying with anisaldehyde reagent (0.5 ml p-anisaldehyde in 50 ml glacial acetic acid and 1 ml conc. sulfuric acid) and heating at 105° C for 10 min

2.2 Column Chromatography

2.2.1 Vacuum liquid chromatography (VLC)

Adsorbent	:	Silica gel 60 (No. 7734) particle size 0.063-0.200 mm (E. Merck)
Packing method	:	Dry packing
Sample loading	:	The sample was dissolved in a small amount of organic solvent, mixed with a small quantity of the adsorbent, triturated, dried and then gradually placed on top of the column.
Detection	:	Each fraction was examined by TLC under UV light at the wavelengths of 254 and 365 nm.

2.2.2 Flash column chromatography (FCC)

Adsorbent	:	Silica gel 60 (No. 9385) particle size 0.040-0.063 mm (E. Merck)
Packing method	:	Wet packing
Sample loading	:	The sample was dissolved in a small amount of the organic solvent, mixed with a small quantity of the adsorbent, triturated, dried and then gradually applied on top of the column.
Detection	:	Fractions were examined in a similar manner as described in section 2.2.1

2.2.3 Gel filtration chromatography

Adsorbent	:	Sephadex LH-20 (Pharmacia)
Packing method	:	An appropriate organic solvent was used as the eluent. Gel filter, suspended in the eluent, was left standing for about 24 hours then poured into the column and left to settle.
Sample loading	:	The sample was dissolved in a small amount of the eluent and then gently applied on top of the column.
Detection	:	Fractions were examined in a similar manner as described in section 2.2.1

2.3 Preperative thin-layer chromatography (PLC)

Technique	:	One dimension, ascending
Absorbent	:	Silica gel 60 F254 (E. Merck) precoated plate
Layer thickness	:	1 mm
Distance	:	15 cm
Temperature	:	Laboratory temperature (30-35°C)
Detection	:	Ultraviolet light at wavelengths of 254 and 365 nm

2.4 Spectroscopy

2.4.1 Mass spectra

Mass spectra were recorded on a microTOF Bruker Daltonics (Department of Chemistry, Faculty of Science, Mahidol University) or a Water, Acquity ultra performance LC mass spectrometer (Department of Medical Sciences, Ministry of Public Health).

2.4.2 Ultraviolet (UV) absorption spectra

UV (in methanol) spectra were obtained on a Perkin-Elmer Lambda 2S UV/VIS spectrophotometer (Department of Medical Sciences, of Ministry Public Health)

2.4.3 Infrared (IR) spectra

IR spectra were obtained on a Perkin-Elmer FT-IR 1760X spectrophotometer (Scientific and Technology Research Equipment Center, Chulalongkorn University).

2.4.4 Proton and carbon-13 nuclear magnetic resonance (^{1}H and ^{13}C-NMR) spectra

^{1}H NMR (300 MHz) and ^{13}C NMR (75 MHz) spectra were recorded on a Bruker Avance DPX-300 FT-NMR spectrometer (Faculty of Pharmaceutical Sciences, Chulalongkorn University).

^{1}H NMR (500 MHz) and ^{13}C NMR (125 MHz) spectra were recorded on an INOVA-500 NMR spectrometer (500 MHz) (Scientific and Technology Research Equipment Center, Chulalongkorn University).

Deuterated solvents for NMR spectra were used, including deuterated chloroform ($CDCl_3$) and deuterated acetone (acetone - d_6). Chemical shifts were reported in ppm scale using the chemical shift of the solvent as the reference signal.

2.5 Solvents

All organic solvents used in this work were of commercial grade and were redistilled prior to use.

3. Extraction and isolation

3.1 Extraction

The dried whole of dendrobium venustum plants (2 kg) were cut into amall pieces, powdered and then macerated for 3 days with methanol (3×5 L). The methanol extract was concentrated under reduced pressure to give 165 g of a crude extract.

3.2 Separation of methanol extract

The methanol extract (165 g) was separated by vacuum liquid chromatography (VLC). The procedure was performed as described in section 2.2.1. Silica gel (No.7734, 600 g) was used as the stationary phase and gradients of hexane-EtOAc (1:0 to 0:1) and EtOAc-methanol (1:0 to 0:1) as the mobile phase. The eluates (about 500 mL per fraction) were collected and examined by silica gel TLC (hexane-EtOAc 6:4) to yield thirty-two fractions. Fractions with similar chromatographic patterns were combined to give eight fractions, i.e. fractions A (0.24 g), B (3.29 g), C (7.05 g), D (1.95 g), E (4.4 g), F (4.97 g), G (16.32 g) and H (90.58 g).

3.2.1 Isolation of compound DV1 (flavanthrinin)

Fraction G (16.32 g) was further separated by FCC using silica gel (No. 9385) as the stationary phase with gradient elution using CH_2Cl_2-MeOH (1:0 to 0:100). Thirty-four fractions were obtained and combined in accordance with their TLC patterns (silica gel, CH_2Cl_2-MeOH 9.5:0.5) to give ten fractions: G1 (0.12 g), G2 (0.38 g), G3 (0.32 g), G4 (1.50 g), G5 (1.00 g), G6 (0.04 g), G7 (2.30 g), G8 (5.07g), G9 (1.00 g) and G10 (1.35 g).

Fraction G4 (1.5 g) was further separated by FCC using silica gel (No. 9385) as the stationary phase with gradient elution of CH_2Cl_2-EtOAc (1:0 to 0:1). Thirty-four fractions were obtained and combined according to TLC patterns (silica gel, CH_2Cl_2-EtOAc 9:1) to give four fractions: G4a (0.218 g), G4b (0.104 g), G4c (0.048 g) and G4d (0.048 g).

Fraction G4a (0.22 g) was purified on a Sephadex LH-20 column, eluted with acetone, to give compound DV1 as brown powder (275 mg, R_f 0.45, silica gel, CH_2Cl_2-EtOAc 9:1). It was identified as flavanthrinin [174].

3.2.2 Isolation of compound DV2 (gigantol)

Fraction G4b (0.10 g) was purified on a Sephadex LH-20 column, eluted with acetone, to give compound DV2 as brown powder (25 mg, R_f 0.38, silica gel, CH_2Cl_2-EtOAc 9:1). It was identified as gigantol [49].

3.2.3 Isolation of compound DV3 (densiflorol B)

Fraction G4c (0.05 g) was purified on a Sephadex LH-20 columm, eluted with acetone, to give compound DV3 as orange powder (21 mg, Rf 0.36, Silica gel, CH_2Cl_2-EtOAc 9:1). It was identified as densiflorol B [146].

3.2.4 Isolation of compound DV4 (lusianthridin)

Fraction G5 (1.00 g) was separated by FCC using silica gel (No. 9385) as the stationary phase with a gradient mixture of CH_2Cl_2-EtOAc (1:0 to 0:1). Twenty-one fractions were obtained and combined according to their TLC patterns (silica gel, CH_2Cl_2-EtOAc 9:1) to give six fractions: G5a (0.31 g), G5b (0.66 g), G5c (0.04 g), G5d (0.06 g), G5e (0.01 g), and G5f (0.11 g). Fraction G5b (0.66 g) was purified on a Sephadex LH-20 column, eluted with acetone to give compound DV4 as brown powder (618 mg, R_f 0.40 silica gel, CH_2Cl_2-EtOAc 9:1). It was identified as lusianthridin [157].

3.2.5 Isolation of compound DV5 (batatasin III)

Fraction G6 (0.04 g) was purified on a Sephadex LH-20 column, eluted with acetone to give thirty fractions. Fractions with similar TLC patterns (silica gel, CH_2Cl_2-EtOAc 6:4) were combined to yield eight fractions: G6a (7.3 mg), G6b (11.1 mg), G6c (2.1 mg), G6d (5.8 mg), G6e (1.4 mg), G6f (45.3 mg), G6g (4.8 mg) and G6h (18.5 mg).

Fraction G6f (45.3 mg) was separated by FCC using silica gel (No. 9385) as the stationary phase with a gradient of CH_2Cl_2-EtOAc (1:0 to 0:1) to give compound DV5 as brown powder (19 mg, R_f 0.30, silica gel, CH_2Cl_2-EtOAc 9:1). It was identified as batatasin III [25].

3.2.6 Isolation of compound DV6 (Phoyunnanin C)

Fraction G8 (5.07 g) was separated by FCC using silica gel (No. 9385) as the stationary phase with a step gradient elution using CH_2Cl_2-MeOH (1:0 to 0:1). Fifteen fractions were obtained and then combined according to their TLC patterns (silica gel, CH_2Cl_2-EtOAc 9:1) to give five fractions: G8a (0.013 g), G8b (0.014 g), G8c (0.051 g), G8d (1.988 g) and G8e (1.042 g).

Fraction G8d (1.988 g) was separated by FCC using silica gel (No. 9385) as the stationary phase with a gradient mixture of CH_2Cl_2- MeOH (1:0 to 0:1). Ten fractions were obtained and then combined according to their TLC patterns (silica gel, CH_2Cl_2-MeOH 9:1) to give three fractions: G8d1 (20.6 mg), G8d2 (340.1 mg) and G8d3 (59.7 mg).

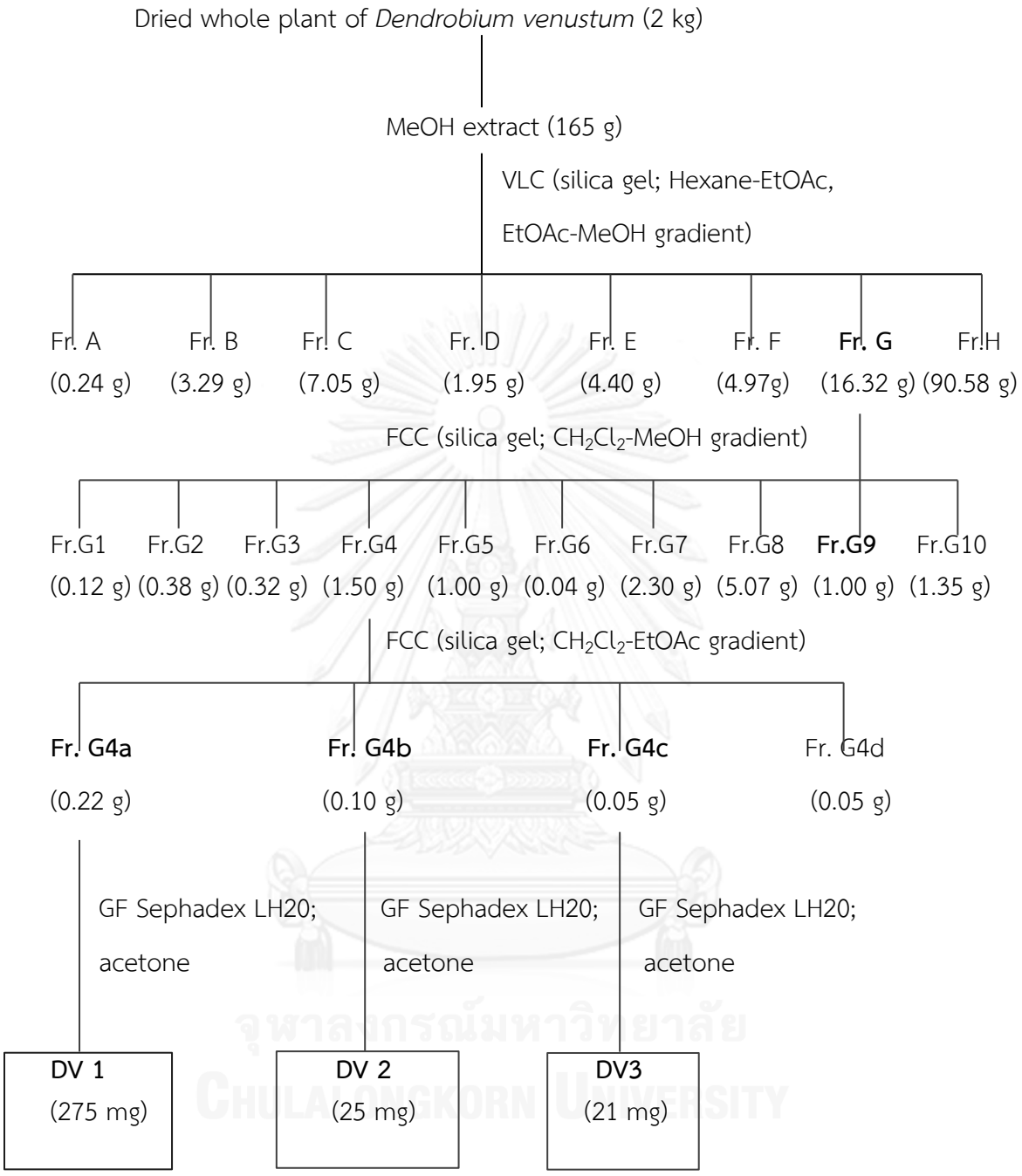
Fraction G8d2 (340.1 mg) was purified on a Sephadex LH-20 columm, eluted with acetone to give thirty-eight fractions and then combined according to their TLC patterns (silica gel, CH_2Cl_2-MeOH 9:1) to give three fractions: G8d21 (56.3 mg), G8d22 (47.3 mg) and G8d23 (31.8 mg).

Fraction G8d22 (47.3 mg) was further purified by PLC (silicagel, CH_2Cl_2-MeOH 9:1 to give compound DV6 as brown powder (32 mg, R_f 0.20, silica gel, CH_2Cl_2- MeOH 9:1). It was identified as phoyunnanin C [266].

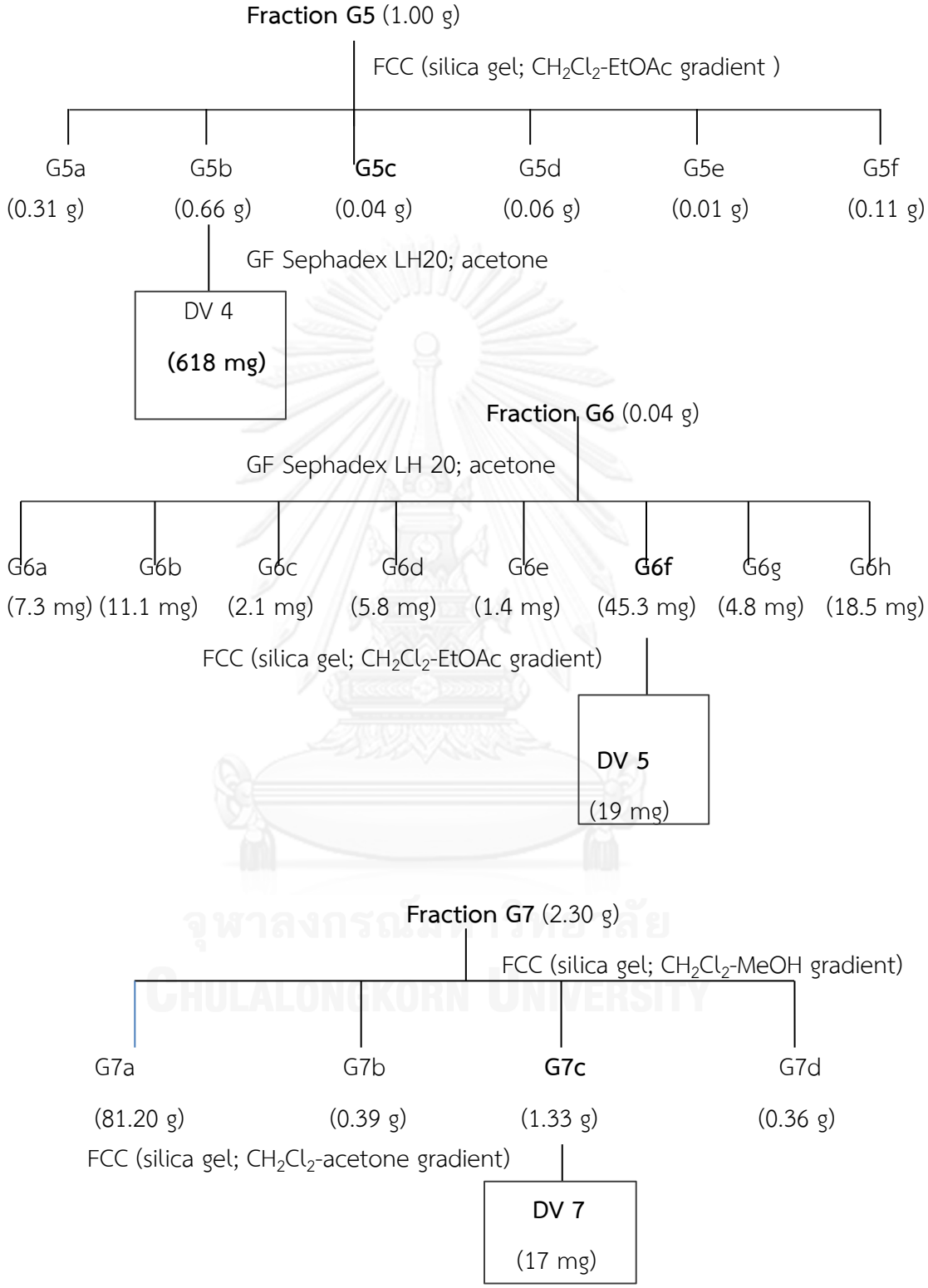
3.2.7 Isolation of compound DV7 (Phoyunnanin E)

Fraction G7 (2.30 g) was separated by FCC using silica gel (No.9385) as the stationary phase, eluted with a gradient mixture of CH_2Cl_2-MeOH (1:0 to 0:1). Seventeen fractions were obtained and then combined according to their TLC patterns (silica gel, CH_2Cl_2-acetone 9:1) to give four fractions: G7a (81.20 g), G7b (0.39 g), G7c (1.33 g) and G7d (0.36 g).

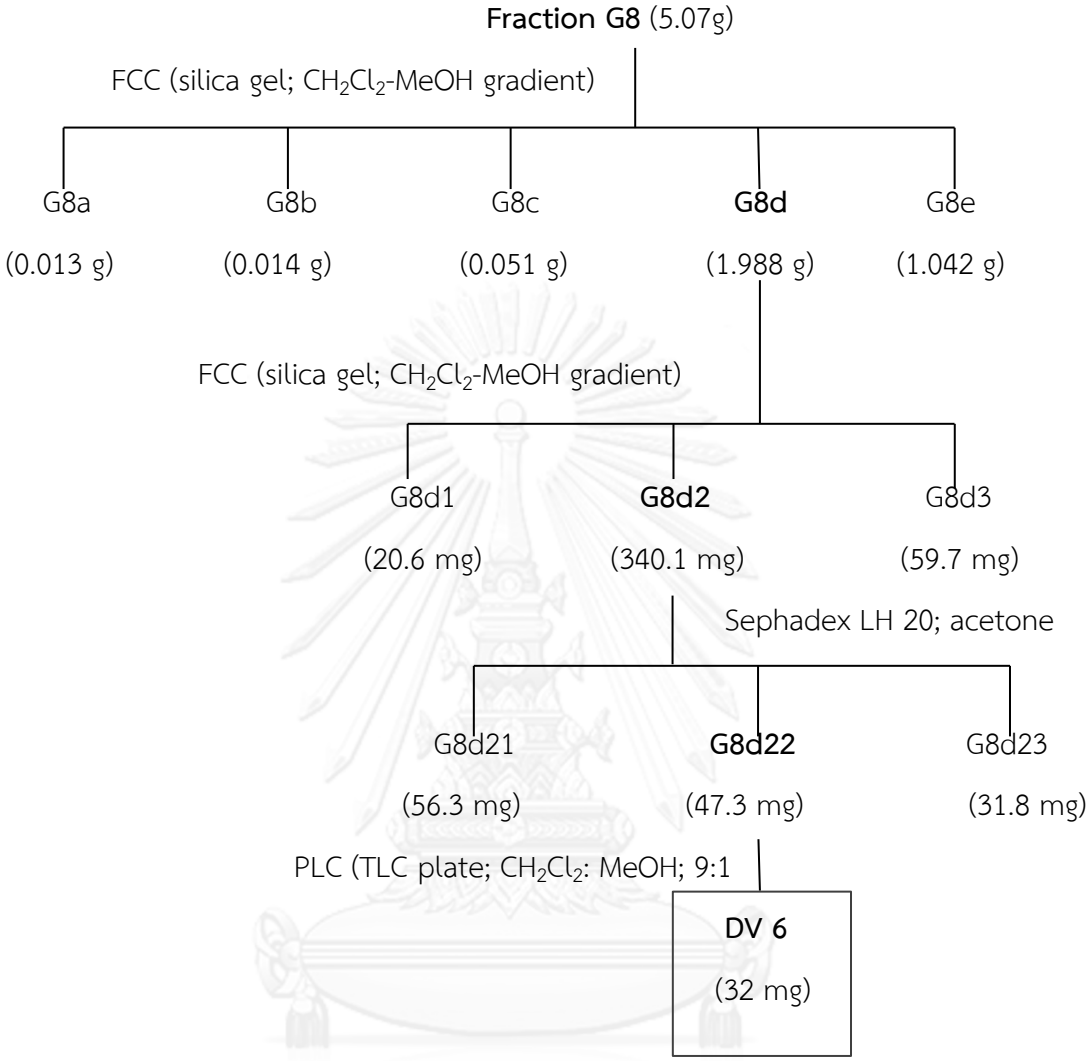
Fraction G7c (1.33 g) was further separated by FCC using silica gel (No.9385) as the stationary phase, eluted with a gradient of CH_2Cl_2-MeOH (1:0 to 0:1) to give compound DV7 as brown powder (17 mg, R_f 0.28, silica gel, CH_2Cl_2-acetone 9:1. It was identified as phoyunnanin E [267].



Scheme 1 Separation of the MeOH extract of *Dendrobium venustum*



Scheme 1 Separation of the MeOH extract of *Dendrobium venustum* (continued)



Scheme 1 Separation of the MeOH extract *of Dendrobium venustum* (continued)

4. Physical and spectral data of isolated compounds

4.1 Compound DV1 (Flavanthirnin)

Compound DV1 was obtained as brown, soluble in CH_2Cl_2 (275 mg, 0.014% based on weight of dried plant materials).

UV : λ_{max} nm (log ε), in methanol: 212 (4.42), 257 (4.64), 282 (4.38), 314 (3.93); Figure 3

FT-IR : ν_{max} cm^{-1} (KBr): 3306, 3000, 2986, 1603, 2940, 1613; Figure 4

ESI-MS : $[M+H]^+$ion at *m/z* 241; Figure 5

^{1}H NMR : δ ppm, 300 MHz, in $CDCl_3$; see Table 2, Figure 6

^{13}C NMR : δ ppm, 75 MHz, in $CDCl_3$; see Table 2, Figure 7

4.2 Compound DV2 (Gigantol)

Compound DV2 was obtained as brown powder, soluble in acetone (25 mg, 0.0012% based on weight of dried plant materials).

UV : λ_{max} nm (log ε), in methanol: 205 (4.52), 280 (3.41); Figure 9

FT-IR : ν_{max} cm^{-1}(KBr): 3399, 3060, 3002, 1614, 1434, 1462; Figure 10

ESI-MS : $[M+H]^+$ion at *m/z* 275; Figure 11

^{1}H NMR : δ ppm, 300 MHz, in acetone- d_6; see Table 3, Figure 12

^{13}C NMR : δ ppm, 75 MHz, in acetone- d_6; see Table 3, Figure 13

4.3 Compound DV3 (Densiflorol B)

Compound DV3 was obtained as orange powder, soluble in DMSO (21 mg, 0.0010% based on weight of dried plant materials).

UV : λ_{max} nm (log ε), in methanol: 230 (4.52), 302 (4.23); Figure 18

FT-IR : ν_{max} cm^{-1} (KBr): 3418, 1670, 1637, 1624, 1595; Figure 19

ESI-MS : $[M+H]^+$ion at m/z 255; Figure 20

^{1}H NMR : δ ppm, 300 MHz, in DMSO- d_6; see Table 4, Figure 21

^{13}C NMR : δ ppm, 75 MHz, in DMSO- d_6; see Table 4, Figure 22

4.4 Compound DV4 (Lusianthridin)

Compound DV4 was obtained as brown powder, soluble in acetone (618 mg, 0.0309% based on weight of dried plant materials).

UV : λ_{max} nm (log ε), in methanol: 211 (4.54), 277 (4.26), 294 (4.09); Figure 24

FT-IR : ν_{max} cm^{-1}(KBr): 3336, 3009, 1610; Figure 25

ESI-MS : $[M+H]^+$ ion at *m/z* 241; Figure 26

^{1}H NMR : δ ppm, 300 MHz, in acetone- d_6; see Table 5, Figure 27

^{13}C NMR : δ ppm, 75 MHz, in acetone- d_6; see Table 5, Figure 28

4.5 Compound DV5 (Batatasin III)

Compound DV5 was obtained as brown powder, soluble in CH_2Cl_2 (19 mg, 0.00095 % based on weight of dried plant materials).

UV : λ_{max} nm (log ε), in methanol: 205 (4.28), 274 (3.18); Figure 30

FT-IR : ν_{max} cm^{-1}(KBr): 3320, 1619, 1595, 1445; Figure 31

ESI-MS : $[M+H]^+$ ion at *m/z* 245; Figure 32

^{1}H NMR : δ ppm, 300 MHz, in $CDCl_3$; see Table 6, Figure 33

^{13}C NMR : δ ppm, 75 MHz, in $CDCl_3$; see Table 6, Figure 34

4.6 Compound DV6 (Phoyunnanin C)

Compound DV6 was obtained as a brown powder, soluble in acetone (32 mg, 0.00159 % based on weight of dried plant materials).

UV : λ_{max} nm (log ε), in methanol: 215 (5.04), 278 (4.84), 297(4.70); Figure 36

FT-IR : ν_{max} cm^{-1}(KBr): 3428, 1612, 1591, 1441; Figure 37

ESI-MS : $[M+Na]^+$ ion at *m/z* 505.1529; Figure 38

^{1}H NMR : δ ppm, 500 MHz, in acetone- d_6; see Table 7, Figure 39

^{13}C NMR : δ ppm, 125 MHz, in acetone- d_6; see Table 7, Figure 40

4.7 Compound DV7 (Phoyunnanin E)

Compound DV7 was obtained as a brown powder, soluble in acetone (17 mg, 0.00084% based on weight of dried plant materials).

UV : λ_{max} nm (log ε), in methanol: 212 (4.60), 278 (4.33), 299 (4.12); Figure 44

FT-IR : ν_{max} cm^{-1} (KBr): 3364, 1656, 1631, 1615, 1591, 1225; Figure 45

ESI-MS : $[M+Na]^+$ ion at *m/z* 505.1627; Figure 46

^{1}H NMR : δ ppm, 500 MHz, in acetone- d_6; see Table 7, Figure 47

^{13}C NMR : δ ppm, 125 MHz, in acetone- d_6; see Table 7, Figure 48

5. Antimalarial activity

Antimalarial activity assay was performed using the microculture radioisotope technique. *Plasmodium falciparum* (K1, multidrug resistant strain) was cultivated in RPMI 1640 medium containing 20 mM HEPES (N-2-hydroxyethylpiperazine-N-2-ethanesulfonic acid), 32 mM $NaHCO_3$ and 10% heat activated human serum with 3% erythrocytes, in humidified 37ºC incubator with 3% CO_2. The culture was passaged with fresh mixture of erythrocytes and medium every day to maintain cell growth. Quantitative assessment of antimalarial activity in vitro was based upon the method described by Desjardins et al. (1979). Briefly, a mixture of 200 µl of 1.5% erythrocytes with 1% parasitemia at the early ring stage was pre-exposed to 25 µl of the medium containing a test sample dissolved in 1% DMSO (0.1% final concentration) for 24 hr. Subsequently, 25 µl of [^{3}H] hypoxanthine (Amersham, USA) in culture medium (0.5 µCi) was added to each well and the plates were incubated for an additional 24 hr period. Levels of incorporated radio labeled hypoxanthine, indicating parasite growth, were determined using a Top Count microplate scintillation counter (Packard, USA). The percentage growth was calculated using the signal count per minute of treated (CPM_T) and untreated conditions (CPM_U), as follows.

$$\% \text{ parasite growth} = CPM_T/CPM_U \times 100$$

IC_{50} represents the concentration which indicates 50% reduction in parasite growth. Dihydroartemisinin and mefloquine were used as positive controls, and 0.1% DMSO was used as a negative control.

6. Cytotoxicity against human skin fibroblast

Study of cytotoxicity was carriedout using HDFn cell line (human dermal fibroblast, neonatal, Cat.no. IIVCc - C - 004 - 5C, Invitrogen, USA). These cells were grown in Dulbecco's Modified Eagle's Medium (DMEM) supplemented with 10% fetal bovine serum, 2mM L-glutamine, 100 unit/ml penicillin and 100 µg/ml streptomycin, and then the cells were incubated at 37ºC in a fully humidified atmosphere with 5% CO_2.

MTT cytotoxicity test was performed. This assay was a modified version of conventional direct and indirect contact tests conformed to the published standard methods (BS-EN30993-5 and ISO10993-5). The MTT assay is a tetrazolium-dye based colorimetric microtitration assay. Metabolism-competent cells are able to metabolize

the tetrazolium (yellow) to formazan (blue); this color change is measured spectrophotometrically with a plate reader. Cells that are metabolically deficient are assumed to not be able to survive, thus the assay also indirectly measure cell viability. The human dermal fibroblast cells were seeded in a 96-well plate at a density of 6,000 cells/ well and incubated for 48 hours. Various concentrations of samples were added to the cells and incubated for 24 hours. The test samples were removed from the cell cultures and the cells were reincubated for a further 24 hours. In fresh medium and then tested with MTT assay. Briefly, 50 µl of MTT in PBS at 5 mg/ml was added to the medium in each well and the cells were incubated for 4 hours. Medium and MTT were then aspirated from the wells, and formazan was solubilized with 200 µL of DMSO and 25 µl of Sorensen's Glycine buffer (pH10.5). The optical density was recorded with a microplate reader (Molecular Devices) at a wavelength of 570 nm. The average of 4 wells was used to determine the mean of each point. A dose-response curve was derived from 8 concentrations in the test range using 4 wells per concentration. Results of toxic compounds are expressed as the concentration of sample required to kill 50% (IC_{50}) of the cells compared to controls. Based on the % cell survival of each test concentration, the sample can be considered cytotoxic if not more than 50% of these cells survived.

7. Selectivity index (SI)

The selectivity index was calculated as the ratio between the IC_{50} of the cytotoxicity of the compounds against human fibroblast and their IC_{50} for growth inhibition of *P. falciparum*

$$SI = \frac{IC_{50} \text{ (cytotoxicity against human fibroblast)}}{IC_{50} \text{ (growth inhibition of } \textit{P. falciparum}\text{)}}$$

CHAPTER IV

RESULTS AND DISCUSSION

In the present study, the whole plants of Dendrobium venustum was macerated with methanol to give crude methanol extract, which was separated by vacuum liquid chromatography to yield eight fractions (A-H). Fraction G, which showed antimalarial activity with an IC_{50} value of 2.60 µg/ml, was further separated using several chromatographic techniques to give seven known compounds [DV1-DV7] including 2 bibenzyls and 5 phenanthrenes. The structures of these compounds were determined by spectroscopic analysis, including UV, IR, MS, and NMR. Each isolate was evaluated for antimalarial activity. The active compounds were then analyzed for their cytotoxicity against human dermal fibroblast, and their selectivity indices were calculated.

1. Structure characterization of isolated compounds

1.1 Structure determination of compound DV1

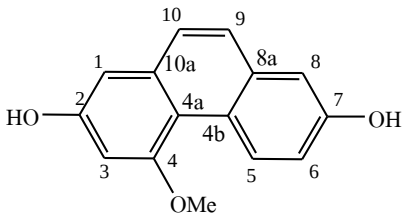
Compound DV1 was obtained as a brown powder. The ESI mass spectrum (Figure 5) showed a pseudomolecular ion [M+H]+ at *m/z* 241, suggesting the molecular formula $C_{15}H_{12}O_3$. The IR spectrum (Figure 4) showed absorption peaks at 3306 cm^{-1} for hydroxyl group, at 3104 cm^{-1} for C-H aromatic stretching and at 1613 cm^{-1} for C=C stretching. The UV spectrum (Figure 3) of this compound exhibited maximal absorptions at 212, 257, 282, and 314 nm, characteristic of a phenanthrene derivative (Zhang *et al*., 2008).

The ^1H NMR data (Figure 6 and Table 2) exhibited signals for methoxy protons at δ_H 4.09 (3H, s, MeO-4), three *meta*-coupled aromatic protons at δ_H 6.86 (1H, d, *J* = 2.4 Hz, H-3), 6.99 (1H, d, *J* = 2.4 Hz, H-1) and 7.43 (1H, d, *J* = 2.5 Hz, H-8), three *ortho*-coupled aromatic protons at δ_H 7.52 (1H, d, *J* = 7.8 Hz, H-5), 7.50 (1H, d, *J* = 9.0 Hz, H-10) and 7.64 (1H, d, *J* = 9.0 Hz, H-9) and a *meta* and *ortho*-coupled aromatic proton δ_H at 7.25 (^1H, dd, *J* = 7.8, 2.5 Hz, H-6).

The ^{13}C NMR spectrum (Figure 7) exhibited fifteen carbon signals, including one methoxyl, seven methines and seven quaternary carbons. The methoxyl group could be placed at C-4 according to its NOESY cross peak with H-3 (Figure 8).

By comparing the ^1H, ^{13}C NMR, UV, IR and MS data of DV1 with previously published data (Zhang *et al*., 2008), the compound was identified as flavanthrinin. Flavanthrinin

has been earlier isolated from *Dendrobium nobile* and studied for antioxidant activity (Zhang *et al*., 2008b).



Flavanthrinin [174]

Table 2 NMR spectral data of compound DV1 ($CDCl_3$) and flavanthrinin ($CDCl_3$)

Position	Compound DV1		Flavanthrinin[a]	
δ_H (mult., *J* in Hz)	δ_C	δ_H (mult., *J* in Hz)	δ_C	
1	6.99 (d, 2.4)	107.3	6.97 (d, 2.5)	107.4
2	-	154.2	-	154.3
3	6.86 (d, 2.4)	101.6	6.84 (d, 2.5)	101.7
4	-	155.4	-	155.5
4a	-	114.0	-	114.4
4b	-	119.9	-	118.8
5	7.52 (d, 7.8)	127.0	7.47 (d, 7.6)	127.1
6	7.25 (dd, 7.8, 2.5)	116.6	7.22 (dd, 7.6, 1.5)	116.6
7	-	153.9	-	154.0
8	7.43 (d, 2.5)	120.6	7.40 (d,1.5)	120.7
8a	-	134.1	-	134.2
9	7.64 (d, 9.0)	129.4	7.62 (d, 8.8)	129.5
10	7.50 (d, 9.0)	125.8	7.43 (d, 8.8)	125.8
10a	-	136.0	-	136.1
4-OMe	4.09 (s)	58.4	4.08 (s)	58.5

a ^{1}H NMR and ^{13}C NMR data from Zhang et al., 2008

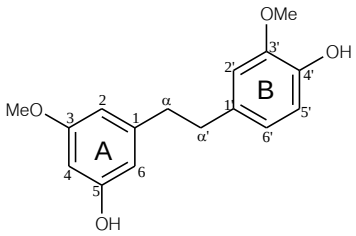
1.2 Structure determination of compound DV2

Compound DV2 was isolated as a brown powder. The ESI mass spectrum (Figure 11) showed a pseudomolecular ion $[M+H]^+$ at *m/z* 275, suggesting the molecular formula C_{16} H_{18} O_4. The IR spectrum (Figure 10) showed absorption bands at 3418 cm^{-1} for hydroxyl group, at 2923 cm^{-1} for C-H stretching and at 1624 cm^{-1} for C=C . The UV spectrum (Figure 9) showed absorption at 205 and 280 nm which were characteristic of a bibenzyl derivative (Chen *et al*., 2008).

The ^{1}H NMR data (Figure 12 and Table 3) exhibited signals for two pairs of methylene protons at δ_H 2.77 (4H, br s, H_2-α, H_2-α'), and two methoxy protons at δ_H 3.69 (3H, s, MeO-3) and 3.78 (3H, s, MeO-3′). On ring A, the ^{1}H NMR showed three *meta*-coupled aromatic protons at δ_H 6.28 (1H, t, *J* = 2.0 Hz, H-2), 6.23 (1H, t, *J* = 2.0 Hz, H-4) and 6.30 (1H, t, *J* = 2.0 Hz, H-6). The assignments of H-2 and H-6 were based on their HMBC correlations (Figure 16) to C-α. For ring B, the ABM splitting system consisting of three protons at δ_H 6.64 (1H, dd, *J* = 8.0, 1.5 Hz, H-6′), 6.70 (1H, d, *J* = 8.0 Hz, H-5′) and 6.79 (1H, d, *J* = 1.5 Hz, H-2′) together with the HMBC correlations of H-2′ and H-6′ with C-α', suggested two substitutions at C-3′ and C-4′.

The ^{13}C NMR (Figure 13 and Table 3), DEPT 135 (Figure 17) and HSQC (Figure 15) spectra showed sixteen carbon signals, corresponding to two methoxyls, two methylenes, six methines and six quaternary carbons. The locations of the two methoxyls were confirmed by a NOESY experiment (Figure 14). The first methoxyl at δH 3.69 was placed at C-3 according to its NOESY correlation peaks with H-2 and H-4. The second methoxyl (δ_H 3.78) was located at C-3′ based on its NOESY cross-peak with H-2′.

By comparing the ^{1}H, ^{13}C NMR, UV, IR and MS data of this compound with previously published data (Chen *et al*., 2008), compound DV2 was identified as gigantol. Gigantol is a bibenzyl frequently found in *Dendrobium* species, for examples *D. aurantiacum* var. *denneanum* (Liu *et al*., 2009a), *D. draconis* (Sritularak *et al*., 2011a) and *D. gratiosissimum* (Zhang *et al*., 2008a)



Gigantol [49]

Table 3 NMR spectral data of compound DV2 (acetone-d_6) and gigantol (acetone-d_6)

Position	Compound DV2			Gigantol[a]	
	δ_H (mult., *J* in Hz)	δ_C	HMBC correlation with ^{1}H	δ_H (mult., J in Hz)	δ_C
1	-	145.5	H_2-α'	-	144.5
2	6.28 (t, 2.0)	106.2	H-4, H-6, H_2-α	6.33 (dd, 2.0, 2.0)	105.3
3	-	161.8	H-2, H-4, 3-OMe	-	160.8
4	6.23 (t, 2.0)	99.6	H-2, H-6	6.30 (dd, 2.0, 2.0)	98.7
5	-	159.2	H-4, H-6,	-	158.2
6	6.30 (t, 2.0)	108.8	H-2, H-4, H_2-α	6.26 (dd, 2.0, 2.0)	107.9
α	2.77 (br s)	39.0	H-2, H-6	2.79 (m)	37.9
α'	2.77 (br s)	37.9	H-2', H-6'	2.78 (m)	36.9
1′	-	134.0	H-5', H_2-α	-	133.1
2′	6.79 (d, 1.5)	115.5	-	6.80 (d, 2.0)	114.6
3′	-	148.0	H-5', 3'-OMe	-	147.0
4′	-	145.1	H-2', H-6'	-	144.2
5′	6.70 (d, 8.0)	112.8	-	6.74 (d, 8.0)	111.9
6′	6.64 (dd, 8.0, 1.5)	121.5	H-2′, H_2-α'	6.66 (dd, 8.0, 2.0)	120.6
3′-OMe	3.78 (s)	56.1	-	3.82 (s)	55.2
3-OMe	3.69 (s)	55.2	-	3.73 (s)	54.3

a ^{1}H NMR and ^{13}C NMR data from Chen *et al*., 2008.

1.3 Structure determination of compound DV3

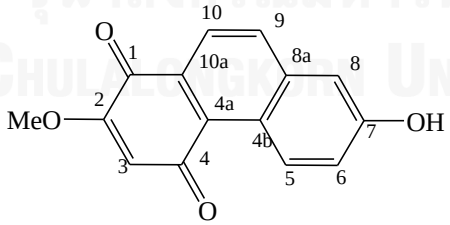
Compound DV3 was obtained as an orange powder. The ESI mass spectrum (Figure 20) showed a pseudomolecular ion $[M+H]^+$ at *m/z* 255, suggesting the molecular formula $C_{15}H_{10}O_4$.

The IR spectrum (Figure 19) showed absorption bands at 3418 cm^{-1} for hydroxyl group, at 1670 and 1637 cm-1 for C=O stretching of aromatic ring, 1624 and 1595 cm-1 for aromatic ring. The UV spectrum (Figure 18) of this compound exhibited maximal absorptions at 230 and 302 nm, characteristic of a phenanthrene (Fan *et al*., 2001).

The appearance of two carbonyl carbons at δ_C 180.4 and δ_C 188.5 suggested a phenanthrenequinone structure for DV3. The ^{1}H NMR data (Figure 21 and Table 4) exhibited proton signal for a methoxyl group at δ_H 3.86 (3H, s, MeO-2) and a singlet signal for H-3 at δ_H 6.28 (1H). The ^{1}H NMR spectrum also revealed the presence of signals for an ABM splitting pattern at δ_H 7.24 (1H, d, *J* = 2.4 Hz, H-8), 7.34 (1H, dd, *J* = 9.6, 2.4 Hz, H-6) and 9.36 (1H, d, *J* = 9.6 Hz, H-5), and a pair of *ortho*-coupled proton signals at δ_H 7.97 (1H, d, *J* = 8.4 Hz, H-10) and at δ_H 8.08 (1H, d, *J* = 8.4 Hz, H-9).

The ^{13}C NMR spectrum (Figure 22 and Table 4) exhibited fifteen peaks. A NOESY experiment (Figure 23) was used to determine the location of the methoxyl group. The NOE interaction of the methoxyl signal at δ_H 3.86 with H-3 placed this methoxyl group at C-2.

By comparing the ^{1}H, ^{13}C NMR, UV, IR and MS data of this compound with previously published data (Fan *et al*., 2001), DV3 was identified as densiflorol B. This compound has been firstly isolated from *Dendrobium densiflorum* (Fan *et al*., 2001).



Densiflorol B [146]

Table 4 NMR spectral data of compound DV3 (DMSO-d_6) and densiflorol B (DMSO-d_6)

Position	Compound DV3		Densiflorol B[a]	
	δ_H (mult., *J* in Hz)	δ_C	δ_H (mult., *J* in Hz)	δ_C
1	-	180.4	-	180.2
2	-	158.5	-	158.3
3	6.28 (s)	111.2	6.30 (s)	111.1
4	-	188.5	-	188.4
4a	-	126.9	-	126.8
4b	-	123.4	-	123.3
5	9.36 (d, 9.6)	121.9	9.35 (d,9.5)	121.8
6	7.34 (dd, 9.6, 2.4)	122.7	7.35 (dd, 9.5, 2.2)	122.4
7	-	157.9	-	157.5
8	7.24 (d, 2.4)	109.9	7.25 (d,2.2)	109.7
8a	-	139.1	-	138.9
9	8.08 (d, 8.4)	132.3	8.10 (d, 8.6)	132.3
10	7.97 (d, 8.4)	129.7	7.95 (d, 8.6)	129.7
10a	-	128.3	-	128.3
2-OMe	3.86 (s)	56.5	3.90 (s)	56.4

a ^{1}H NMR and ^{13}C NMR data from Fan *et al*., 2001

1.4 Structure determination of compound DV4

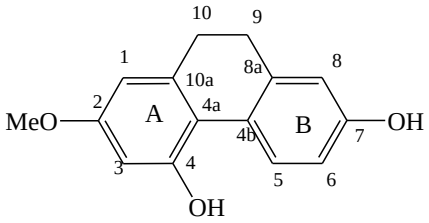
Compound DV4 was obtained as a brown powder. The ESI mass spectrum (Figure 18) showed a pseudomolecular ion $[M+Na]^+$ at *m/z* 265, suggesting the molecular formula $C_{15}H_{14}O_3$.

The IR spectrum (Figure 25) showed absorption bands at 3336 cm^{-1} for hydroxyl group, at 3009 cm^{-1} for C-H stretching, and at 1610 cm^{-1} for C=C stretching. The UV spectrum (Figure 24) of this compound exhibited maximal absorptions at 211, 277 and 294 nm, characteristic of dihydrophenanthrene (Guo *et al*., 2007).

This was supported by the presence of two methylene protons (H-9, H-10) at δH 2.66 (4H, m) and two carbon signals at δ_C 30.6 (C-9) and δ_C 31.4 (C-10). The appearance of ABM spin system at δ_H 6.68 (^{1}H, dd, *J* = 9.0, 2.5 Hz, H-6), 6.69 (1H, d, *J* = 2.5 Hz, H-8) and 8.21 (1H, d, *J* = 9.0 Hz, H-5) suggested a monosubstitution of ring B. On ring A, the ^{1}H NMR (Figure 27) showed two meta-coupled aromatic proton signals at δH 6.36 (^{1}H, d, *J* = 1.5 Hz, H-1) and δ_H 6.42 (1H, d, *J* = 1.5 Hz, H-3). The ^{1}H NMR spectrum also displayed a signal for a methoxyl group at δ_H 3.72 (3H, s). This methoxyl group was placed at C-2 from its NOE (Figure 29) cross-peak with H-1 and H-3.

The ^{13}C NMR spectrum (Figure 28 and Table 5) exhibited fifteen peaks, including those of one methoxyl, two methylenes, five methines and seven quaternary carbons.

Through comparison of the ^{1}H, ^{13}C NMR, UV, IR and MS data of this compound with previously published data (Guo *et al*., 2007), compound DV4 was identified as lusianthridin. Lusianthridin is a dihydrophenanthrene frequently found in the genus *Dendrobium*, for example, *D. aphyllum* (Chen *et al*., 2008a), *D. loddigesii* (Ito *et al*., 2010), *D. nobile* (Yang *et al*., 2007; Hwang *et al*., 2010) and *D. plicatile* (Yamaki and Honda, 1996).



Lusianthridin [157]

Table 5 NMR spectral data of compound DV4 (acetone- d_6) and lusianthridin (acetone- d_6)

Position	Compound DV4		Lusianthridin[a]	
	δ_H (mult., *J* in Hz)	δ_C	δ_H (mult., *J* in Hz)	δ_C
1	6.36 (d, 1.5)	105.8	6.37 (d, 2.6)	106.0
2	-	159.2	-	159.3
3	6.42 (d, 1.5)	101.5	6.44 (d, 2.6)	101.6
4	-	155.8	-	155.9
4a	-	115.7	-	115.9
4b	-	125.8	-	125.9
5	8.21 (d, 9.0)	129.8	8.22 (d, 7.5)	129.9
6	6.68 (dd, 9.0, 2.5)	113.4	6.68 (dd, 7.5, 2.7)	113.5
7	-	155.9	-	156.1
8	6.69 (d, 2.5)	114.9	6.69 (m)	115.0
8a	-	139.7	-	139.8
9	2.66 (m)	30.6	2.67 (m)	30.8
10	2.66 (m)	31.4	2.67 (m)	31.5
10a	-	141.3	-	141.4
2-OMe	3.72 (s)	55.2	3.74 (s)	55.3

a ^{1}H NMR and ^{13}C NMR data from Guo *et al*., 2007

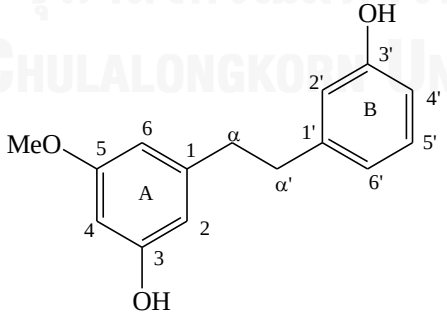
1.5 Structure determination of compound DV5

Compound DV5 was obtained as a brown powder. The ESI mass spectrum (Figure 32) showed a protonated molecular ion $[M+H]^+$ at *m/z* 245, suggesting the molecular formula $C_{15}H_{16}O_3$.

The IR spectrum (Figure 31) showed absorption bands at 3320 cm^{-1} for hydroxyl group, at 1619, 1595 and 1455 cm^{-1} for aromatic ring. The UV spectrum (Figure 30) of this compound exhibited maximal absorptions at 205 and 274 nm which were characteristic of a bibenzyl derivative (Chen *et al*., 2008).

The ^{1}H NMR data (Figure 33 and Table 6) exhibited proton signals for two pairs of methylene protons at δ_H 2.85 (4H, br s, H_2-**α**, H_2-**α′**), a methoxyl group at δ_H 3.77 (3H, s, MeO-5). On ring A, the ^{1}H NMR spectrum showed three protons at δ_H 6.27 (2H, br s, H-2, H-4) and δ_H 6.33 (1H, br s, H-6). In the aromatic region of ring B, the ^{1}H NMR spectrum showed protons at δ_H 6.33 (1H, br s, H-2′), 6.68 (1H, m, H-4′), 6.78 (1H, br d, *J* = 7.5 Hz, H-6′) and 7.16 (1H, dd, *J* = 8.4, 7.5 Hz, H-5′).

The ^{13}C NMR spectrum (Figure 34 and Table 6) exhibited fifteen carbon signals, including signals at δ_C 37.3 and 37.6 for methylene carbons, signals at δ_C 55.2 for a methoxy carbon, signals at δ_C 99.0-129.5 for methine carbons and signals at δ_C 143.5-160.8 for quaternary carbons. The methoxyl group was placed at C-5 due to its NOESY (Figure 35) correlations with H-4 and H-6. By comparing the ^{1}H, ^{13}C NMR, UV, IR and MS properties of this compound with previously published data (Chen *et al*., 2008) compound DV5 was identified as batatasin III. Batatasin III is a bibenzyl frequently found in *Dendrobium* species, such as *D. draconis* (Sritularak *et al*., 2011a), *D. gratiosissimum* (Zhang *et al*., 2008a) and *D. loddigesii* (Ito *et al*., 2010).



Batatasin III [25]

Table 6 NMR spectral data of compound DV5 ($CDCl_3$) and batatasin III ($CDCl_3$)

Position	Compound DV5		Batatasin III[a]	
	δ_H (mult., *J* in Hz)	δ_C	δ_H (mult., *J* in Hz)	δ_C
1	-	144.4	-	144.4
2	6.27 (br s)	106.7	6.29 (dd, 1.4, 1.4)	106.9
3	-	160.8	-	160.7
4	6.27 (br s)	99.0	6.27 (dd,1.4, 1.4)	99.3
5	-	156.5	-	156.4
6	6.33 (br s)	107.9	6.34 (dd, 1.4,1.4)	108.2
α	2.84 (br s)	37.3	2.80 (m)	36.9
α'	2.84 (br s)	37.6	2.81 (m)	37.3
$1'$	-	143.5	-	143.4
$2'$	6.67 (br s)	115.3	6.64 (dd, 2.4, 2.4)	115.4
$3'$	-	155.5	-	155.4
$4'$	6.69 (m)	112.8	6.67 (dd, 8, 2.4)	112.9
$5'$	7.16 (dd, 8.4, 7.5)	129.5	7.12 (dd, 8, 8)	129.3
$6'$	6.78 (br d, 7.5)	120.9	6.74 (d, 8)	120.8
5-OMe	3.77 (s)	55.2	3.73 (s)	55.2

a ^{1}H NMR and ^{13}C NMR data from Chen *et al*., 2008

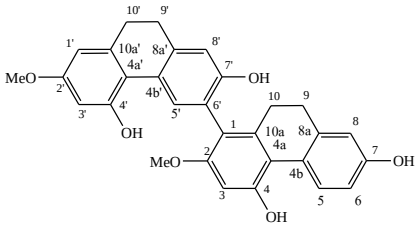
1.6 Structure determination of compound DV6

Compound DV6 was obtained as a brown powder. The ESI mass spectrum (Figure 38) showed a sodium adduct molecular ion $[M+Na]^+$ at *m/z* 505.1529 (calculated for 505.1627; $C_{30}H_{26}O_6Na$), suggesting the molecular formula $C_{30}H_{26}O_6$.

The IR spectrum (Figure 37) showed absorption bands at 3428 cm^{-1} for hydroxyl groups, at 1591 and 1441 cm^{-1} for C=C aromatic rings. The UV (Figure 36) absorptions at 215, 278 and 297 nm were suggestive of a dihydrophenanthrene structure (Gou *et al*., 2007).

The appearance of signals for four pairs of methylene proton signals at δ_H 2.54 (4H, m, H_2-9, H_2-10), and at δ_H 2.75 (4H, br s, H_2-9′, H_2-10′) and the carbon signals at δ 27.4 (C-10), 29.6 (C-9, C-9′) and 30.7 (C-10′) in the ^1H, ^{13}C NMR and DEPT135 spectra (Table 7 and Figures 39, 40 and 43) suggested that DV6 was a dimeric dihydrophenanthrene. For the first monomer unit, the ^1H NMR spectrum exhibited two proton signals at δ_H 6.40 (2H, br s, H-1′, H-3′) and two sharp singlet protons at δ_H 6.79 (1H, s, H-8′) and δ_H 8.11 (1H, s, H-5′). The assignment of H-1′ was based on its HMBC correlation (Figure 41) with C-10′. The singlet proton signal at δ_H 6.79 was assigned to H-8′ due to its correlation with C-9′ and C-4b′ in HMBC spectrum. This was confirmed by its NOESY (Figure 42) cross-peak with H2-9′. The HMBC correlations of C-4a′ with H-1′, H-3′, H-5′ and H2-10′ were also observed. The aromatic protons of another monomer were observed as a sharp singlet proton at δ_H 6.59 (1H, s, H-3) and an ABM spin system at δ_H 6.68 (1H, d, *J* = 2.4 Hz, H-8), 6.71 (1H, dd, *J* = 8.4, 2.4 Hz, H-6), and 8.26 (1H, d, *J* = 8.4 Hz, H-5). The assignment of H-3 was based on its HMBC correlation with C-4a. Moreover, the HMBC correlations of C-4a with H-5 and H_2-10 were observed. The ^1H NMR of DV16 also revealed the presence of two methoxyls at δ_H 3.66 and 3.73. The first methoxyl group (δ_H 3.66) could be located at C-2 based on its NOESY correlation with H-3. The NOE cross-peaks of the second methoxyl (δ_H 3.73) with H-1′ and H-3′ placed this methoxyl at C-2′. The three-bond correlations of C-1 with H_2-10, H-3 and H-5′ in the HMBC spectrum indicated that the two monomers should be linked at C-1 and C-6′.

Based on the above spectral evidence, compound DV6 was identified as phoyunnanin C [266] (Gou *et al*., 2007), a compound previously reported as a new dihydrophenenthrene dimer from *Pholidota yunnanensis* (family Orchidaceae). However, this is the first report of its accurrence in the genus *Dendrobium*.



Phoyunnanin C [266]

Table 7 NMR spectral data of compound DV6 (acetone- d_6) and phoyunnanin C (acetone- d_6)

Position	Compound DV6			Phoyunnanin C [a]	
	δ_H (mult., *J* in Hz)	δ_C	HMBC correlation with ^{1}H	δ_H (mult., *J* in Hz)	δ_C
1	-	117.4	H-3, H_2-10, H-5′	-	118.4
2	-	156.6	2-OMe	-	157.6
3	6.59 (s)	99.4	-	6.58 (s)	99.4
4	-	154.2	H-3	-	155.1
4a	-	114.9	H-3, H-5, H-10	-	115.8
4b	-	125.7	H-6, H-8, H_2-9	-	126.3
5	8.20 (d, 8.4)	129.2	-	8.24 (d, 8.5)	130.2
6	6.71 (dd, 8.4, 2.7)	112.5	H-8	6.70 (dd, 8.5,2.7)	113.4
7	-	155.1	H-5	-	156.1
8	6.68 (d, 2.4)	113.8	H-6, H2-9	6.67 (d, 2.7)	114.7
8a	-	139.2	H-5, H2-10	-	140.2
9	2.54 (m)	29.6	H-8	2.56 (m)	30.6
10	2.54 (m)	27.4	-	2.52 (m)	28.4
10a	-	140.1	H_2-9	-	141.1
1′	6.40 (br s)	105.1	H-3′, H_2-10′	6.40 (br s)	106.1
2′	-	158.3	2′-OMe	-	159.3
3′	6.40 (br s)	100.7	H-1′	6.40 (br s)	101.6
4′	-	155.0	H-3′	-	155.9
4a′	-	115.0	H-1′, H-3′, H-5′, H_2-10′	-	116.0
4b′	-	124.3	H-8′, H_2-9′	-	125.7
5′	8.11 (s)	131.7	-	8.10 (s)	132.6
6′	-	121.5	H-8′	-	122.6
7′	-	152.8	H-5′	-	153.7
8′	6.79 (s)	114.3	H_2-9′	6.78 (s)	115.2
8a′	-	137.6	H-5′, H_2-10′	-	138.6
9′	2.75 (m)	29.6	H-8′	2.75 (m)	30.5
10′	2.75 (m)	30.7	H-1′	2.75 (m)	31.6
10a′	-	140.5	H-9′	-	141.4
2-OMe	3.66 (s)	54.8	-	3.66 (s)	55.7
2′-OMe	3.73 (s)	54.4	-	3.73(s)	55.2

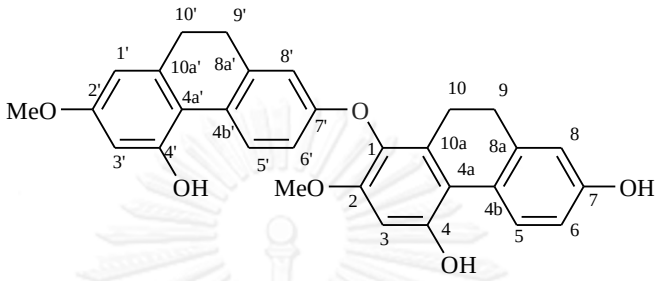
a ^{1}H NMR and ^{13}C NMR data from Guo et al.,2007

1.7 Structure determination of compound DV7

Compound DV7 was obtained as a brown powder. The IR spectrum (Figure 45) showed absorption bands at 3364 cm^{-1} for hydroxyl group, at 1615 and 1591 cm^{-1} for aromatic ring. The UV spectrum (Figure 44) exhibited absorptions at 212 and 278 nm, suggestive of a dihydrophenanthrene skeleton (Guo *et al*., 2006). It has a molecular formula $C_{30}H_{26}O_6$, as indicated by the $[M+Na]^{+}$ at *m/z* 505.1627 (calculated for 505.1627; $C_{30}H_{26}O_6Na$), suggesting that this compound was an isomer of DV6.

The ^{1}H NMR spectrum (Table 8 and Figure 47) showed four pairs of methylene protons at δ_H 2.62 (4H, br s, H_2-9, H_2-10) and δ_H 2.69 (4H, br s, H2-9', H2-10') which correlated with carbons at δ 22.9, 29.4 and at δ 29.7, 30.4, respectively, in the HSQC spectrum (Figure 50). The ^{13}C NMR, DEPT135 and HSQC spectra (Figures 48, 52) showed 30 carbon signals, corresponding to two methoxyls, four methylenes, nine aromatic methines, and fifteen quaternary carbons. For the first monomer unit, the ^{1}H NMR spectrum displayed proton signals similar to those of compound DV4 [157] (lusianthridin) with an ABM splitting system [δ_H 6.63 (1H, dd, *J* = 8.7, 2.7 Hz, H-6′), 6.68 (1H, d, *J* = 2.7 Hz, H-8′), 8.27 (1H, d, *J* = 8.7 Hz, H-5′], two *meta*-coupled proton signals at δ_H 6.39 (1H, d, *J* = 2.4 Hz, H-1′) and δ_H 6.44 (1H, d, *J* = 2.4 Hz, H-3′) and a methoxys at δ_H 3.75 (MeO-2′). The proton assignments were based on the analysis of HMBC (Figure 49) and NOESY (Figure 51) spectra. Important HMBC correlations were found between C-4a′ with H-1′, H-3′, H-5′ and H_2-10′. The assignment of H-1′ was based on its three-bond correlation with C-10′ in HMBC spectrum and its NOE cross-peak with H-10′ in NOESY spectrum. The methoxy was placed at C-2′ according to its NOESY correlation peaks with H-1′ and H-3′. The 1H NMR properties of the other dihydrophenenthrene unit also resembled these of DV4, except for the absence of two *meta*-coupled proton signals, with an ABM spinning systems at δ_H 6.71 (1H, d, *J* = 2.7, H-8), 6.74 (1H, dd, *J* = 8.4, 2.7, H-6), 8.29 (1H, d, *J* = 8.4, H-5) and a methoxyl at δ_H 3.72 (MeO-2). The presence of a singlet proton signal at δ_H 6.67, assignable to H-3 based on its HMBC correlations with C-4a and C-4, and oxygenated quaternary carbon signal at δ 132.9 suggested that the two monomeric units of DV4 should be connected by an ether linkage at C-7′ and C-1. The carbon signal at δ 132.9 was assigned to C-1 according to its HMBC correlations with H-3 and H_2-10. The methoxyl was located at C-2, as shown by its NOESY interaction with H-3. The NOESY correlation between H-8 and H_2-9 was also observed. Moreover, the HMBC spectrum also displayed correlations of C-4a with H-5 and H_2-10.

Compound DV7 [267] was identified as phoyunnanin E by analysis of its spectral data and comparison with previously reported data (Guo *et al*., 2006). This compound was first isolated *from Pholidota yunnanensis* (family Orchidaceae). In this study, phoyunnanin E was identified from the genus *Dendrobium* for the first time.



Phoyunnanin E [267]

Table 8 NMR spectral data of compound DV7 (acetone- d_6) and phoyunnanin E (acetone- d_6)

Position	Compound DV7			Phoyunnanin E [a]	
	δ_H (mult., *J* inHz)	δ_C	HMBC correlation with ^{1}H	δ_H (mult., *J* in Hz)	δ_C
1	-	132.9	H-3, H_2-10	-	133.9
2	-	151.0	2-OMe, H-3	-	152.0
3	6.67 (s)	99.8	-	6.68 (s)	100.8
4	-	151.7	H-3	-	152.6
4a	-	114.8	H-3, H-5, H_2-10	-	115.8
4b	-	124.6	H-6, H-8, H_2-9	-	125.6
5	8.29 (d, 8.4)	129.3	-	8.29 (d, 8.2)	130.2
6	6.74 (dd, 8.4, 2.7)	112.7	H-8	6.72 (dd, 8.2, 2.7)	113.6
7	-	155.5	H-5	-	156.4
8	6.71 (d, 2.7)	114.1	H-6, H_2-9	6.70 (d, 2.7)	115.0
8a	-	138.9	H-5, H_2-10	-	139.8
9	2.62 (br s)	29.4	H-8	2.62 (m)	30.0
10	2.62 (br s)	22.9	-	2.62 (m)	23.8
10a	-	133.1	H_2-9	-	134.0
1′	6.39 (d, 2.4)	105.0	H-3′, H_2-10′	6.38 (d, 2.5)	106.0
2′	-	158.6	H-1′, H-3, 2′-OMe	-	159.6
3′	6.44 (d, 2.4)	100.6	H-1′	6.43 (d, 2.5)	101.6
4′	-	155.2	H-3′	-	156.1
4a′	-	114.5	H-1′, H-3′, H-5′, H_2-10′	-	115.5
4b′	-	126.7	H-6′, H-8′, H_2-9′	-	127.6
5′	8.27 (d, 8.7)	128.8	-	8.26 (d, 8.7)	129.8
6′	6.63 (dd, 8.7, 2.7)	111.7	H-8′	6.64 (dd, 8.7, 2.8)	112.6
7′	-	156.8	H-5′	-	157.7
8′	6.68 (d, 2.7)	113.2	H-6′, H_2-9′	6.69 (d, 2.8)	114.2
8a′	-	138.8	H-5′, H_2-10′	-	139.7
9′	2.69 (br s)	29.7	H-8′	2.68 (m)	30.7
10′	2.69 (br s)	30.4	-	2.68 (m)	31.4
10a′	-	140.6	H_2-9′	-	141.6
2-OMe	3.72 (s)	55.1	-	3.72 (s)	56.0
2′-OMe	3.75 (s)	54.4	-	3.74 (s)	55.3

a ^{1}H NMR and ^{13}C NMR data from Guo *et al*., 2006

2. Antimalarial activity

Although pharmacological activities of compounds from *Dendrobium* spp. have been reported, there have been no report on the antimalarial activity of *Dendrobium venustum*.

In this study, the methanolic extract from the whole plant of *Dendrobium venustum* showed strong antimalarial activity against *Plasmodium falciparum* with IC_{50} 3.27 µg /ml. This extract was separated by vacuum liquid chromatography to yield eight fractions (A-H). Only fraction G showed antimalarial activity with an IC_{50} value of 2.60 µg/ml, therefore, a chemical investigation of this fraction was pursued. The chemical study of fraction G resulted in the isolation of seven known compounds. Each of these isolates was evaluated for its antimalarial activity and the results are summarized in Table 9. Dihydroartemisinin and mefloquine were used as positive controls.

Table 9 IC_{50} values for antimalarial activity, cytotoxicity to human fibroblast cells and SI of compounds from *Dendrobium venustum*

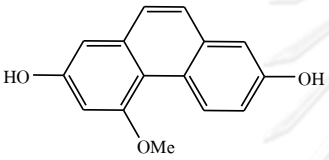
Compounds	Antimalarial activity		Cytotoxicity to human fibroblast cells		SI
	IC_{50} (µg/ml)	IC_{50} (µM)	IC_{50} (µg/ml)	IC_{50} (µM)	
Flavanthrinin DV1 [174]	NA	NA	ND	ND	ND
Gigantol DV2 [49]	3.35	12.22	> 100	> 364.96	> 29.86
Densiflorol B DV3 [146]	0.328	1.29	78.52	309.13	239.63
Lusianthridin DV4 [157]	NA	NA	ND	ND	ND
Batatasin III DV5 [25]	9.59	39.30	> 100	> 409.83	> 10.42
Phoyunnanin C DV6 [266]	2.80	5.80	30.42	60.35	10.40
Phoyunnanin E DV7 [267]	0.555	1.15	48.19	95.61	83.14
Dihydroartemisinin	-	0.0018	ND	ND	-
Mefloquine	-	0.0314	ND	ND	-

NA = no activity (<50% inhibition of parasite growth at 10 µg/ml).

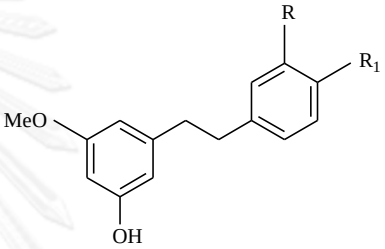
ND = not determined.

SI (selectivity index) = IC_{50} (cytotoxicity to human fibroblast cells)/ IC_{50} (growth inhibition of *P. falciparum*).

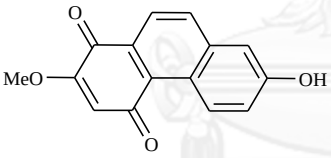
From Table 9, it can be seen that among the isolates, compounds DV7 and DV3 showed the strongest antimalarial activity with IC_{50} values of 1.15 and 1.29 μM, respectively. Compounds DV2, DV5 and DV6 showed lower antimalarial activity with IC_{50} values of 12.22, 39.30, 5.80 μM, respectively. Dihydroartemisinin and mefloquine were used as positive controls with the IC_{50} values of 0.0018 and 0.0314 μM, respectively. The 1,4-napthoquinone skeleton of DV3 is most likely important for activity, as there are many reports of 1,4-napthoquinone that show antimalarial activity (Likhitwitayawuid *et al*., 1998, Kapadia *et al*., 2001). It should be noted that the dimeric phenanthrenes DV6 and DV7 were active but the monomer DV4 was devoid of activity.



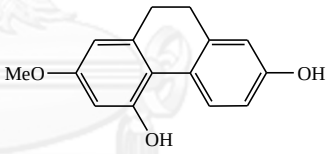
DV1 [174]



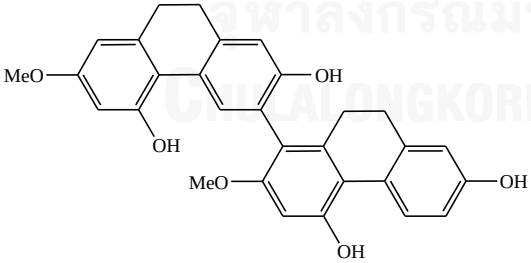
	R	R1
DV2 [49]	OMe	OH
DV5 [25]	OH	H



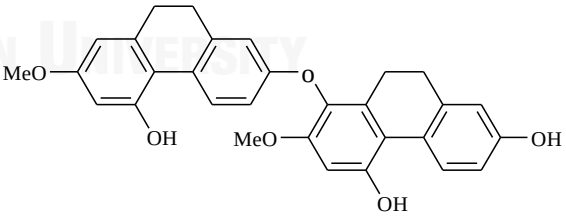
DV3 [146]



DV4 [157]



DV6 [266]



DV7 [267]

3. Cytotoxicity against human skin fibroblast cells

The compounds that showed antimalarial potential were evaluated for cytotoxicity against human skin fibroblast cell by the bioassay laboratory of National Center for Genetic Engineering and Biotechnology (BIOTEC). The results are summarized in Table 9.

Based on the % cell survival of each test concentration, the toxicity of sample can be indicated as follows:

a) Non-cytotoxic effect if cell survived >50%

b) Cytotoxic effect if cell survived ≤50%.

From Table 9, the results showed that DV 2, DV 3 and DV 5 were non-cytotoxic to human skin fibroblast cells. Then, the selectivity index of each compound was calculated.

4. Selectivity index (SI)

The selectivity index was calculated as the ratio of IC_{50} (cytotoxicity against human fibroblast) with IC_{50} (growth inhibition of *P. falciparum*)

$$SI = \frac{IC_{50} \text{ (cytotoxicity against human fibroblast)}}{IC_{50} \text{ (growth inhibition of } P. falciparum)}$$

From Table 9, compounds DV3 and DV7 exhibited a selective antimalarial activity with SI values of 239.63 and 83.14. Compounds DV2, DV5 and DV6 showed SI values ranging from 10.40 to 29.86.

CHAPTER V

CONCLUSION

Seven pure compounds were isolated from the methanol extract of Dendrobium venustum. They were characterized as flavanthrinin, gigantol, densiflorol B, lusianthridin, batatasin III, phoyunnanin C and phoyunnanin E. These compounds were evaluated for antimalarial activity. Gigantol, densiflorol B, batatasin III, phoyunnanin C and phoyunnanin E showed moderate antimalarial activity. Densiflorol B and phoyunnanin E possessed selective antimalarial effect with high SI values. Furthermore, phoyunnanin C and phoyunnanin E were isolated from the genus *Dendrobium* for the first time. The chemical data obtained in this study should be useful for the chemotaxonomic study of plants in the genus *Dendrobium*, whereas the information on the antimalarial potential of the isolated compounds should provide lead structures for the future development of antiplasmodial agents.

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APPENDIX

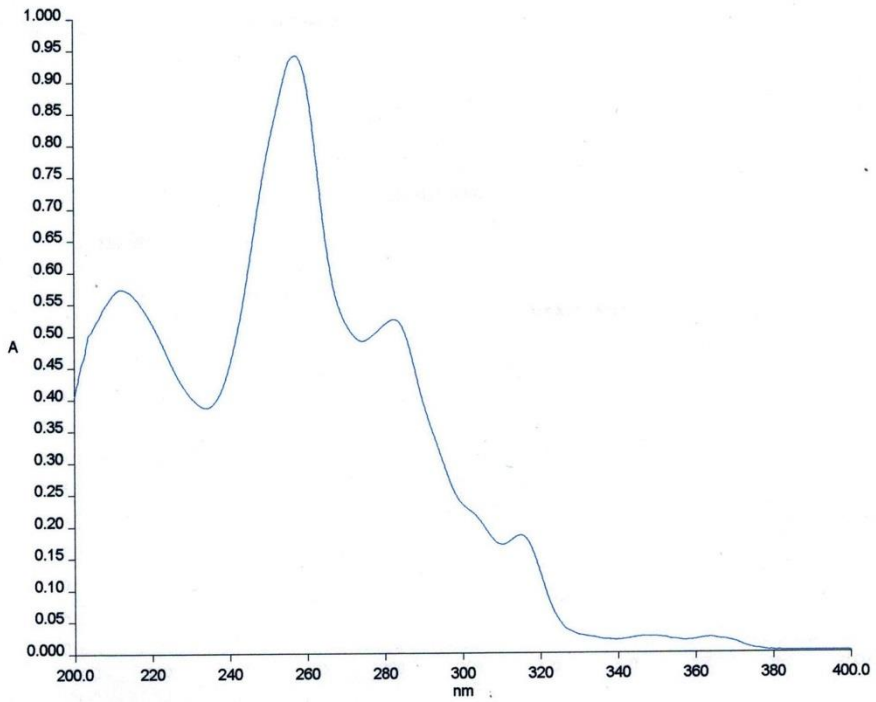

Figure 3 UV Spectrum of compound DV1 (MeOH)

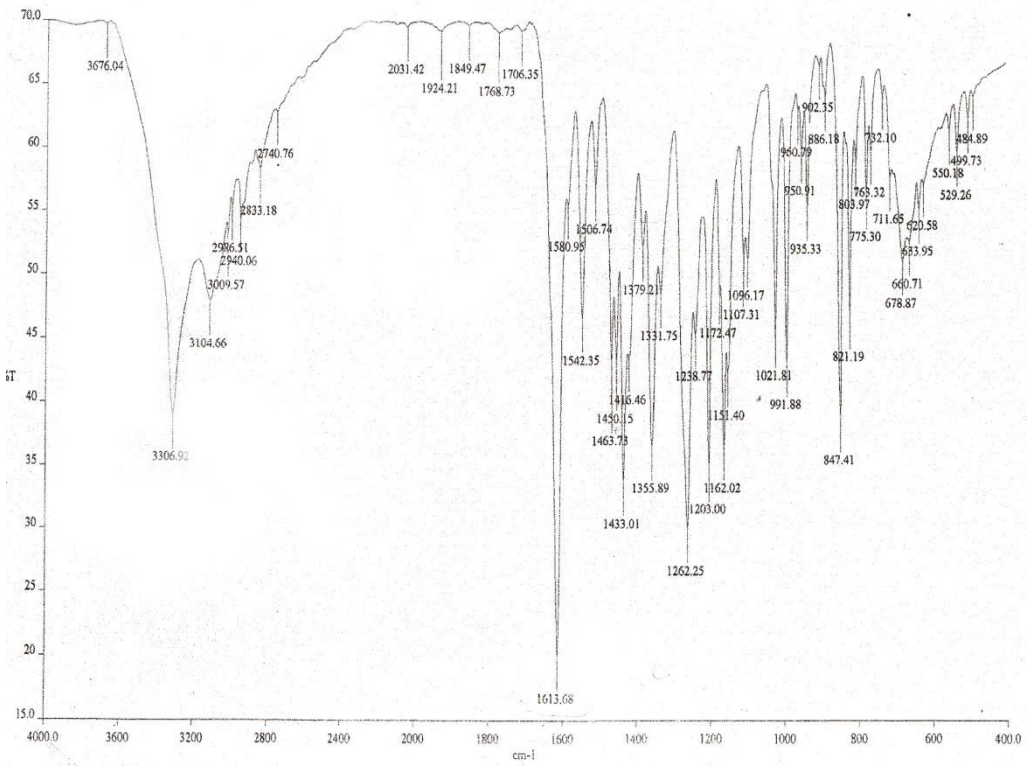

Figure 4 IR Spectrum of compound DV1

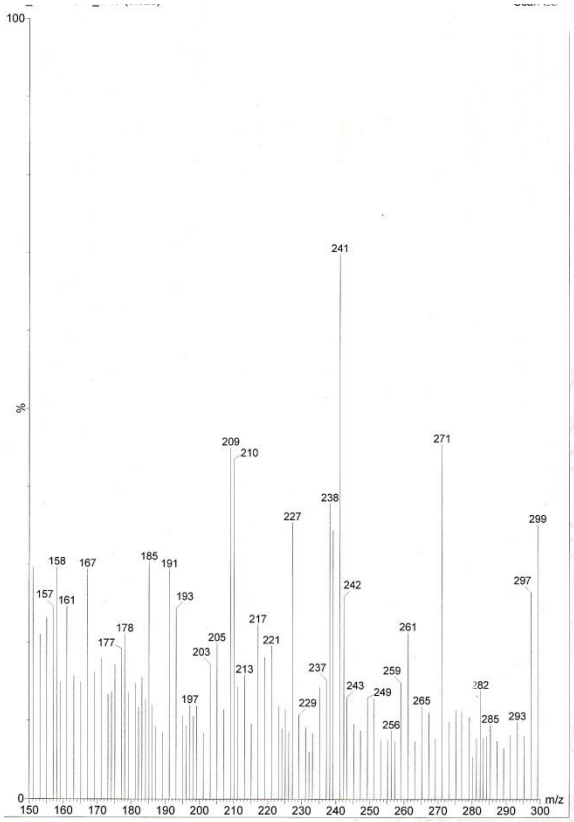

Figure 5 Mass spectrum of compound DV1

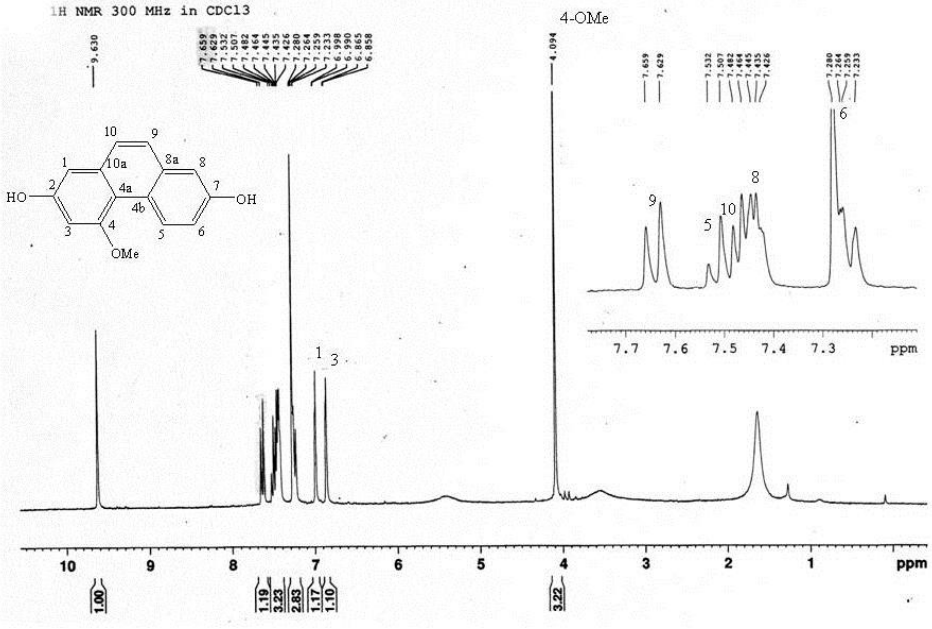

Figure 6 ^{1}H-NMR (300 MHz) Spectrum of compound DV1 ($CDCl_3$)

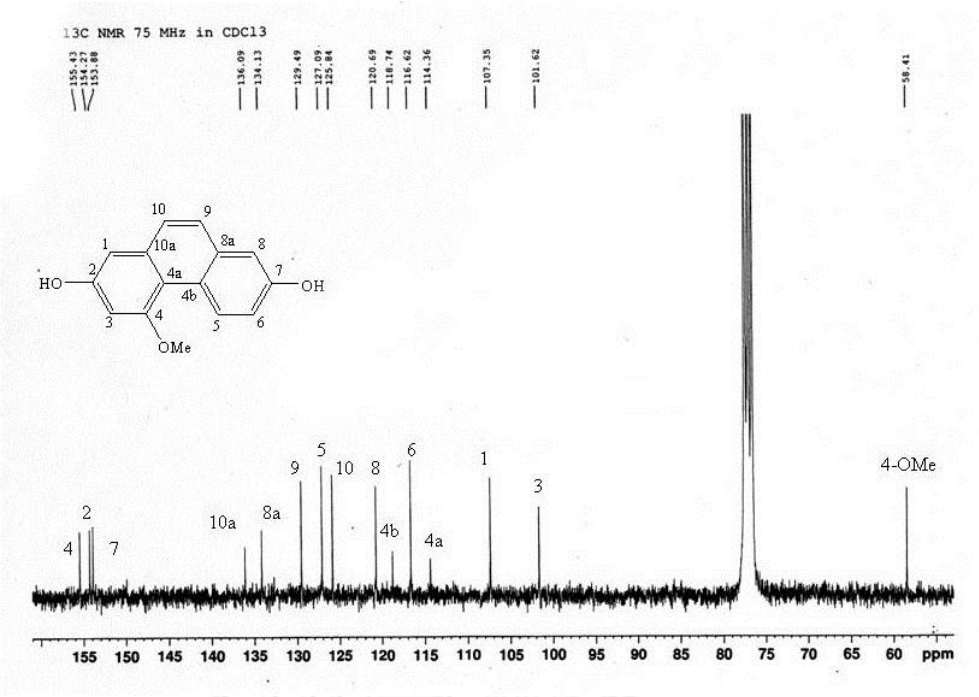

Figure 7 ^{13}C-NMR (75 MHz) Spectrum of compound DV1 ($CDCl_3$)

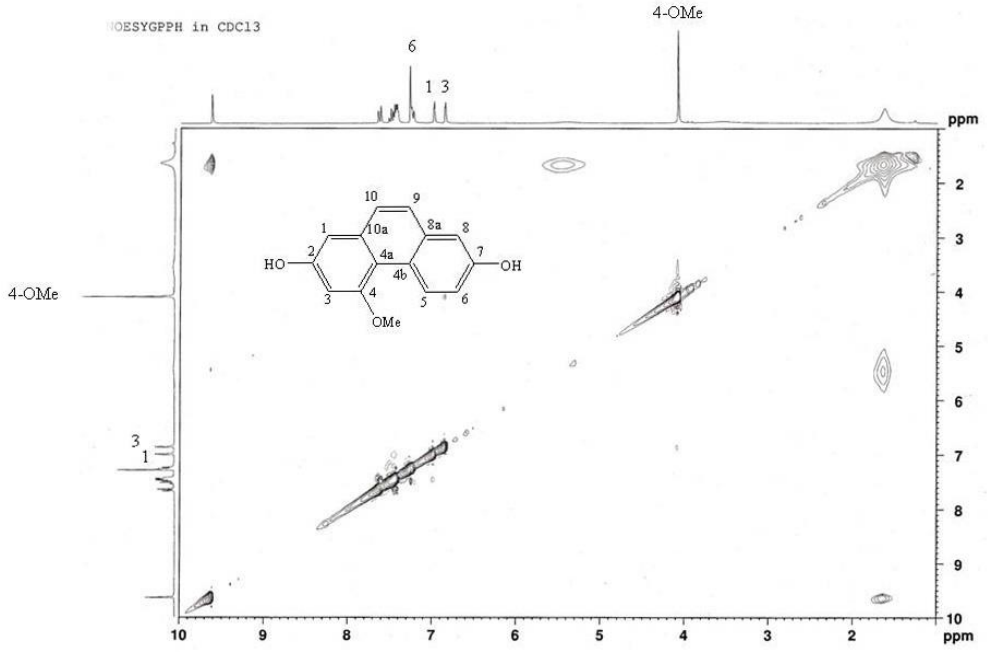

Figure 8 NOESY Spectrum of compound DV1 ($CDCl_3$)

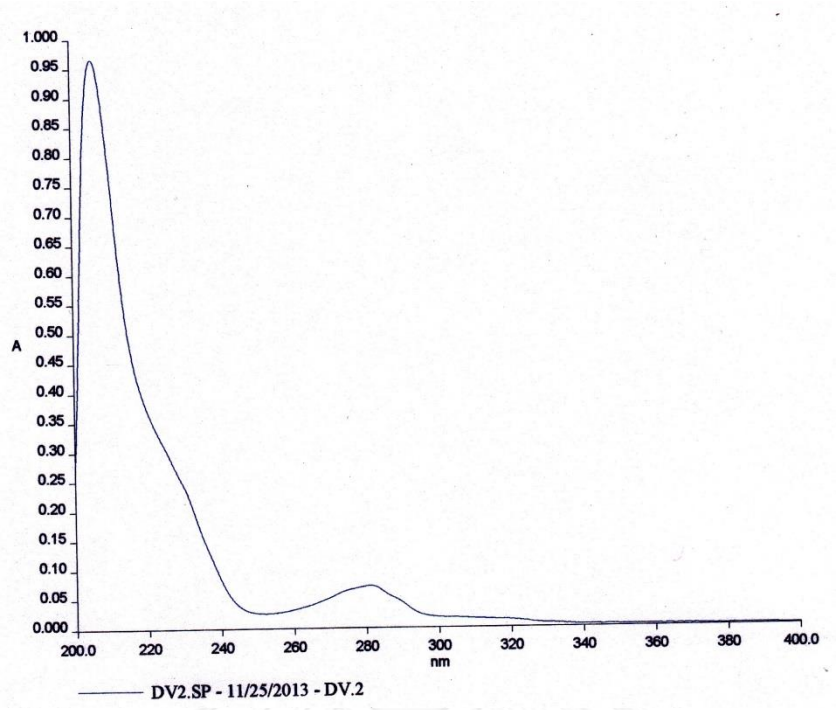

Figure 9 UV Spectrum of compound DV2 (MeOH)

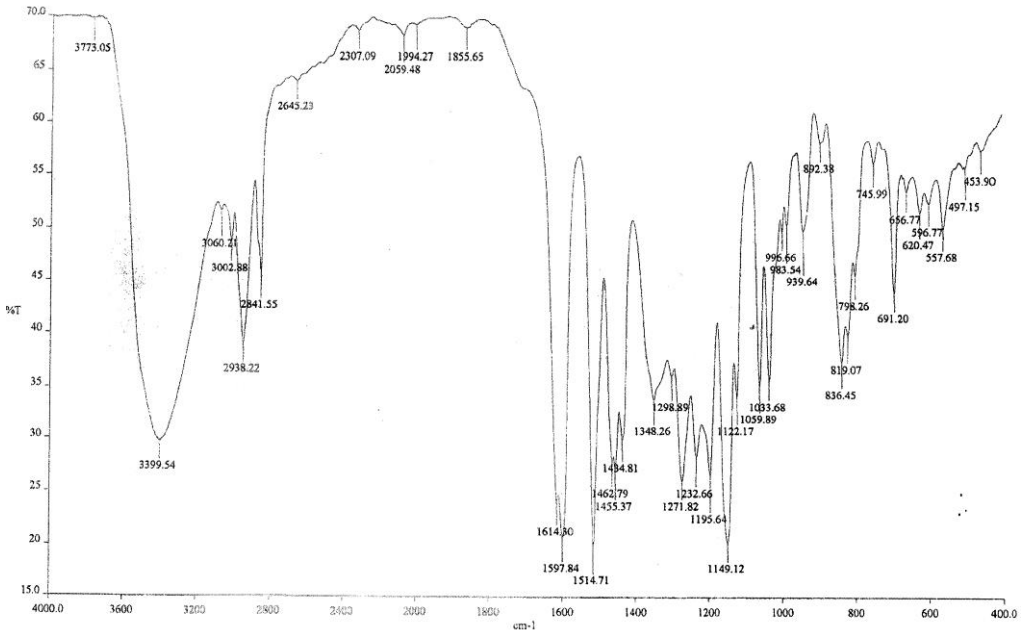

Figure 10 IR Spectrum of compound DV2

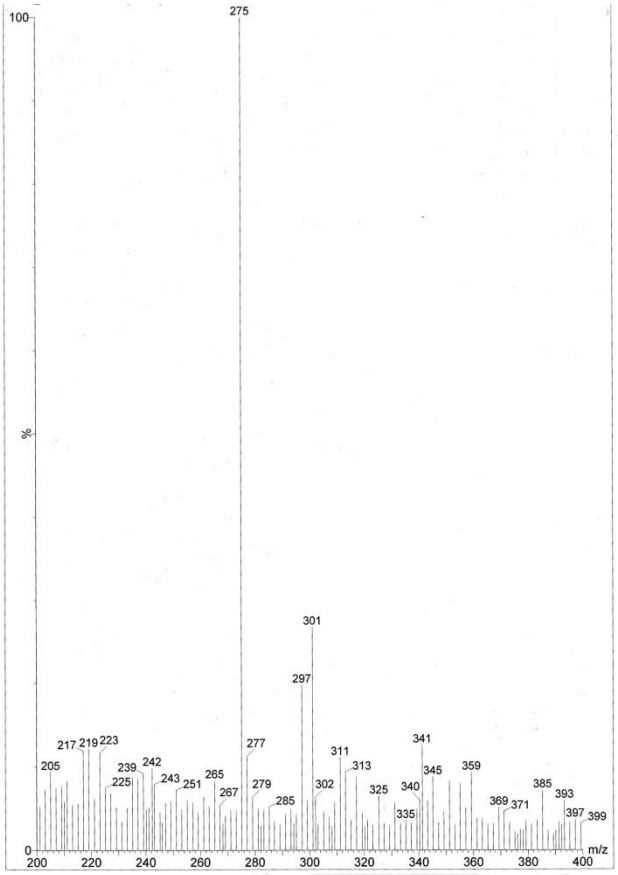

Figure 11 Mass spectrum of compound DV2

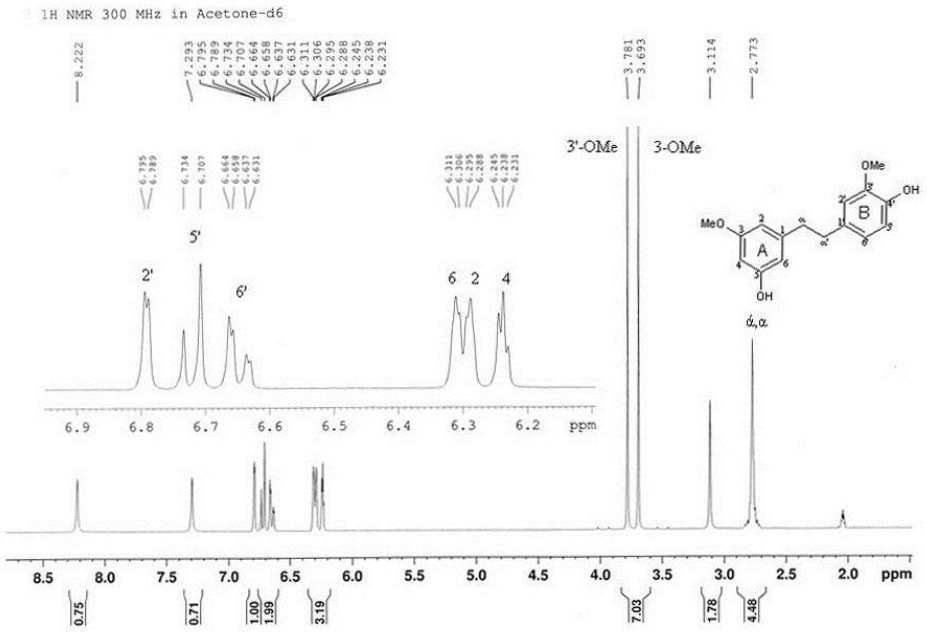

Figure 12 ^{1}H-NMR (300 MHz) Spectrum of compound DV2 (acetone-d_6)

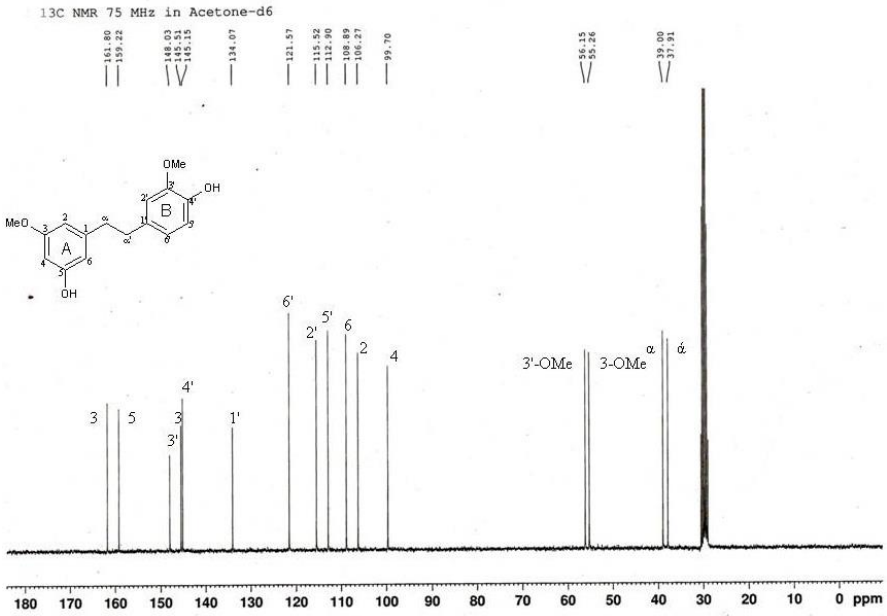

Figure 13 ^{13}C-NMR (75 MHz) Spectrum of compound DV2 (acetone-d_6)

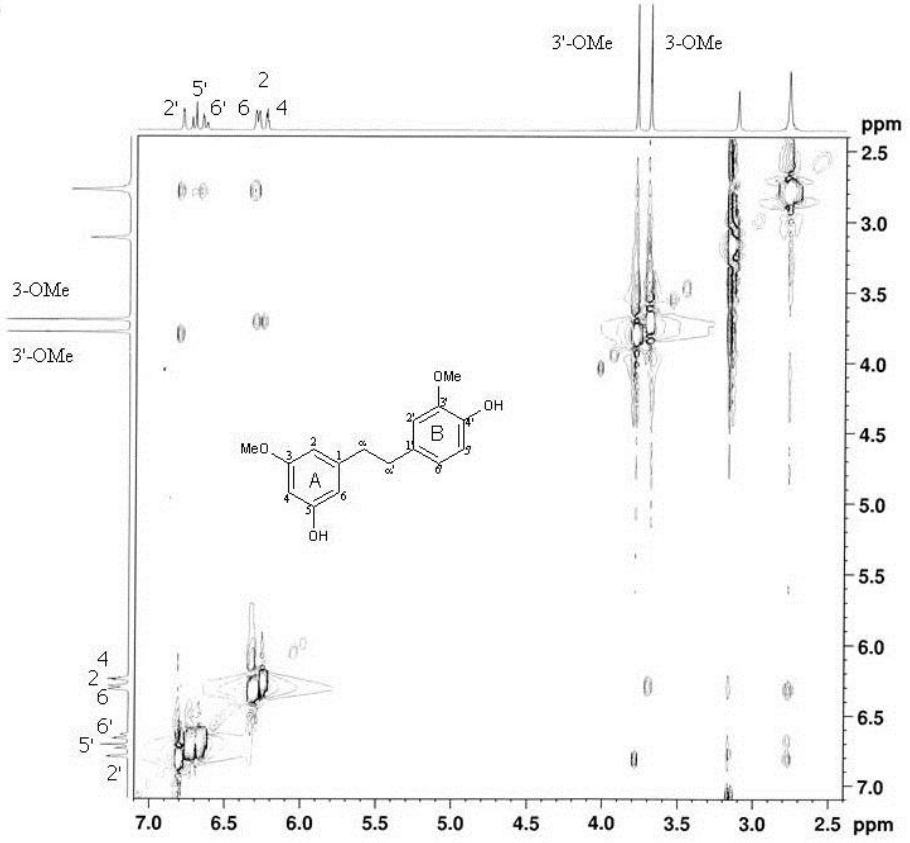

Figure 14 NOESY Spectrum of compound DV2 (acetone-d_6)

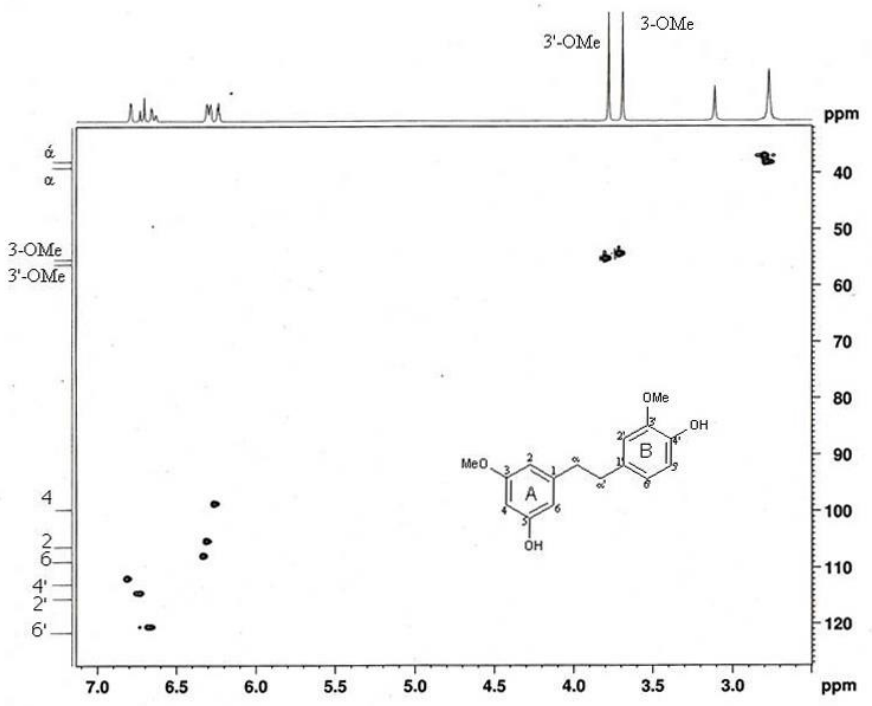

Figure 15 HSQC Spectrum of compound DV2 (acetone-d_6)

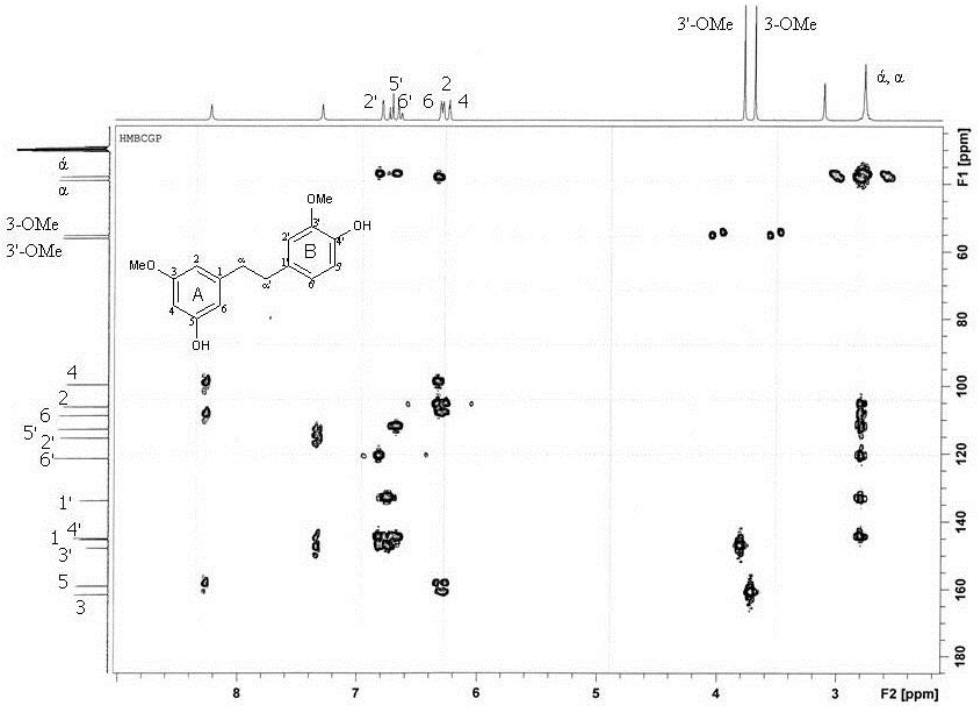

Figure 16 HMBC Spectrum of compound DV2 (acetone-d_6)

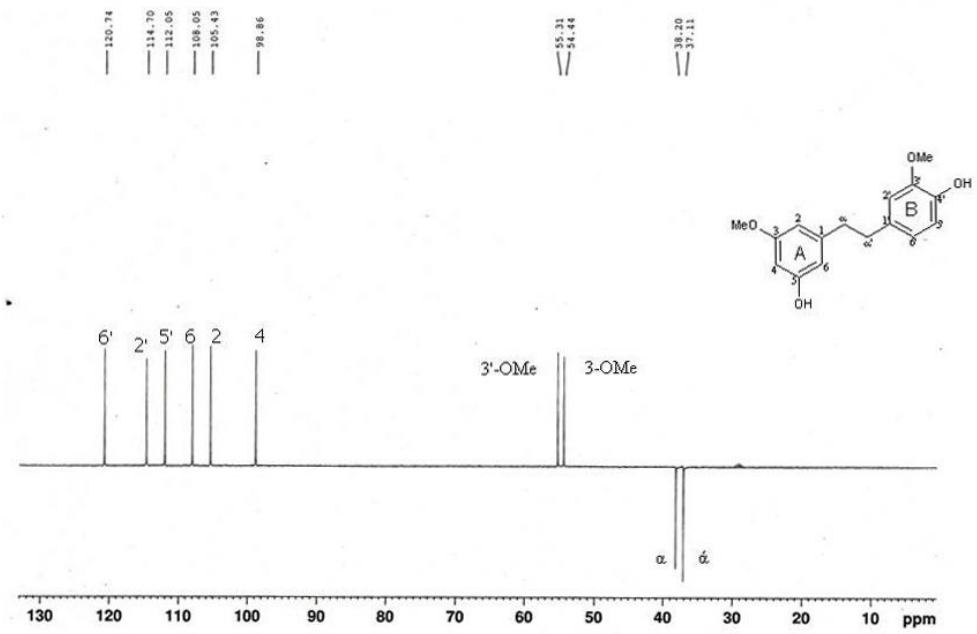

Figure 17 DEPT135 Spectrum of compound DV2 (acetone-d_6)

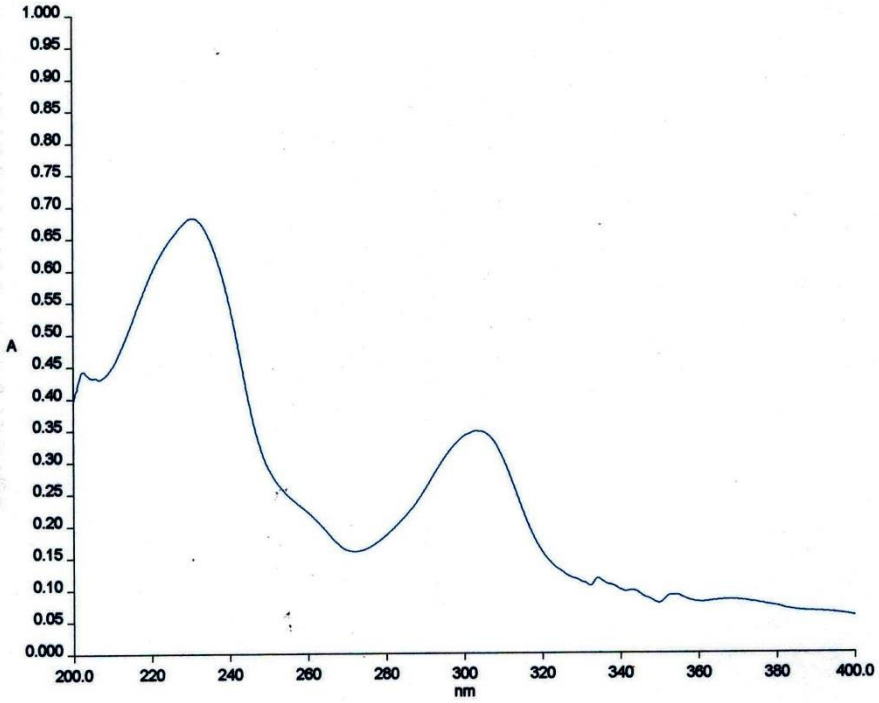

Figure 18 UV Spectrum of compound DV3 (MeOH)

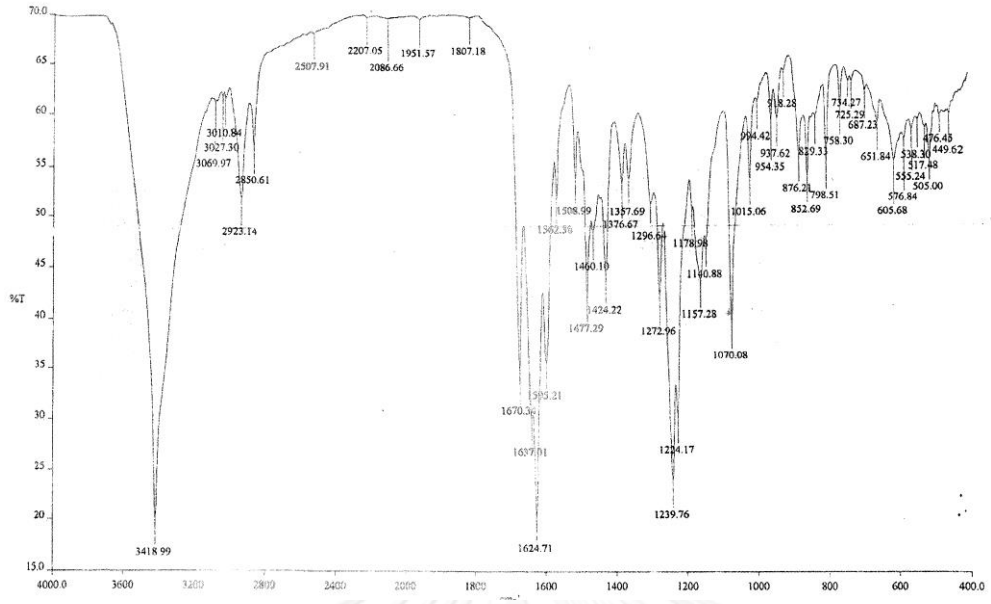

Figure 19 IR Spectrum of compound DV3

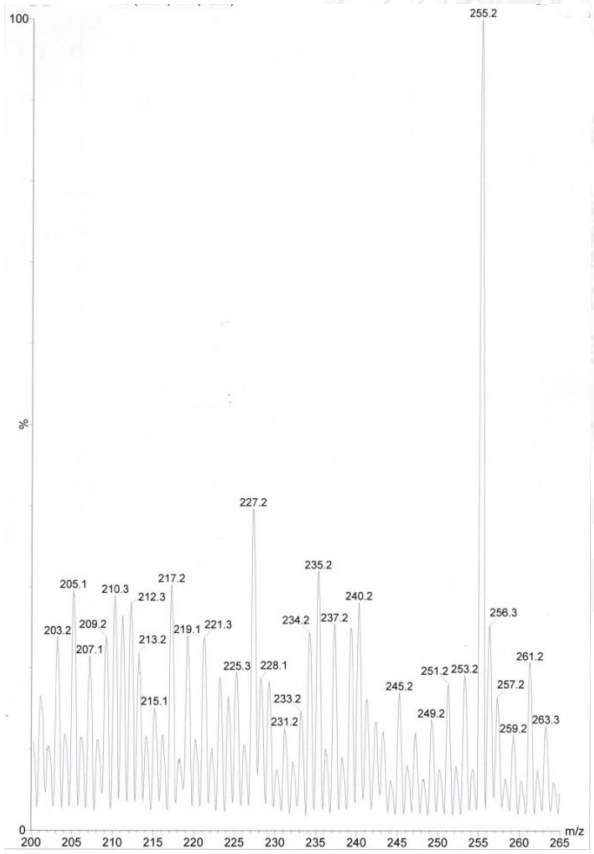

Figure 20 Mass spectrum of compound DV3

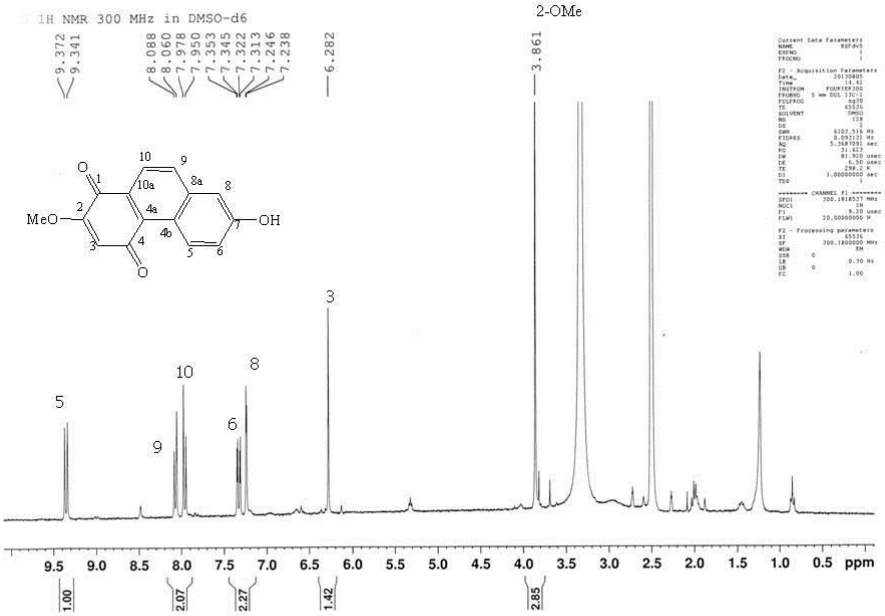

Figure 21 ^{1}H-NMR (300 MHz) Spectrum of compound DV3 (DMSO-d_6)

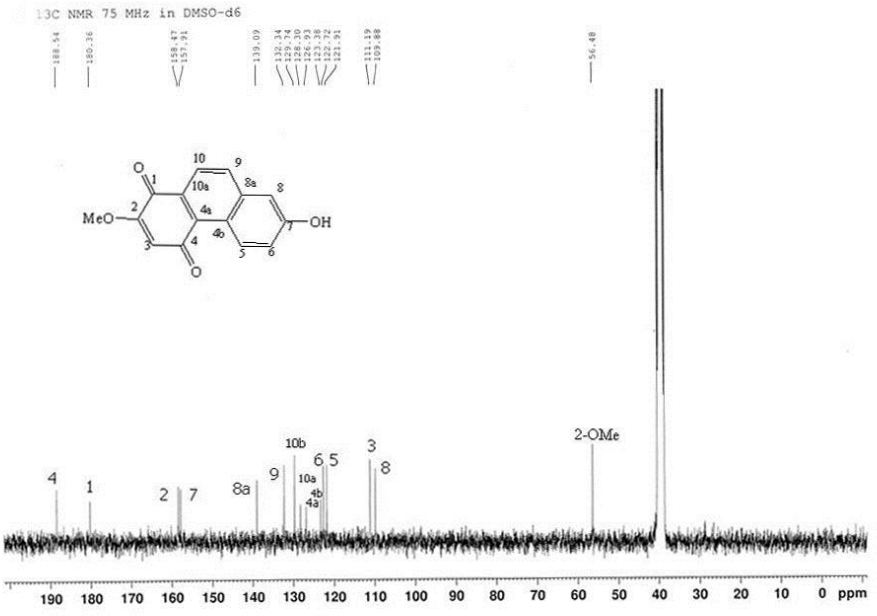

Figure 22 ^{13}C-NMR (75 MHz) Spectrum of compound DV3 (DMSO-d_6)

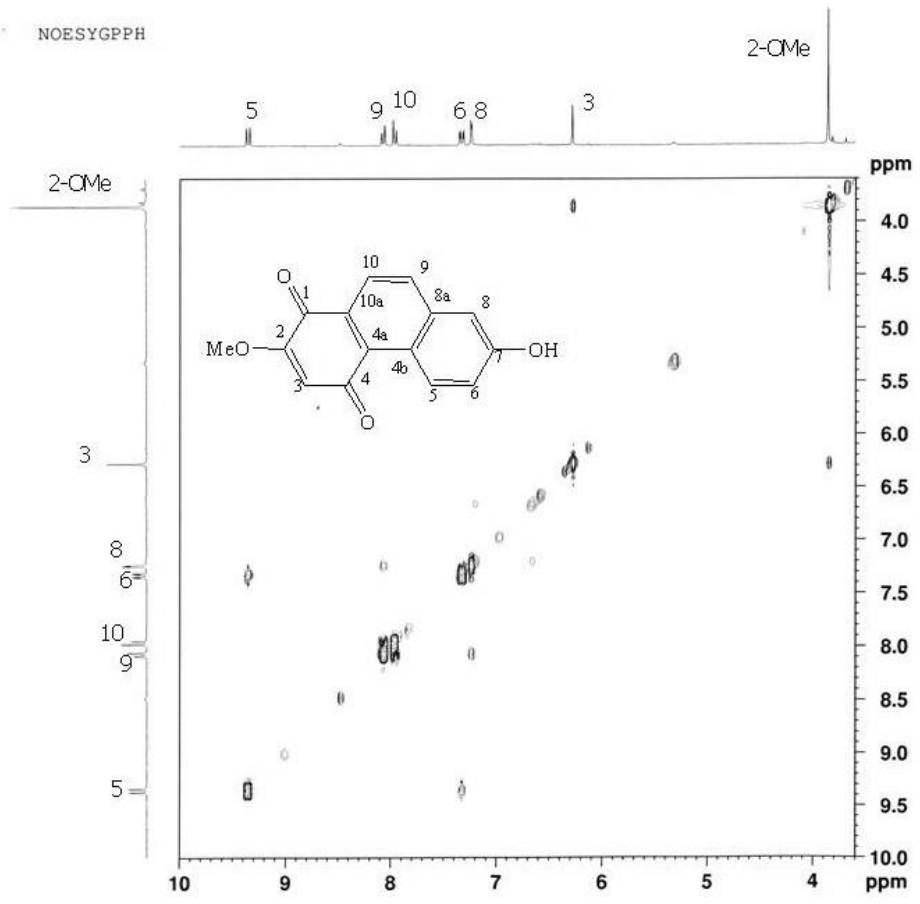

Figure 23 NOESY Spectrum of compound DV3 (DMSO-d_6)

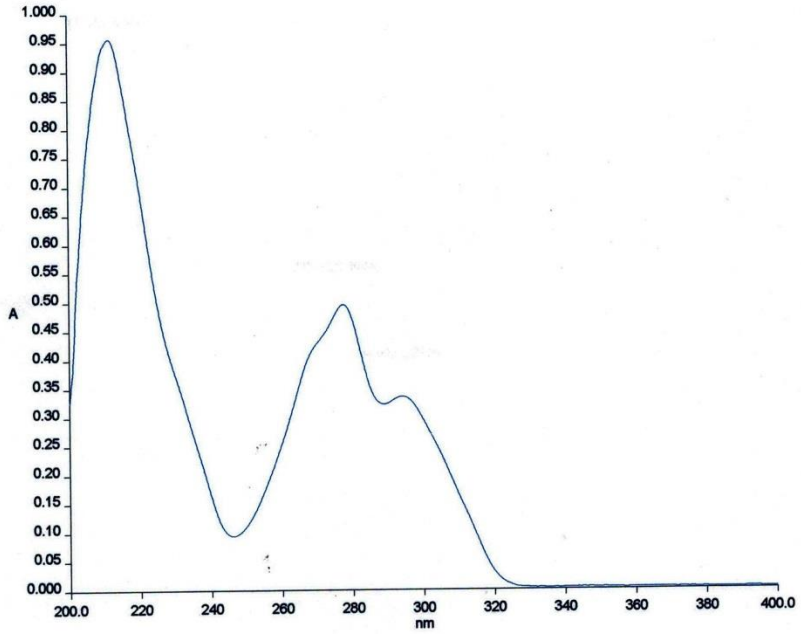

Figure 24 UV Spectrum of compound DV4 (MeOH)

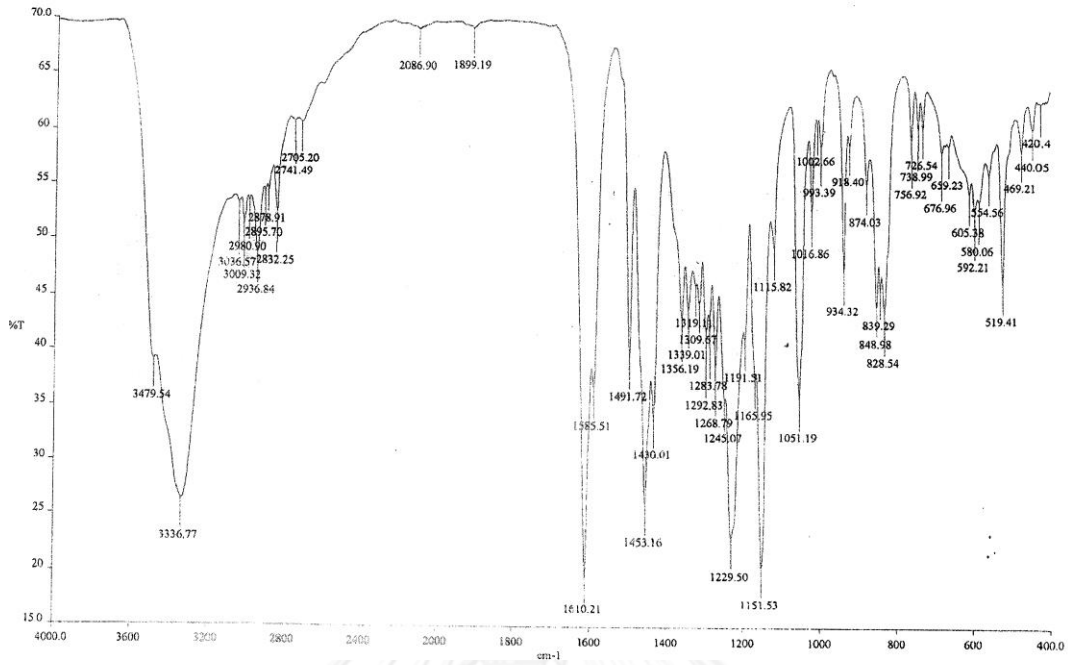

Figure 25 IR Spectrum of compound DV4

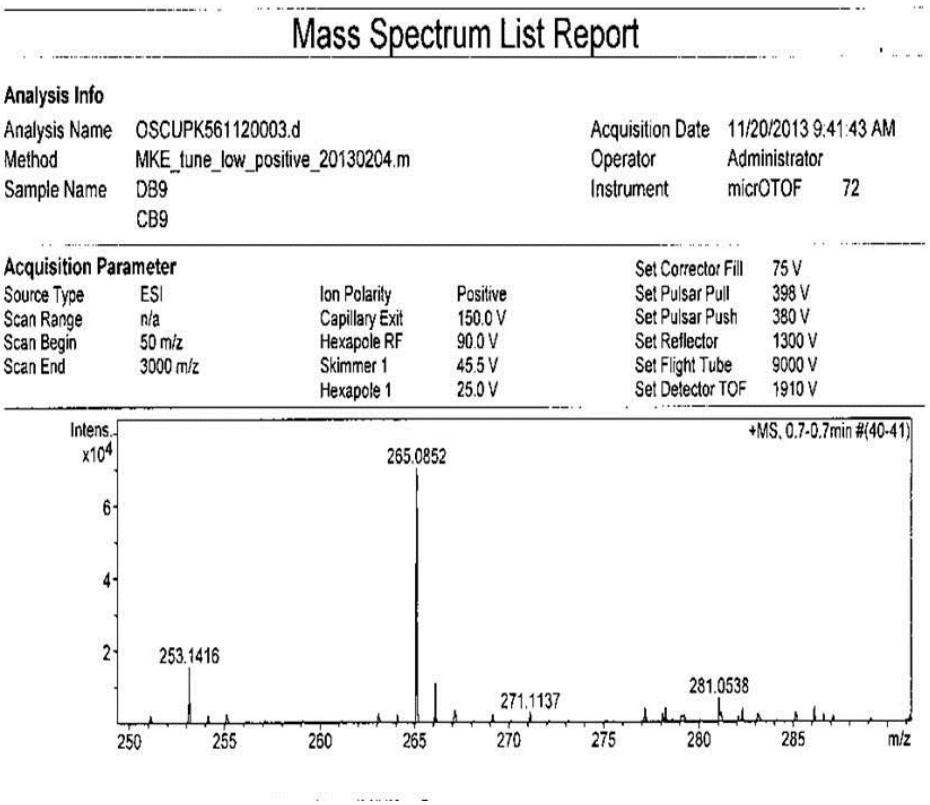

Figure 26 Mass spectrum of compound DV4

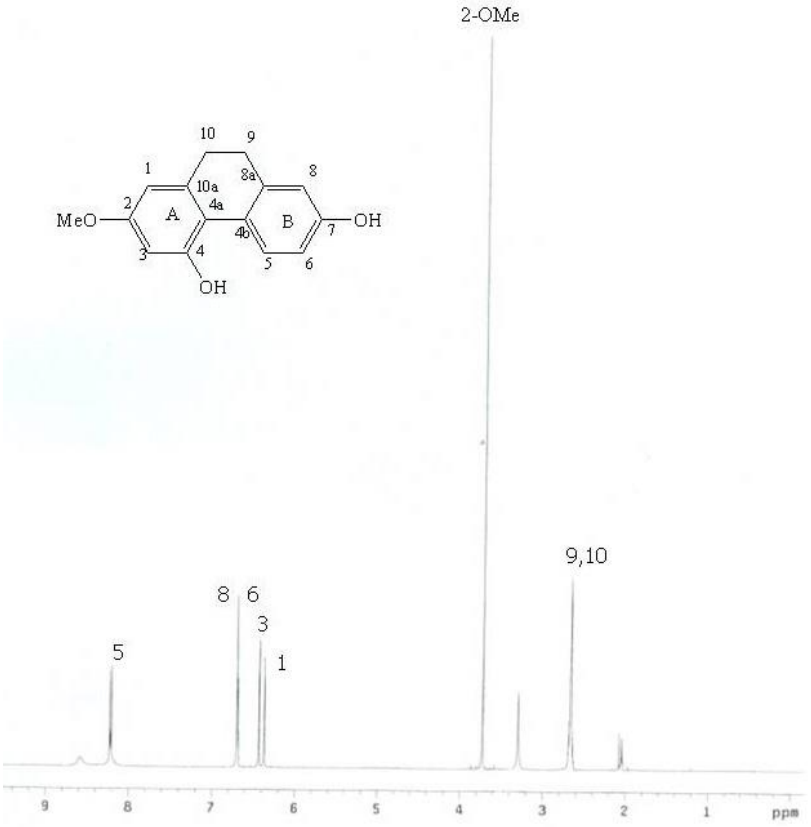

Figure 27 ^{1}H-NMR (300 MHz) Spectrum of compound DV4 (acetone-d_6)

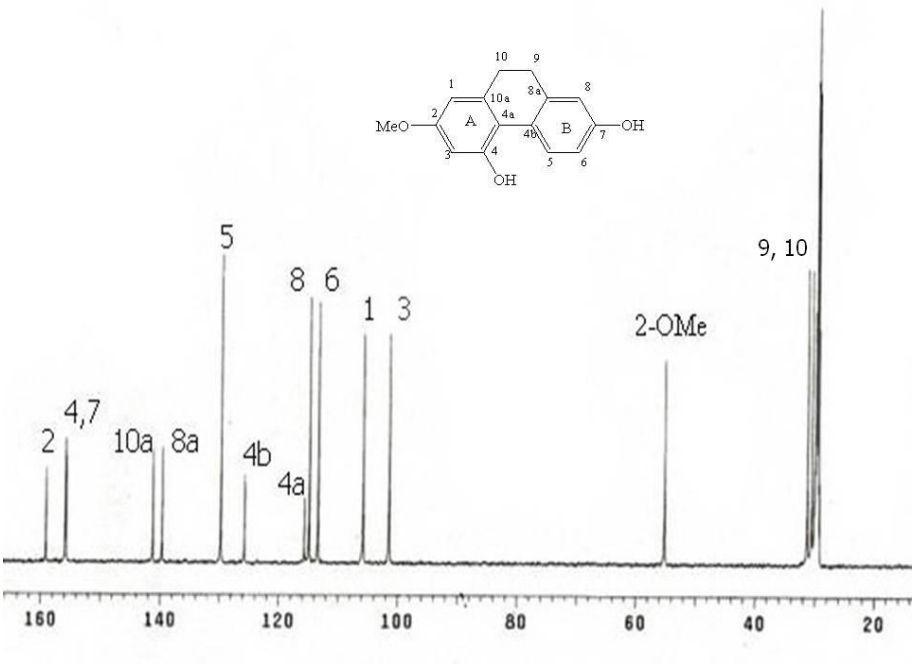

Figure 28 ^{13}C-NMR (75 MHz) Spectrum of compound DV4 (acetone-d_6)

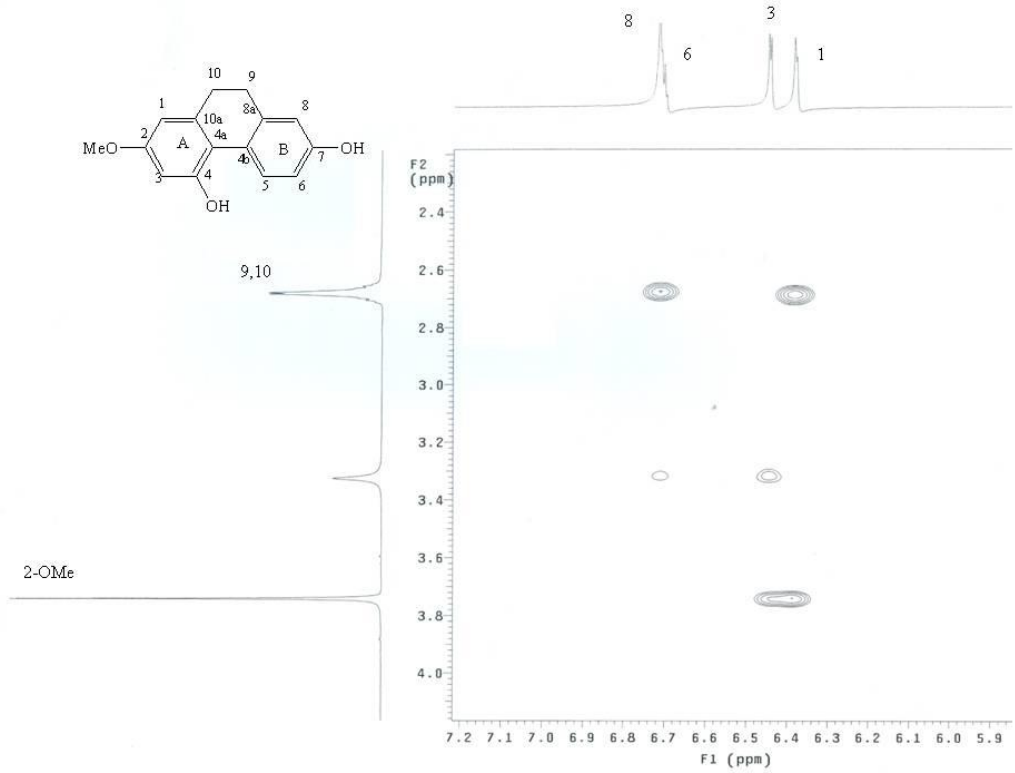

Figure 29 NOESY Spectrum of compound DV4 (acetone-d_6)

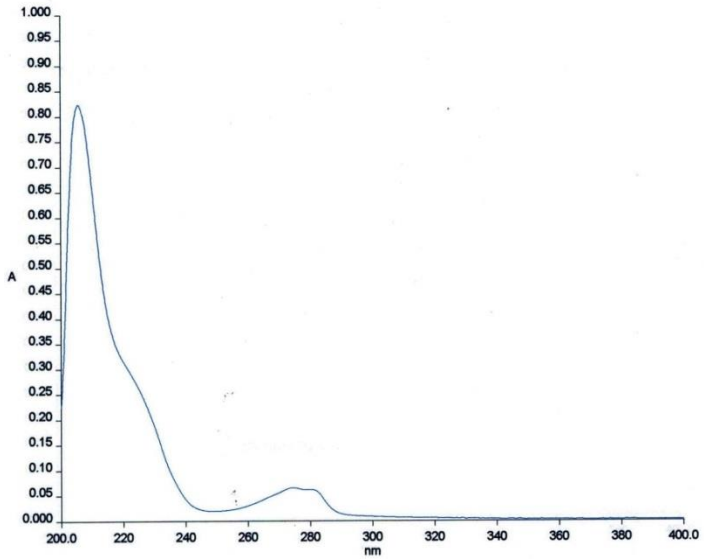

Figure 30 UV Spectrum of compound DV5 (MeOH)

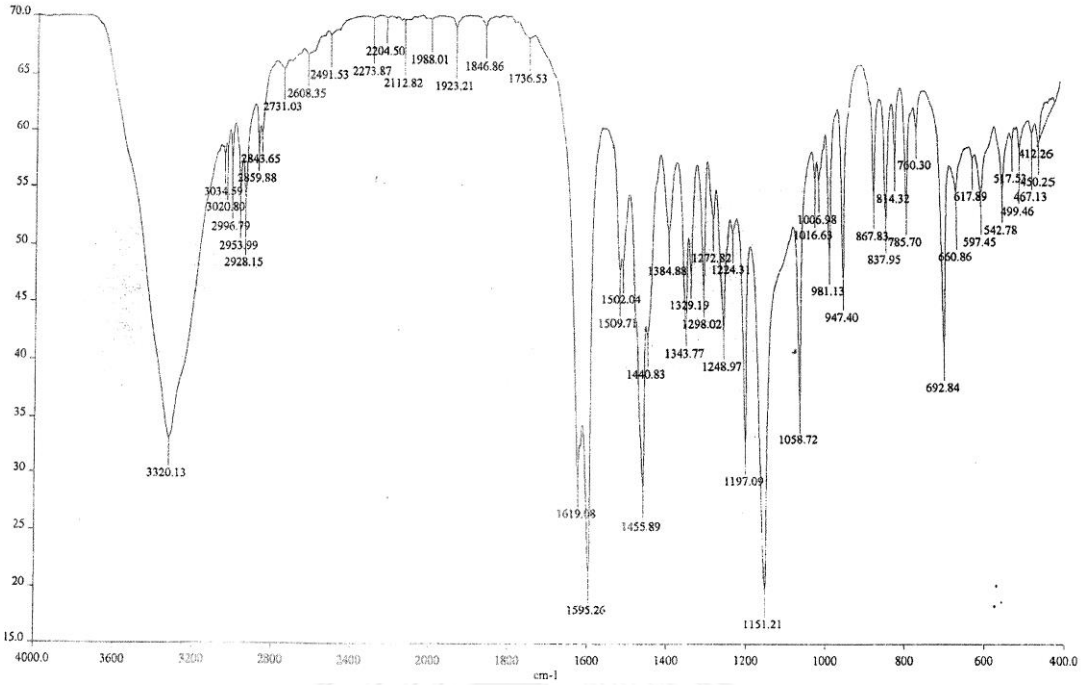

Figure 31 IR Spectrum of compound DV5

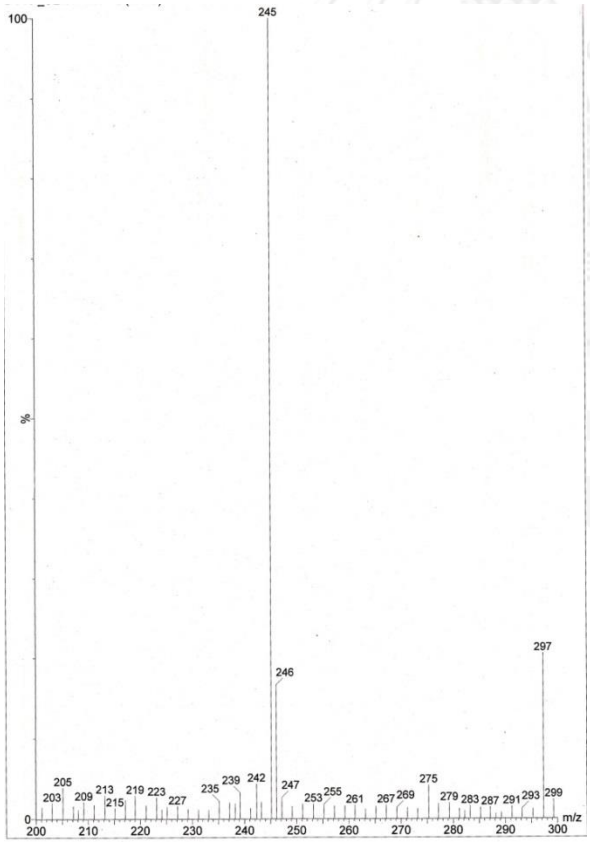

Figure 32 Mass spectrum of compound DV5

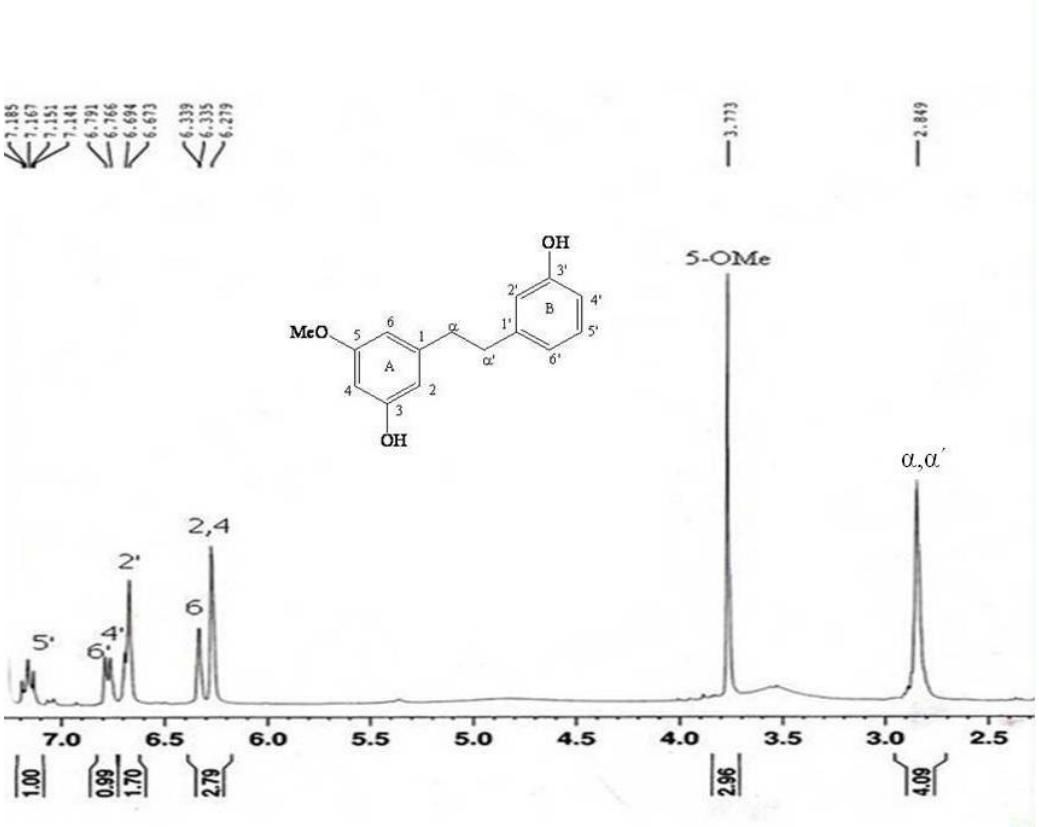

Figure 33 ^{1}H-NMR (300 MHz) Spectrum of compound DV5 ($CDCl_3$)

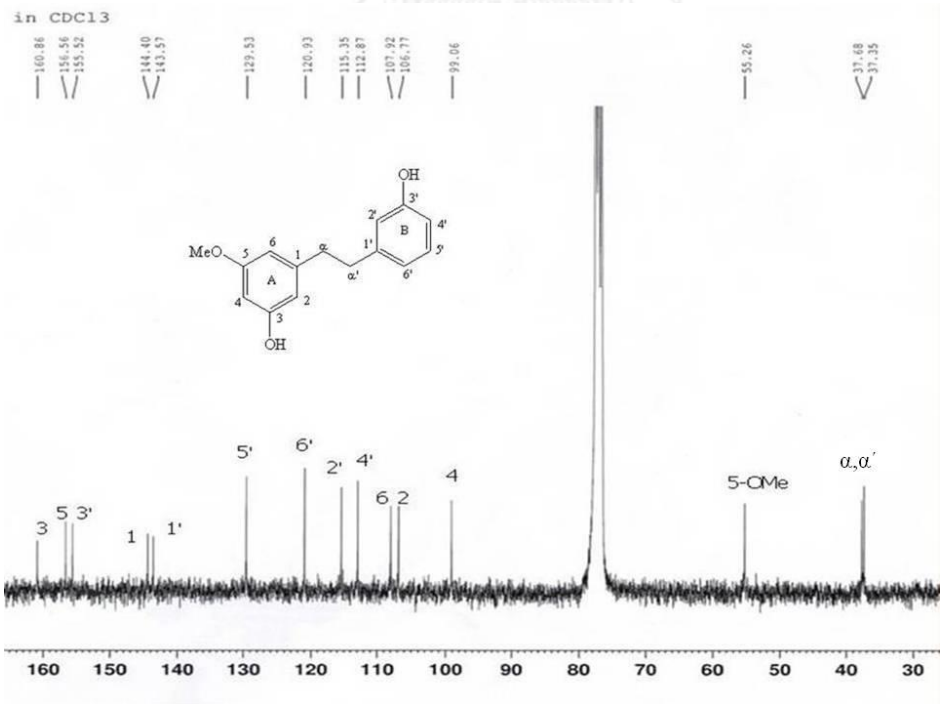

Figure 34 ^{13}C-NMR (75 MHz) Spectrum of compound DV5 ($CDCl_3$)

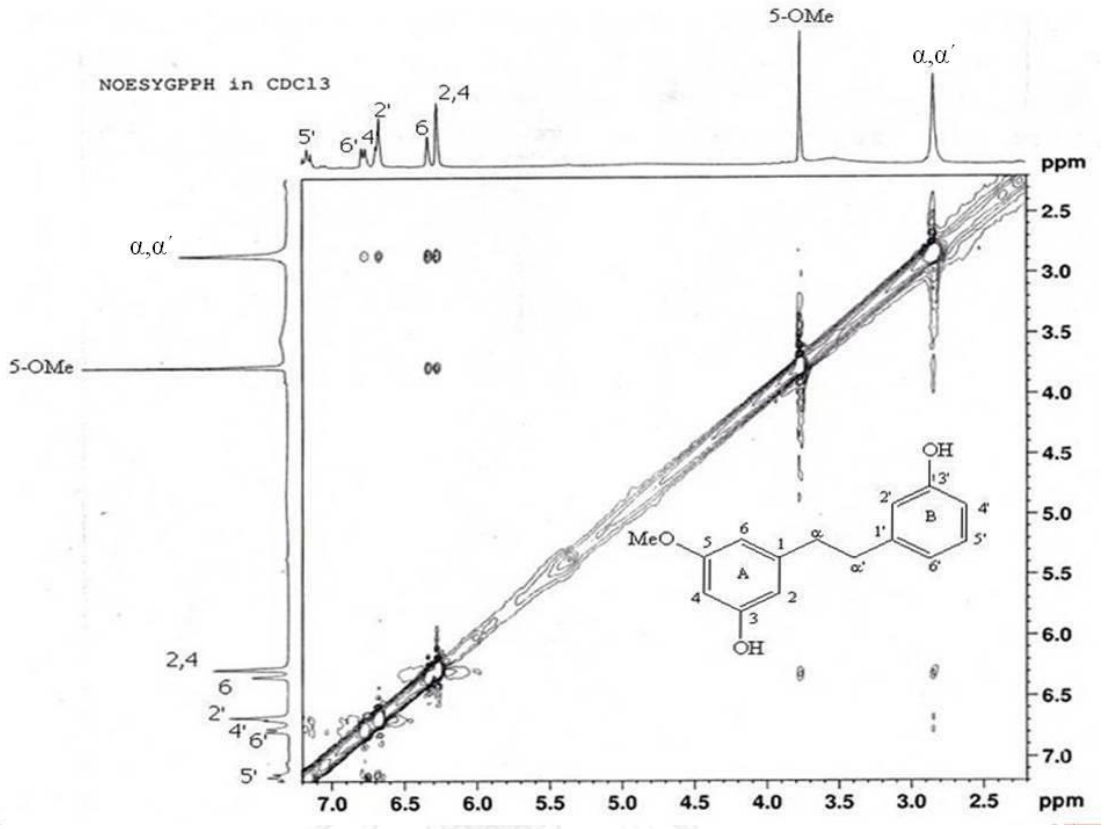

Figure 35 NOESY Spectrum of compound D DV5 ($CDCl_3$)

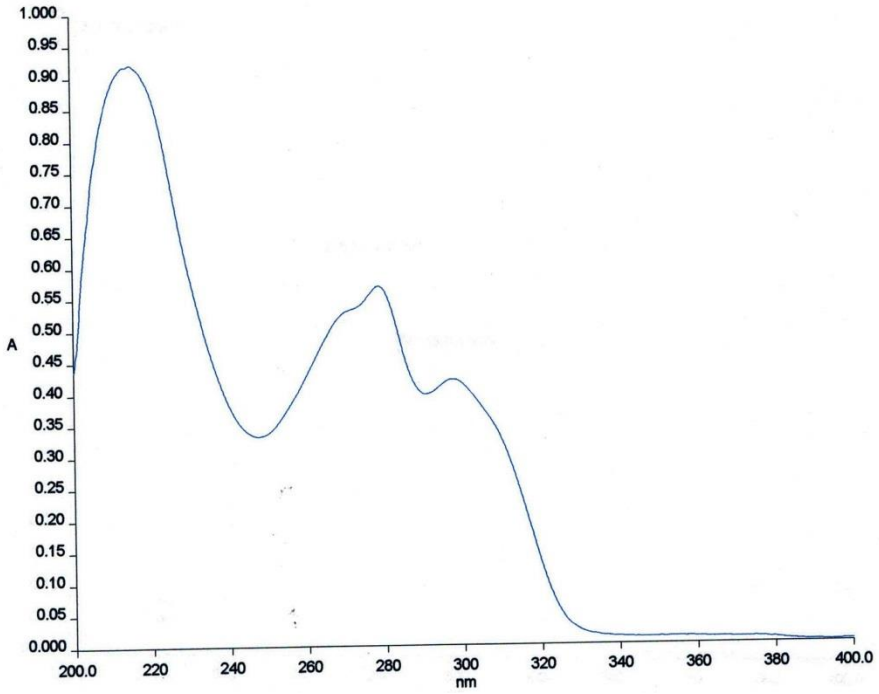

Figure 36 UV Spectrum of compound DV6 (MeOH)

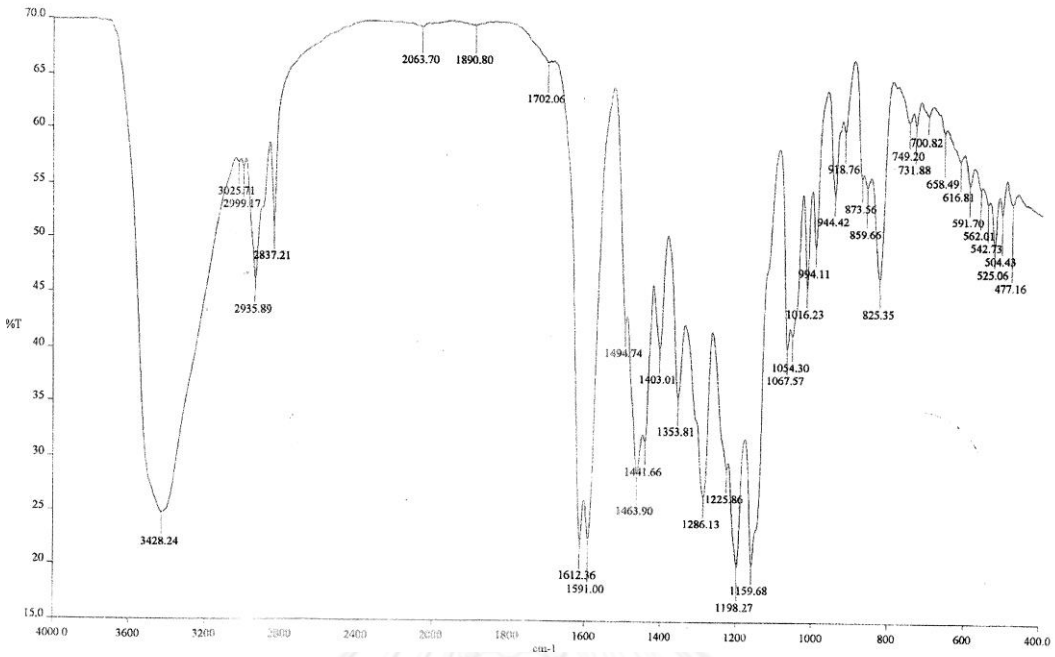

Figure 37 IR Spectrum of compound DV6

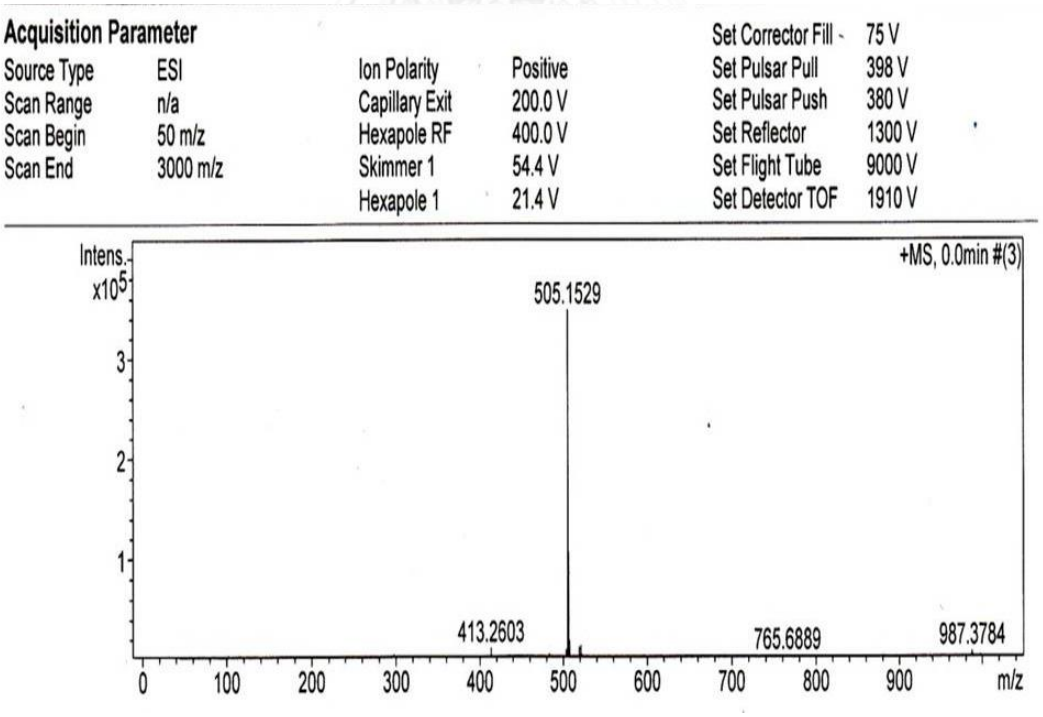

Figure 38 Mass spectrum of compound DV6

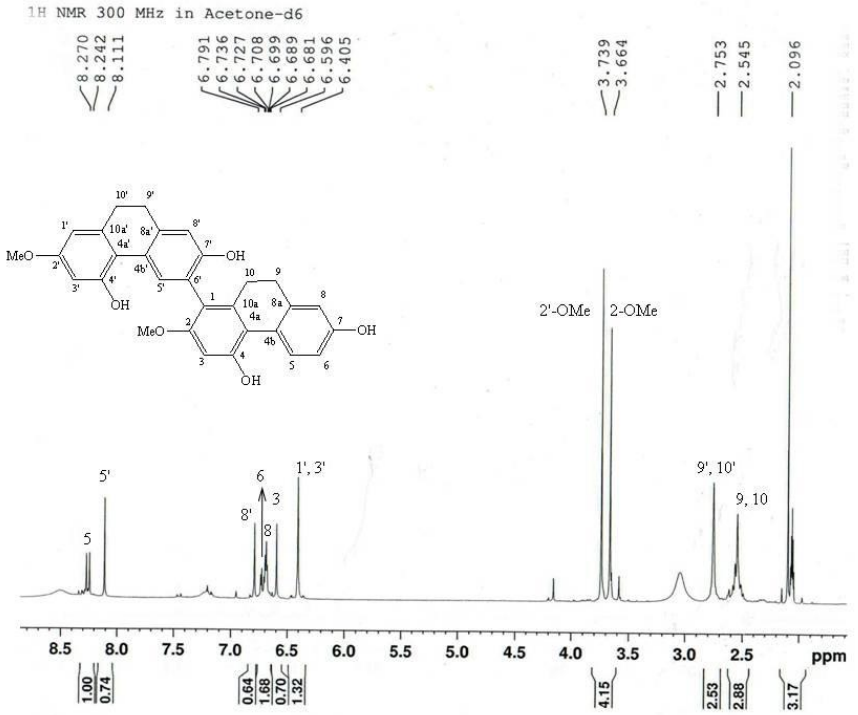

Figure 39 ^{1}H-NMR (500 MHz) Spectrum of compound DV6 (acetone-d_6)

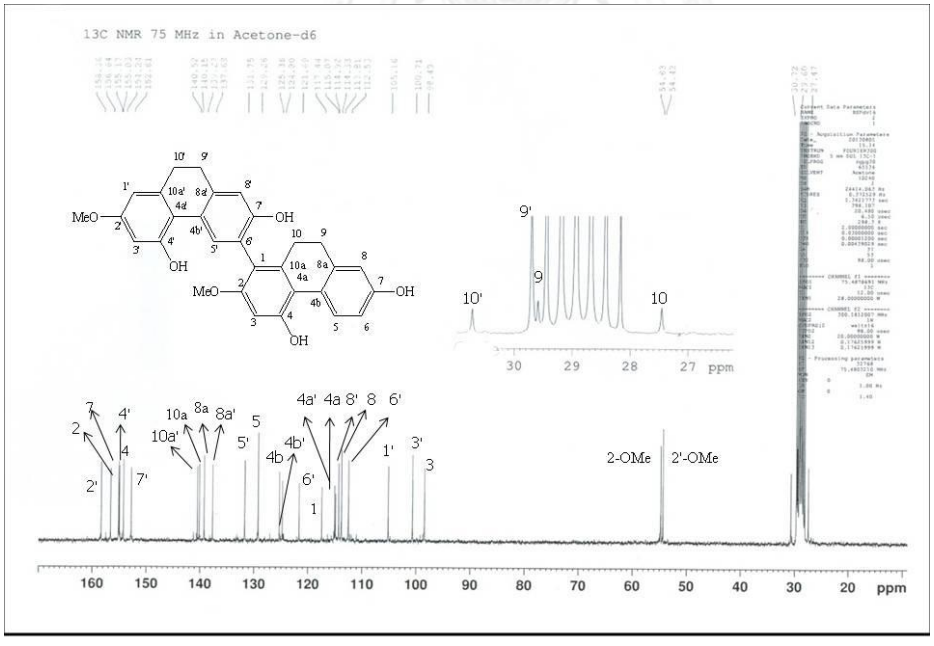

Figure 40 ^{13}C-NMR (125 MHz) Spectrum of compound DV6 (acetone-d_6)

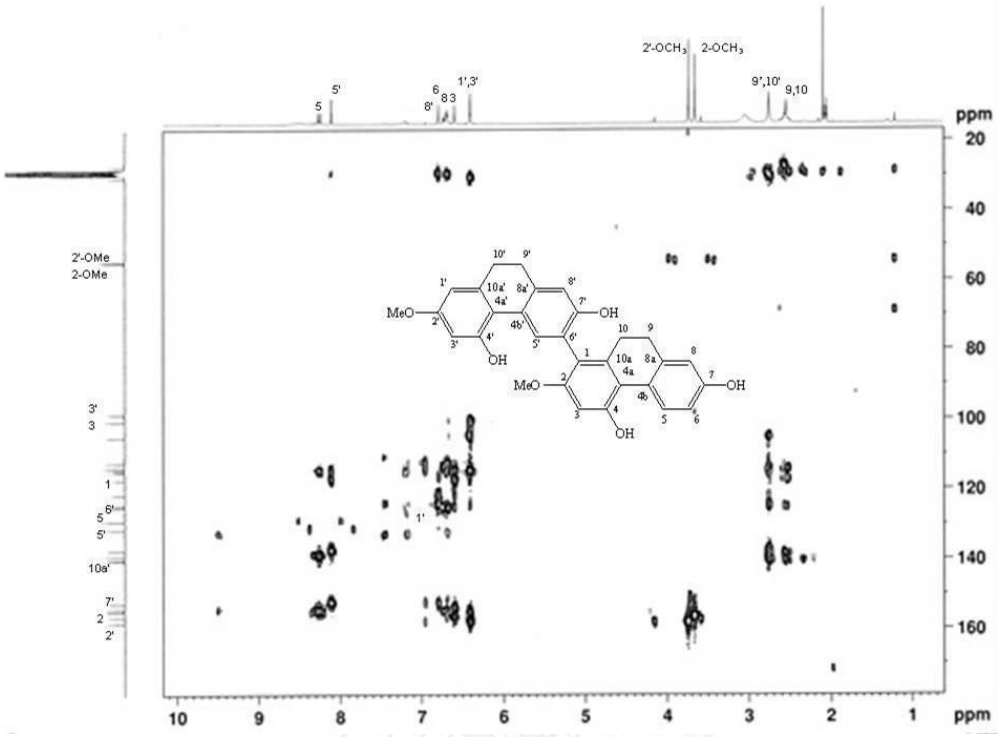

Figure 41 HMBC Spectrum of compound DV6 (acetone-d_6)

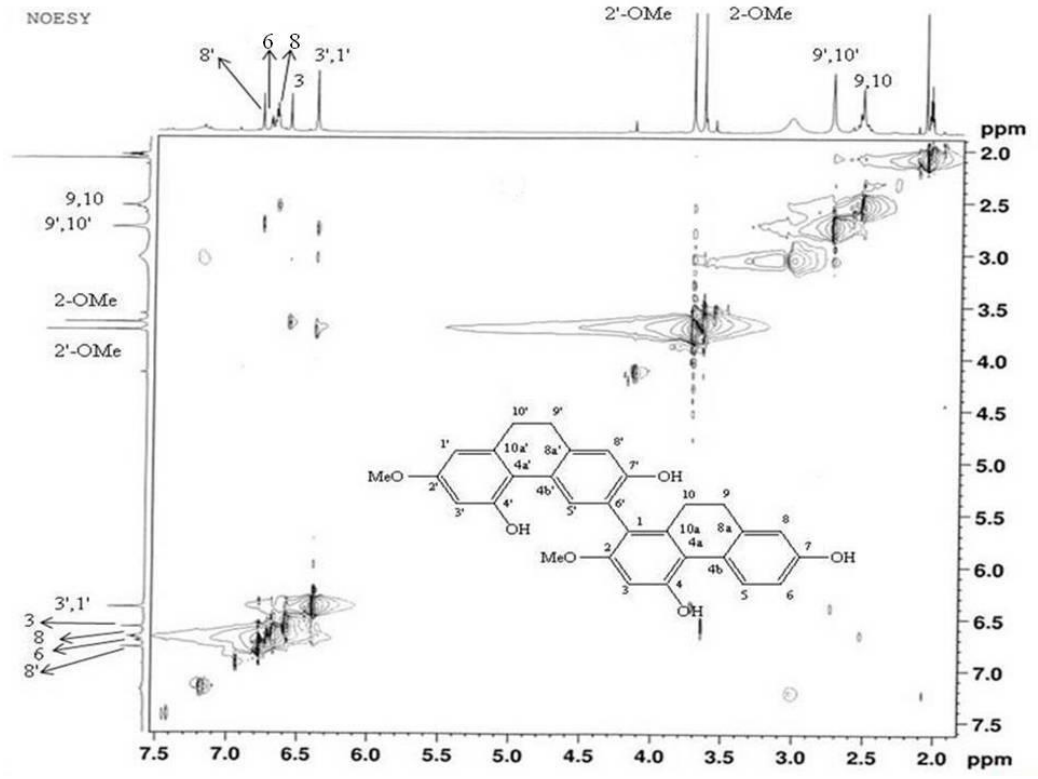

Figure 42 NOESY Spectrum of compound DV6 (acetone-d_6)

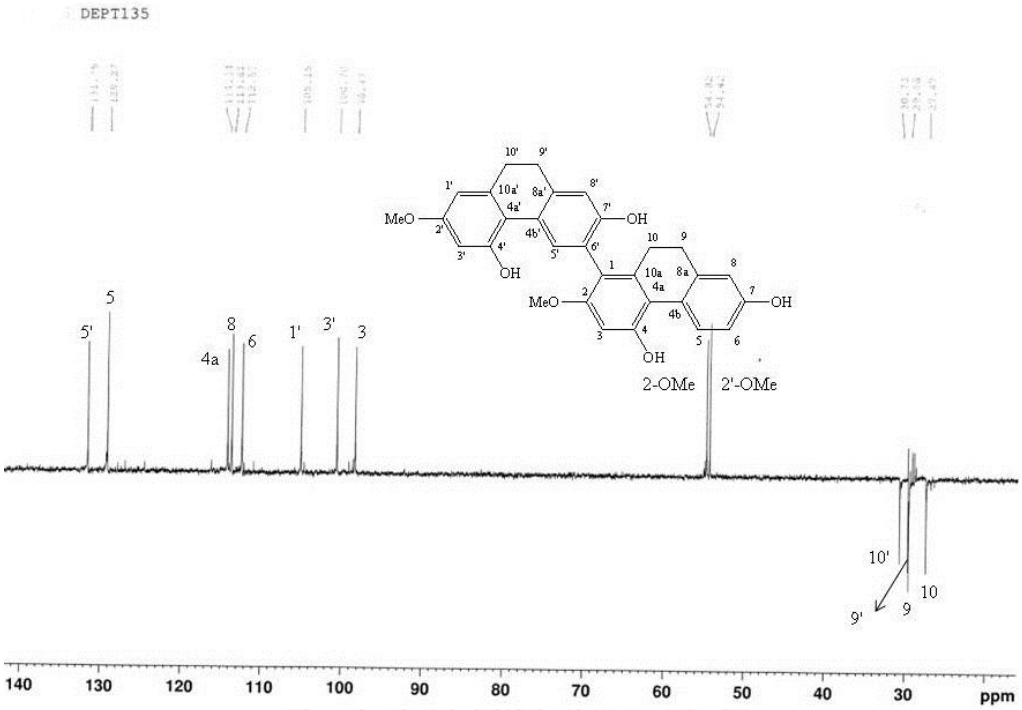

Figure 43 DEPT135 Spectrum of compound DV6 (acetone-d_6)

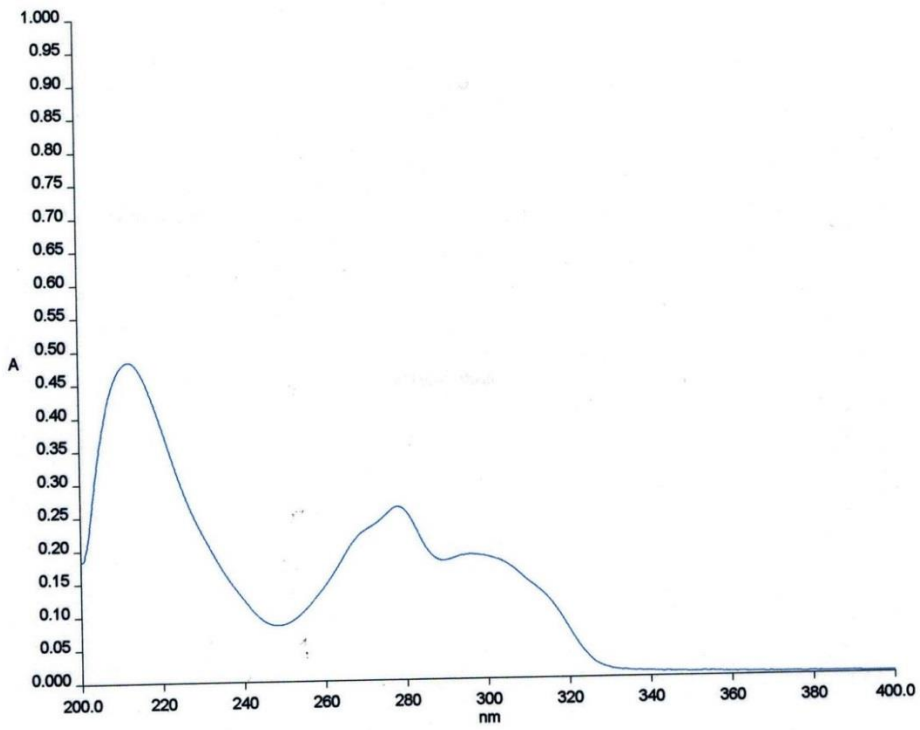

Figure 44 UV Spectrum of compound DV7 (MeOH)

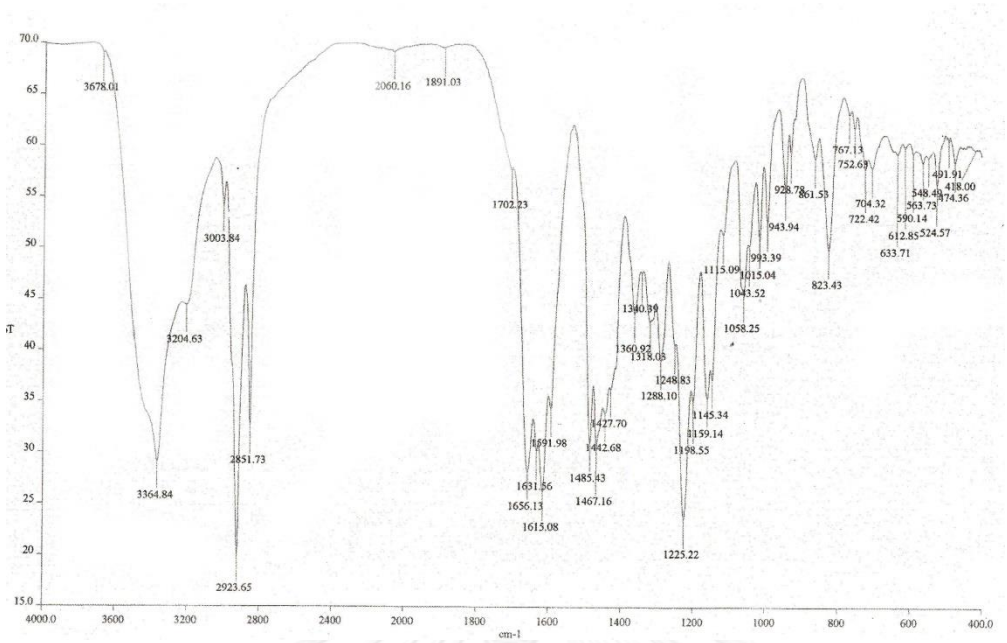

Figure 45 IR Spectrum of compound DV7

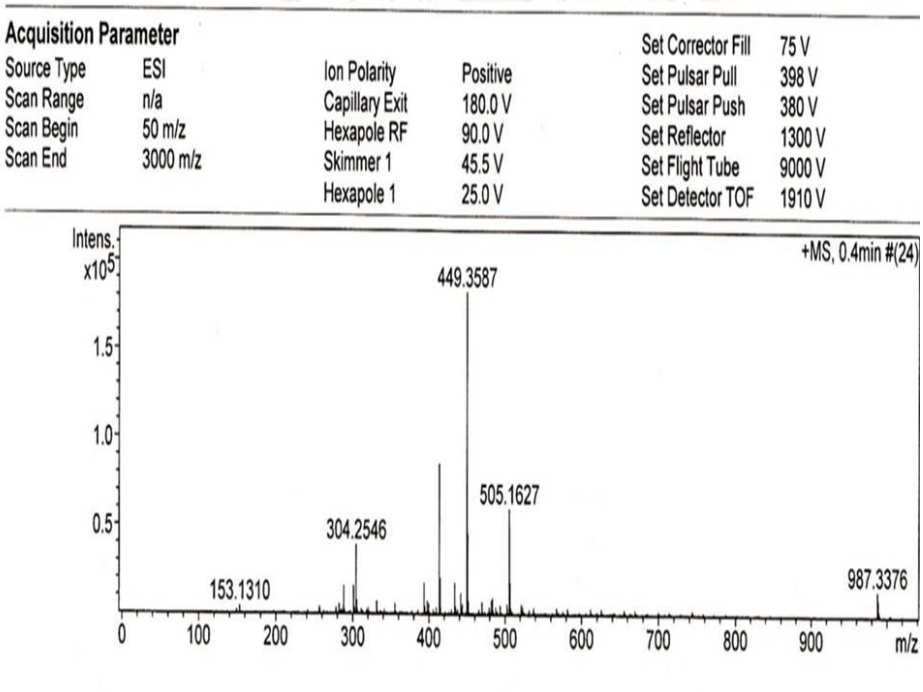

Figure 46 Mass spectrum of compound DV7

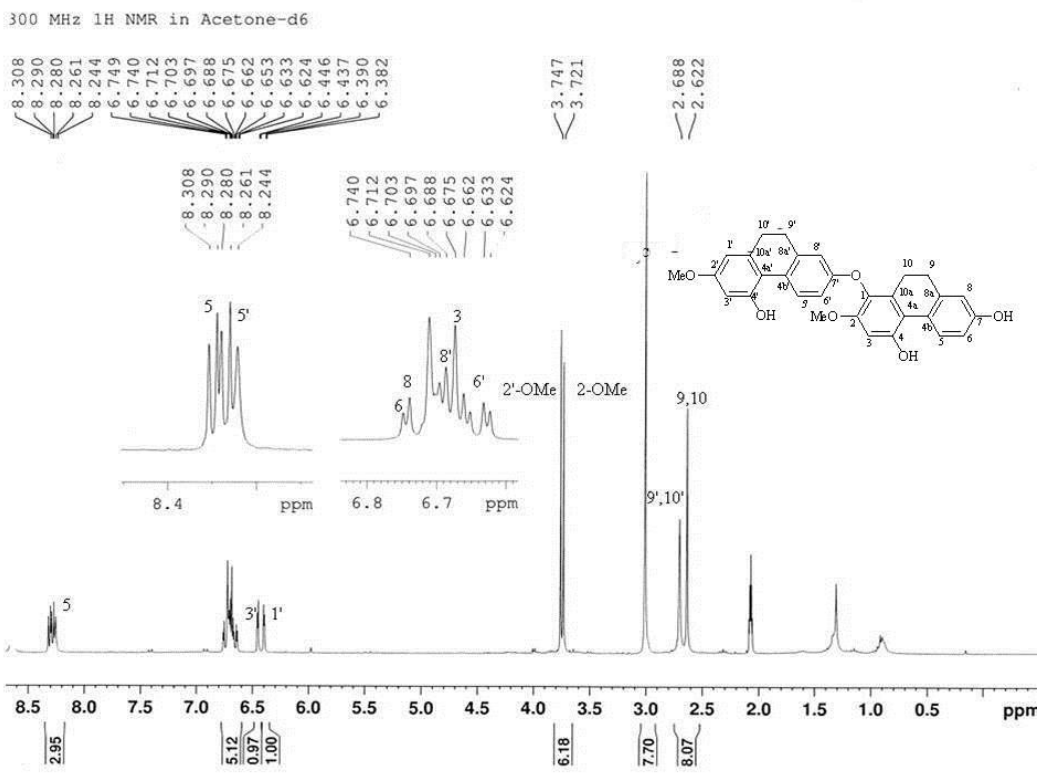

Figure 47 ^{1}H-NMR (500 MHz) Spectrum of compound DV7 (acetone-d_6)

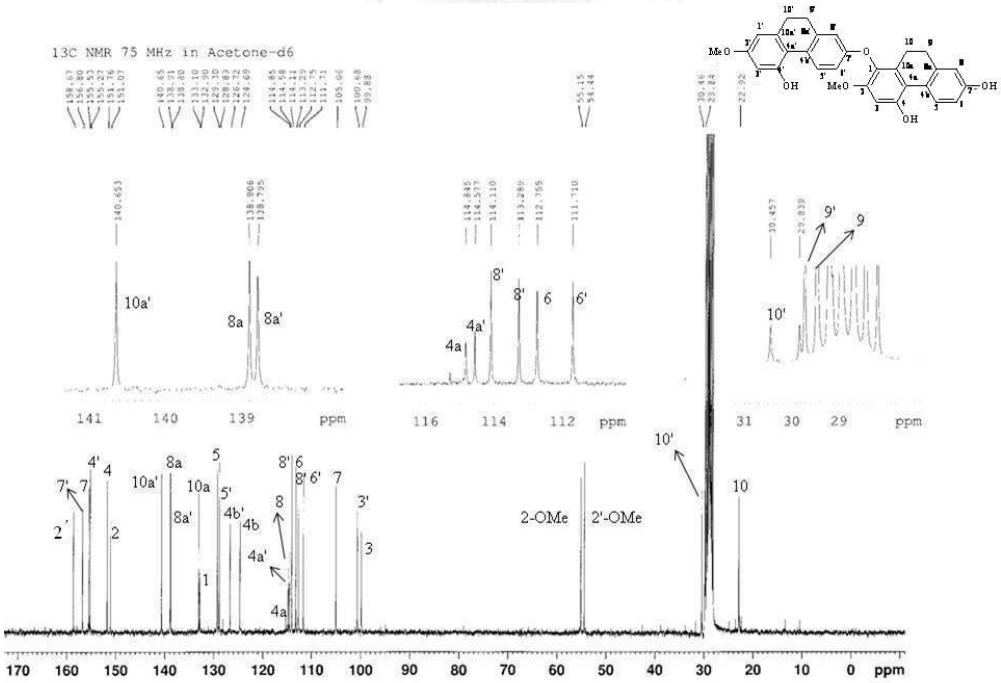

Figure 48 ^{13}C-NMR (125 MHz) Spectrum of compound DV7 (acetone-d_6)

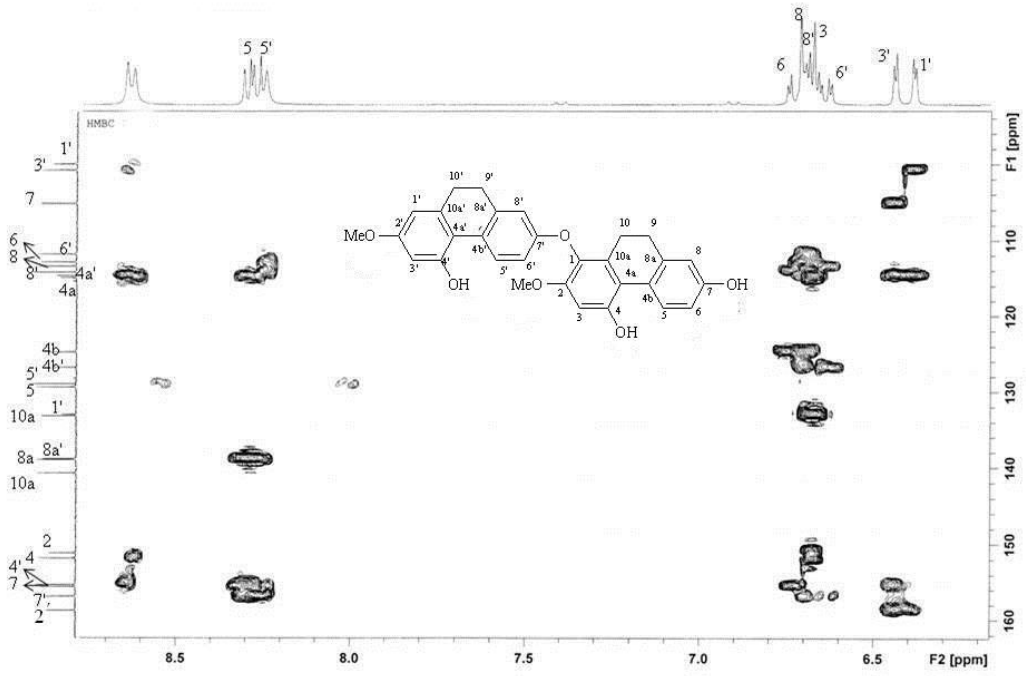

Figure 49 HMBC Spectrum of compound DV7 (acetone-d_6)

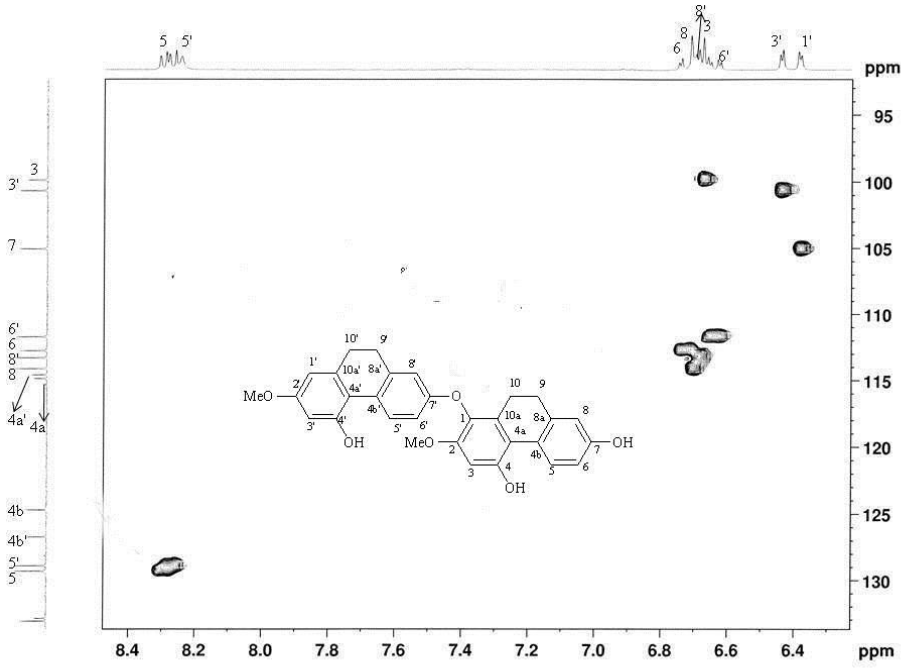

Figure 50 HSQC Spectrum of compound DV7 (acetone-d_6)

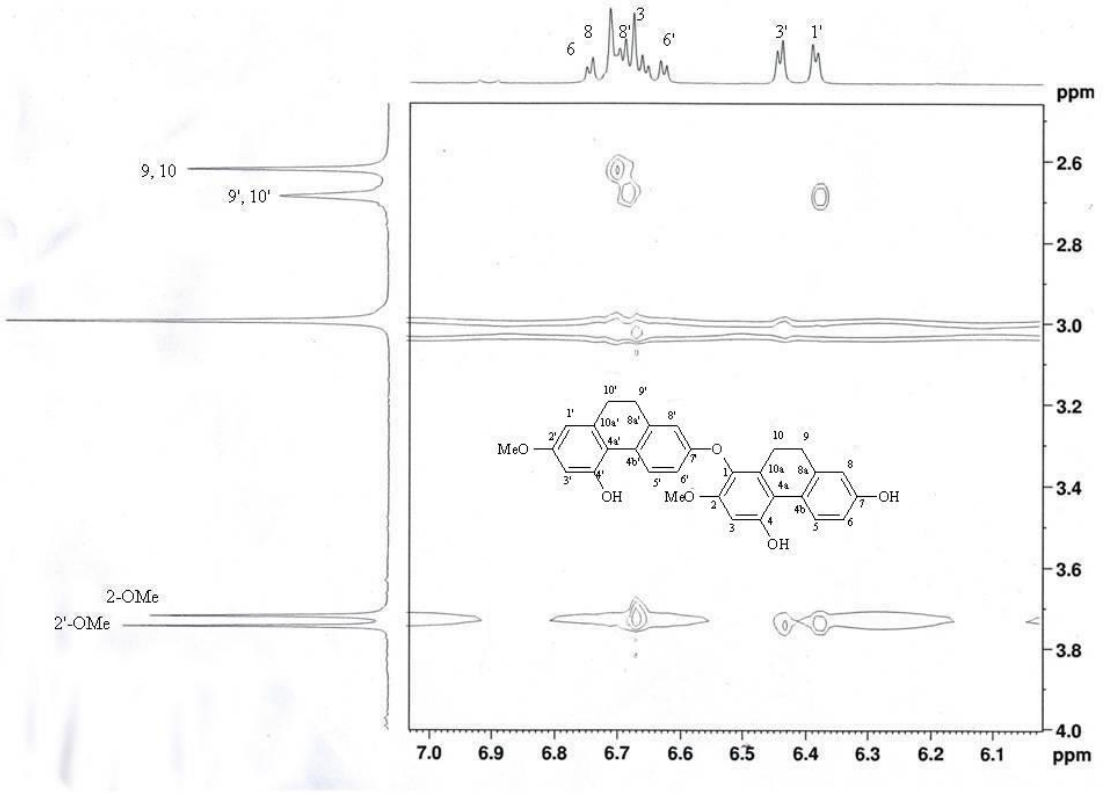

Figure 51 NOESY Spectrum of compound DV7 (acetone-d_6)

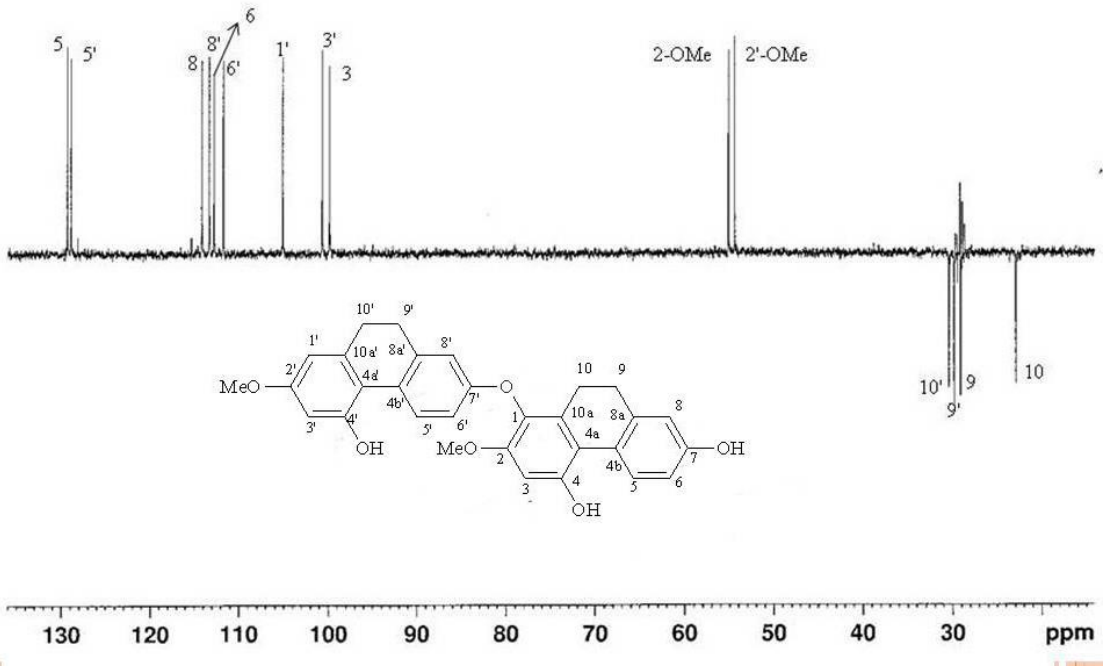

Figure 52 DEPT135 Spectrum of compound DV7 (acetone-d_6)

VITA

Miss Prapapun Sukphan was born on March 20, 1984 in Chinat, Thailand. In 2007, she received her bachelor's degree from the Faculty of pharmacy, Huachiew Chalermprakiet University.

Poster presentation

Prapapun Sukphan, Boonchoo Sritularak and Kittisak Likhitwitayawuid. Chemical Constituents of *Dendrobium venustum* and Cytotoxic Activity Against KB Oral Cavity Cancer Cell. Proceedings of the 15th Graduate Research Conference Khonkaen University, March 28, 2014, Khonkaen, Thailand, P.162.

Publication

Prapapun Sukphan, Boonchoo Sritularak, Wanwimon Mekboonsonglarp, Vimolmas Lipipun and Kittisak Likhitwitayawuid. 2014. Chemical Constituents of *Dendrobium venustum* and their Antimalarial and Anti-herpetic Properties. Natural Product Communications 9: 825-827.

REFERENCES

APPENDIX

VITA

Miss Prapapun Sukphan was born on March 20, 1984 in Chinat, Thailand. In 2007, she received her bachelor's degree from the Faculty of Pharmacy Sciences, Huachiew Chalermprakiet University, Thailand.

Poster presentation

Prapapun Sukphan, Boonchoo Sritularak and Kittisak Likhitwitayawuid.

Antimalarial compounds from Dendrobium venustum. Proceeding of the 15th Graduate Research Conference Khon Kaen University, 28 March 2014 in Khon Kaen University, Bangkok, Thailand. 162.