Sains Malaysiana 43(9)(2014): 1283–1293

A Palynological Investigation of *Vatica* L. (Dipterocarpaceae) in Peninsular Malaysia

(Suatu Penelitian Palinologi *Vatica* L. (Dipterocarpaceae) di Semenanjung Malaysia

HOUSSEIN M.A. EL-TAGURI & A. LATIFF*

ABSTRACT

Pollen morphology of 24 species of Vatica *L. had been investigated using light and scanning electron microscopes*. Vatica *is a stenopalynous genus, the pollens are radially symmetrical, isopolar, subprolate to suboblate sometimes prolate rarely oblate, all tricolpate. Exine ornamentation varies from thin to medium reticulate. On the basis of pollen shape two groups of* Vatica *have been recognized. Within the genus pollen diversity is valuable for identification and delimiting species*.

Keywords: Dipterocarpaceae; Peninsular Malaysia; pollen; Vatica

ABSTRAK

Morfologi debunga 24 spesies Vatica *L. telah dikaji dengan menggunakan mikroskop cahaya dan imbasan elektron*. Vatica *ialah genus stenodebunga, debunga adalah bersimetri jejari, isokutub, subprolat hingga suboblat, kadang-kadang prolat jarang oblat, semua trikolpat. Hiasan eksin bervariasi daripada retikulat nipis hingga sederhana. Bentuk debunga dua kumpulan* Vatica *telah dikenal pasti. Adalah penting dalam genus kepelbagaian debunga untuk pengecaman dan penghadan sempadan spesies*.

Kata kunci: Debunga; Dipterocarpaceae; Semenanjung Malaysia; Vatica

INTRODUCTION

The genus *Vatica* L. (Dipterocarpaceae) or locally known as *resak* is a small- to medium-sized trees and is among the important producers of semi-durable hard woods for house posts and other minor construction materials. Worldwide it is represented by about 66 species distributed from Sri Lanka, southern and eastern India, Myanmar, Indochina, southern China, Thailand and throughout Malesia. In Malaysia it is usually an understorey and main canopy trees and mostly found in the lowland dipterocarp forests, rarely in hill forests. In the Malay Peninsula, Ridley (1922) had produced the earliest and most comprehensive account of the genus and he recorded a total of five species only. Symington (1943, revised 2004) had comprehensively treated the genus for the Malay Peninsula and he recognized a total of 23 species, excluding a newly described species, *V. yeechongii* L.G. Saw and one undescribed species from Perak, tentatively named by him as *Vatica* sp. 'A'. Ashton (1982) in his treatment of the Dipterocarpaceae for *Flora Malesiana* listed and described a total of 56 species of *Vatica* in two sections namely, sect. *Vatica* and sect. *Sunaptea*. For Peninsular Malaysia, he included a total of 20 species, 11 in sect. *Vatica* and 9 in sect. *Sunaptea*. Recently, two species, namely *V. sarawakensis* Heim and *V. pedicellata* Brandis were reported to occur in Peninsular Malaysia by El-Taguri and Latiff (2010). Subsequently, two new species of *Vatica* from Peninsular Malaysia, *V. spatulata* (Sect. *Sunaptea*) and *V. cuneata* (Sect. *Vatica*) and two new records, namely *V. rassak* (Korth.) Blume and *V. acrocarpa* Sloot. (Sect. *Vatica*) are reported for Peninsular Malaysia (El-Taguri & Latiff 2012).

Palynological studies, of Dipterocarpaceae are very restricted in the number of taxa (Erdtman 1952; Maury et al. 1975; Nornafizah 2006; Penny et al. 2012; Talip 2008). The first palynological investigation of Dipterocarpaceae was carried out by Erdtman (1952) on six species within three genera and he stated the pollens of *Dipterocarpus* and *Monotes* are 3-colpate, oblate-subprolate, the longest axis 27-65 μm and the exine ornamentation is reticulate. Maury et al. (1975) illustrated the exine structure of nine species from six genera of Dipterocarpaceae, including *Vatica pauciflora* and they described the pollens as spherical-subprolate, P/E 0.92 (1.08) 1.24, tricolpate, P 21 (25) 31 μm, E 18 (24) 27 μm, colpi length 18 (22) 26 μm, colpi width 1-2 μm, exine thickness 1.8 μm, width of muri 0.25 (0.6) 1 μm and its thickness 0.38 (0.45) 0.6 μm, their surface is smooth, size of lumina 0.5 to 1 μm, there are much small pits or perforation of 0.1 μm in diameter. The pollen morphological study conducted by Talip (2008) showed that the pollen grains in *Shorea*, *Hopea*, *Parashorea* and *Neobalanocarpus* (Dipterocarpaceae) are fairly uniform in characters and she claimed that some *Shorea* species can be distinguished from others by their exine ornamentation. Penny et al. (2012) also stated that pollen morphology has diagnostic value for distinguishing four dipterocarp species of *Parashorea* and *Shorea* in Sabah. The latest study on the pollen morphology of *Vatica* was by Nor Nafizah (2006) who observed the pollens of

41 species of Dipterocarpaceae, including 12 species of *Vatica* from Peninsular Malaysia and she described the pollens as having homogeneous ornamentation with slight variations in the size of perforation and they are tricolpate. The present investigation is the first comprehensive pollen morphological investigation of 24 species (86%) of *Vatica* in Peninsular Malaysia using both the light and scanning electron microscope (SEM).

Materials and Methods

Pollen samples were obtained from the specimens lodged at the Herbaria of Forest Research Institute Malaysia (KEP), Singapore Botanic Gardens (SING), Universiti Kebangsaan Malaysia (UKMB), University of Malaya (KLU) and the School of Forestry Kepong, Malaysia (Table 1). The pollen slides were prepared for light microscope (LM)

TABLE 1. The list of species and specimens used in this study

Species	Specimens studied	Herbarium
Vatica acrocarpa	Malaysia, Sabah, Kudat, Banggi Island, Lajangah, 36116, 14 May 1963; Sabah, Sandakan, Suan Lambah Kechil, Cuadra 1487, 23 Sept. 1948	KEP
Vatica bella	Malaysia, Kedah, Panchor Ayer F.R., Wilkinson 17730, 19 Oct. 1951	KEP
Vatica cinerea	Malaysia, Kedah, Pulau Langkawi, Stone & Mahmud Sider 15066, 4 March 1982; Terengganu, Pulau Redang, Liew 273, 12 May 1977	KLU
Vatica cuspidata	Malaysia, Perak, Manjung, Segari Melintang F.R., Ramli 77607, 25 Nov. 1953; no. locality, Anon. 29925, in 1900	KEP
Vatica flavida	Malaysia, Perak, Perak Tengah, Universiti Petronas Campus, Yong et al. 46821, 7 May 2007	KEP
Vatica havilandii	Malaysia, Perak, Kinta, Parit FR, Parit FR, C9, Mohd. Som 50903, no date.	SING
Vatica hullettii	Malaysia, Johor, Mersing, Endau-Kluang Wildlife Reserve, Ogata 110346, 22 March 1968	KEP
Vatica lobata	Malaysia, Pahang, Sg. Selambai, Mohamad 31530, 16 July 1936	KEP
Vatica lowii	Malaysia, Perak, Kuala Kangsar, Piah FR, Jaamat 39336, no date	SING
Vatica maingayi	Malaysia, Johor, Mersing, Jemaluang road, 14mile Mawai-Jemaluang Road, Corner 37098, no date	SING
Vatica mangachapoi	Malaysia, Sabah, Lahad Datu, P. Sakar, Chai 29380, 11 April 1962	KEP
Vatica nitens	Malaysia, Perak, Hulu Perak, Ulu Kenderong, Hamid 11562, 19 Mar. 1926;	KEP
	Indonesia, East Kalimantan, Berau, Inhutani I area, Arifin & Newman 570, 29 June 1997;	KLU
	Penang, Mount Olivia, Mohd Haniff 9101, 13 March 1923	SING
Vatica odorata	Malaysia, Kelantan, Jeram Pasu Forest Reserve, Stone & Soepadmo 15207, 31 May 1982	KLU
Vatica pallida	Malaysia, Johor, Kluang, Sg. Madek, Teo 5331, 17 Nov. 2006; Penang, Timur Laut, P. Jerjak, Sidek 419, 14 Feb. 1976	KEP
Vatica pauciflora	Malaysia, Pahang, kuala Rompin, Sg. Mencali F.R., sani Miran 2156, 7 April 2011;	UKMB
	Pahang, Pekan, Sg. Bebar, Zahid 58, 9 April 2005; Pahang, Kuantan, Lambak 3558, 17 Sept. 1921	KLU SING
Vatica pedicellata	Malaysia, Terengganu, Setiu, Sg. Pelong, Suppiah, 14868, 9 April 1971	KEP
Vatica perakensis	Malaysia, Perak, Larut, King's collector 7549, in April 1885;	SING
	Selangor, Gombak, Forest Research Institute, Chua 41799, 12 April 2002	KEP
Vatica rassak	Malaysia, Terengganu, Hulu Terengganu FR, Sekayu, Compt. 43, Suppiah 11852, 22 Sept. 1969;	SING
V. ridleyana	Singapore, no locality, Anon. 4449, 29 Oct. 1892;	SING
	Maranta Avenue, Henderson 98, 13 March 1931	KEP

(continue)

Continued (TABLE 1)

Species	Specimens studied	Herbarium
Vatica sarawakensis	Malaysia, Sabah, Tawau, Kalabakan, Ahmad 65840, 16 June 1969	KEP
Vatica scortechinii	Malaysia, Perak, no locality, Scortechini 1940, no date	SING
Vatica stapfiana	Malaysia, Penang, Government Hill, Curtis 1161, in April 1890; Selangor, Gombak, FRIM, Arboretum, Kochummen 79145, no date	SING
V. umbonata	Malaysia, Sabah, Kota Kinabalu, P. Gaya F.R., Emik 479, in Nov. 1949	KEP
	Penang, Government Hill, Curtis s.n., in March 1900	SING
Vatica yeechongii	Malaysia, Negeri Sembilan, Seremban, Setul F.R., Bohari 46720, 15 March 2005	KEP

All herbarium acronyms follow *Index Herbariorum* except SFK = Herbarium, School of Forestry Kepong, Malaysia, and s.n. = *sine nomine* (without number)

and scanning electron microscope (SEM) by the standard methods described by Erdtman (1952).

For light microscopy**,** the pollens were mounted in unstained glycerine jelly and observations were made with an Olympus BX43F microscope under (plan N 40 X / 0.65), using 10 × eye piece. For each species 20-30 readings were taken and the following parameters were recorded: Polar diameter, equatorial length, colpus length and width, exine thickness.

For scanning electron microscopy**,** the pollens were suspended in a drop of water, directly transferred with a fine pipette to a metallic stub using double sided cellotape and coated with gold in a sputtering chamber (BIO RAD sputter coater SC500). The S.E.M examination was carried out on a ZEISS scanning electron microscope SUPRA 55VP.

The terminology used is in accordance with Erdtman (1952), Faegri & Iversen (1964), Kremp (1965) and Walker and Doyle (1975). The numerical analysis was conducted using real-result numbers matrix which was constructed with 24 rows of operational taxonomic units (species) and 11 columns of characters. The scoring of the characters was carried out in Microsoft Excel software and the matrix was exported into Multivariate Statistic Packages (MVSP) for Windows version 3.1.

RESULTS AND DISCUSSION

GENERAL DESCRIPTION OF THE POLLEN MORPHOLOGY OF THE GENUS *VATICA L.*

Pollens are radially symmetrical, isopolar, subprolate to suboblate sometimes prolate rarely oblate, all tricolpate, amb pertreme to goniotreme or fossaperturate and colpal membrane granulated. Tectum reticulate, reticulum of variable types from thin to medium reticulate. Two groups of *Vatica* have been recognized on the basis of pollen shape, Group I: Pollen prolate or subprolate and Group II: Pollen suboblate, oblate or oblate spheroidal (Figure 1). Group I includes the following species: *Vatica bella* Sloot., *V. cuspidata* (Ridl.) Sym., *V. havilandii* Brandis, *V. lobata* Foxw., *V. lowii* King, *V. maingayi* Dyer, *V. perakensis* King, *V. ridleyana* Brandis in Hook. f., *V. scortechinii* (King) Brandis, *V. stapfiana* (King) Sloot. and *V. umbonata* (Hook. f.) Burck and Group II includes the following species: *V. cinerea* King, *V. flavida* Foxw., *V. hullettii* (Ridl.) Ashton, *V. mangachapoi* Blco, *V. nitens* King, *V. odorata* (Griff.) Sym., *V. pallida* Dyer, *V. pauciflora* (Korth.) Blume, *V. pedicellata* Brandis, *V. rassak* (Korth.) Blume, *V. sarawakensis* Heim, *V. acrocarpa* Sloot. and *V. yeechongii* L.G. Saw.

General Measurements: Polar axis (P): 11.67(20.07)29.11 μm; equatorial length (E): 11.84(19.92)29.99 μm; P/E: 1.06-1.76 in Group I and 0.62-0.98 in Group II; Shape: prolate or subprolate in Group I and suboblate, oblate or oblate spheroidal in Group II; Colpus length: 8.47(15.11)24.59 μm; Colpus width: 1.43(2.95)5.3 μm; Total exine thickness: 0.92(2.11)4.33 μm. All species measurement details are given in Table 2.

Exine ornamentation general descriptions: The sculpture is reticulate that includes two sizes of lumina and the width of muri somewhat different in different species. The big lumina size: 0.49(1)2.42 μm long; the small lumina size: 0.07(0.16)0.47 μm; the width of muri: 0.10(0.47)1 μm; number of small lumina in 9 μm^2: 1(8)28 lumen (Figure 2A-X). All species exine ornamentation details are given in Table 3.

Vatica is a stenopalynous genus. There is a remarkable diversity in the pollen morphology in various characters such as pollen size, shape, exine ornamentation and total exine thickness. The present pollen study is based on 24 species of *Vatica*. Our findings are in agreement with the pervious works as tremendous palynological diversity has been also observed in all the taxa studied, though limited (Maury et al. 1975; Nor Nafizah 2006). The shape class varies from subprolate to suboblate sometimes prolate rarely oblate and the apertural size varies from 8.47 to 23.96 μm length and 1.43 to 5.3 μm width. Similarly, the tectum also exhibits considerable variation from thin to medium reticulate.

On the basis of pollen shape the genus *Vatica* has been divided into two groups, Group I: Pollen prolate or subprolate and Group II: Pollen suboblate, oblate or oblate spheroidal. However, the sectional classification of *Vatica* which was based on calyx morphology is incompatible with pollen morphology.

FIGURE 1. Light micrographs of pollen grains shape: *V. bella*: A, *V. cinerea*: B, *V. cuspidata*: C, *V. flavida*: D, *V. havilandii*: E, *V. hullettii*: F, *V. lobata*: G, *V. lowii*: H, *V. maingayi*: I, *V. mangachapoi*: J, *V. nitens*: K, *V. odorata*: L, *V. pallida*: M, *V. pauciflora*: N, *V. pedicellata*: O, *V. perakensis*: P, *V. rassak*: Q, *V. ridleyana*: R, *V. sarawakensis*: S, *V. scortechinii*: T, *V. stapfiana*: U, *V. acrocarpa*: V, *V. umbonata*: W, *V. yeechongii*: X. (Scale bar =10 µm)

TABLE 2. Pollen characters of the 24 species of *Vatica* studied

Species	polar axis (P) in µm	Equatorial length (E) in µm	P/E	Shape	Colpus length in µm	Colpus width in µm	Exine thickness in µm
V. bella	18.05	12.61	1.18	subprolate	11.8	2.1	0.92
	(19.98)	(14.59)	(1.37)		(13.48)	(2.95)	(1.28)
	21.4	18.05	1.58		15.5	3.4	1.66
V. cinerea	18.61	20.85	0.78	suboblate	15.2	2.65	1.67
	(19.95)	(23.14)	(0.86)		(15.68)	(3.31)	(2.14)
	22.4	24.78	0.96		17.1	4.53	2.73
V. cuspidata	16.42	11.84	1.12	subprolate	13.03	1.84	1.22
	(17.59)	(13.62)	(1.28)		(13.96)	(2.1)	(1.64)
	18.86	14.62	1.56		14.68	2.82	2.27
V. flavida	16.66	17.84	0.83	oblate	10.43	2.16	1.40
	(18.63)	(20.27)	(0.91)	spheroidal	(13.09)	(2.67)	(1.67)
	20.59	22.27	0.98		16.13	3.42	1.98
V. havilandii	20.72	16.3	1.16	subprolate	15	2.06	1.9
	(22.03)	(17.25)	(1.27)		(16.59)	(2.31)	(1.97)
	23.31	19.94	1.39		19.2	2.91	2.06
V. hullettii	16.85	21.02	0.7	suboblate	11.03	1.99	1.72
	(18.68)	(23.6)	0.79)		(11.63)	(2.37)	(2.25)
	20.88	27.53	0.91		12.78	3.72	2.75

(continue)

Continued (TABLE 2)

Species	polar axis (P) in µm	Equatorial length (E) in µm	P/E	Shape	Colpus length in µm	Colpus width in µm	Exine thickness in µm
V. lobata	25.07	15.19	1.25	prolate	21.18	2.58	1.52
	(26.55)	(18.7)	(1.4)		(22.13)	(3.2)	(1.85)
	28.51	22.09	1.76		23.62	4.11	2.44
V. lowii	16.84	12.45	1.18	subprolate	9.92	1.43	1.45
	(18.93)	(14.44)	(1.22)		(13.61)	(1.96)	(1.8)
	20.96	17.17	1.49		17.25	3.2	2.79
V. maingayi	20.07	13.51	1.16	prolate	12.9	1.54	1.86
	(21.75)	(15.85)	(1.39)		(16.02)	(2.11)	(2.27)
	23.88	19.69	1.66		19.35	2.76	2.69
V. mangachapoi	14.77	20.22	0.67	oblate	9.45	2.47	2.48
	(16.47)	(22.07)	(0.75)		(10.63)	(3.01)	(2.88)
	19.23	23.65	0.91		13.05	4	3.43
V. nitens	14.49	19.2	0.66	suboblate	12.83	2.27	2.45
	(16.95)	(20.31)	(0.83)		(13.5)	(2.7)	(2.66)
	18.39	21.82	0.95		14.54	3.2	3.18
V. odorata	14.07	18.95	0.69	suboblate	8.47	1.94	2.43
	(15.86)	(19.97)	(0.79)		(9.82)	(2.58)	(2.96)
	17.81	21.44	0.88		10.87	3.4	4.33
V. pallida	11.67	17.33	0.62	oblate	8.97	1.98	1.69
	(13.59)	(19.5)	(0.69)		(10.06)	(2.13)	(1.86)
	17.16	21.33	0.8		12.28	2.35	2.07
V. pauciflora	18.83	21.56	0.83	suboblate	11.1	3.17	1.29
	(19.58)	(22.42)	(0.87)		(12.79)	(3.39)	(1.59)
	20.87	23.34	0.93		15.4	3.69	1.91
V. pedicellata	18.42	22.63	0.77	suboblate	12.53	2.97	1.75
	(19.92)	(23.78)	(0.83)		(13.43)	(3.43)	(2.32)
	21.78	26.32	0.89		14.33	4.26	3.26
V. perakensis	16.96	12.51	1.18	subprolate	13.67	2.17	1.27
	(19.28)	(14.66)	(1.3)		(14.44)	(2.5)	(1.34)
	21.23	17.11	1.45		15.23	3.05	1.52
V. rassak	19.01	22.24	0.8	suboblate	14.3	3.23	1.45
	(21.01)	(24.2)	(0.86)		(15.03)	(3.53)	(1.59)
	23.34	25.54	0.97		16.32	4.09	1.82
V. ridleyana	23.84	17.28	1.14	subprolate	20.36	2.03	1.15
	(25.21)	(19.45)	(1.28)		(21.78)	(2.44)	(1.33)
	27.37	21.12	1.49		23.96	3.28	1.66
V. sarawakensis	14.6	18.51	0.75	suboblate	9.76	2.37	2.36
	(16.15)	(19.86)	(0.81)		(10.37)	(2.7)	(2.54)
	18.2	21.32	0.93		11.89	3.02	2.93
V. scortechinii	16.53	13.16	1.06	subprolate	10.92	2.21	2.04
	(19.62)	(15.32)	(1.27)		(13.02)	(2.75)	(2.18)
	24.46	18.09	1.53		14.9	3.6	2.51
V. stapfiana	23.09	18.08	1.22	prolate	19.55	2.74	1.64
	(26.18)	(19.01)	(1.38)		(22.4)	(2.94)	(1.88)
	29.89	20.27	1.61		24.59	3.33	2.24
V. acrocarpa	17.46	20.08	0.8	oblate	13.55	3.2	1.73
	(18.62)	(21.06)	(0.88)	spheroidal	(14.49)	(3.5)	(2.13)
	19.76	22.31	0.98		16	4.26	2.82
V. umbonata	22.06	17.44	1.17	subprolate	19.69	2.33	1.37
	(25.08)	(19.49)	(1.28)		(20.44)	(3.16)	(1.97)
	27.69	21.63	1.49		21.65	4.18	2.82
V. yeechongii	20.38	23.49	0.7	suboblate	15.66	2.82	1.71
	(22.13)	(26.7)	(0.81)		(16.41)	(3.31)	(2.15)
	25.58	29.99	0.91		17.2	4.45	2.76

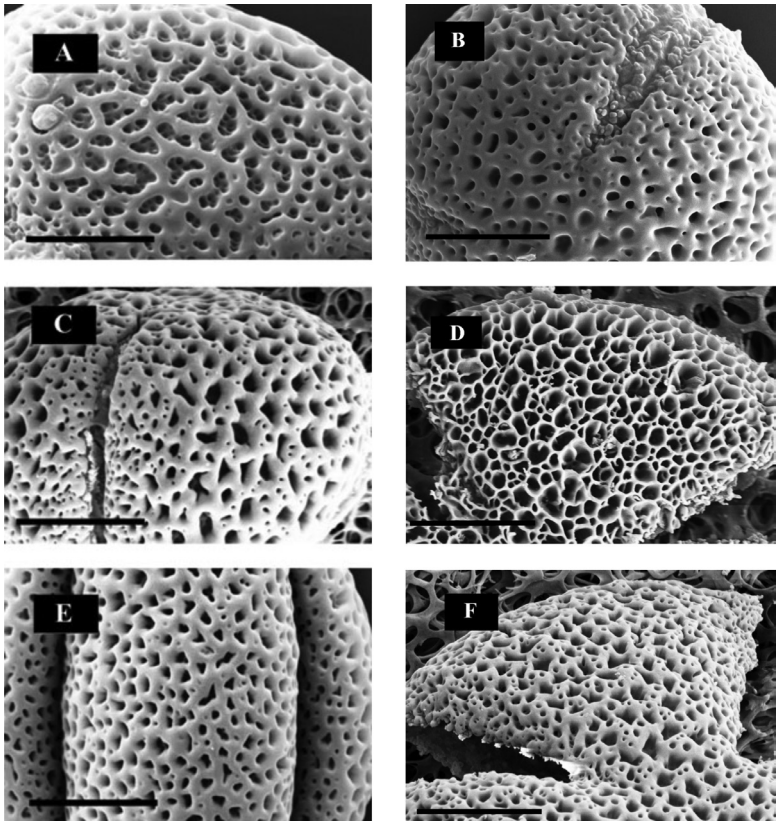

FIGURE 2. Scanning electron micrographs of the sculpture of pollen grains: *V. bella*: A, *V. cinerea*: B, *V. cuspidata*: C, *V. flavida*: D, *V. havilandii*: E, *V. hullettii*: F. (Scale bar = 5 μm)

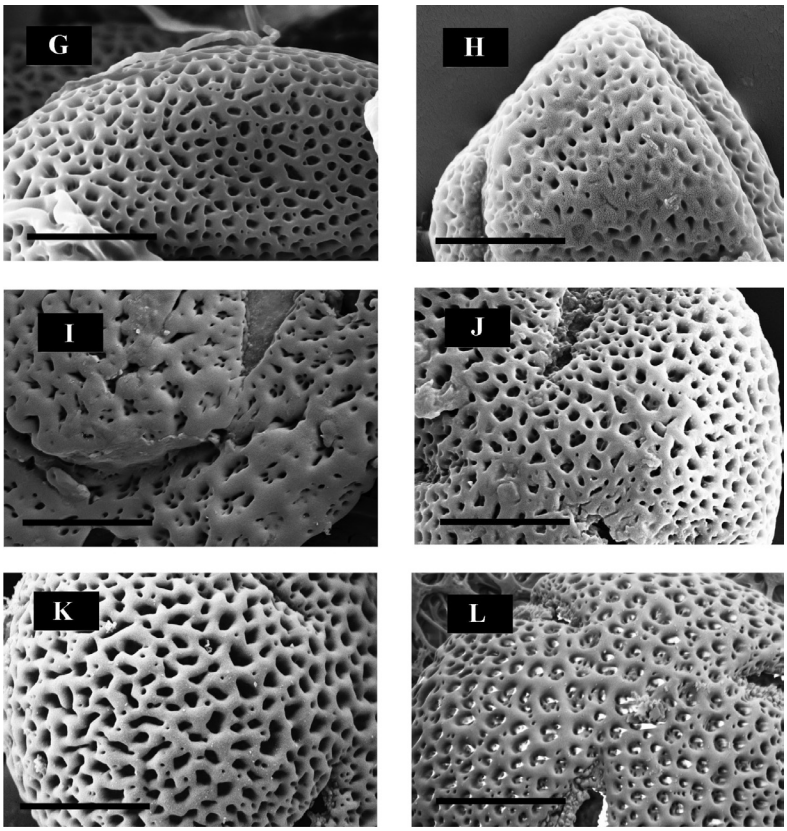

FIGURE 2 (continue). Scanning electron micrographs of the sculpture of pollen grains: *V. lobata*: G, *V. lowii*: H, *V. maingayi*: I, *V. mangachapoi*: J, *V. nitens*: K, *V. odorata*: L. (Scale bar = 5 μm)

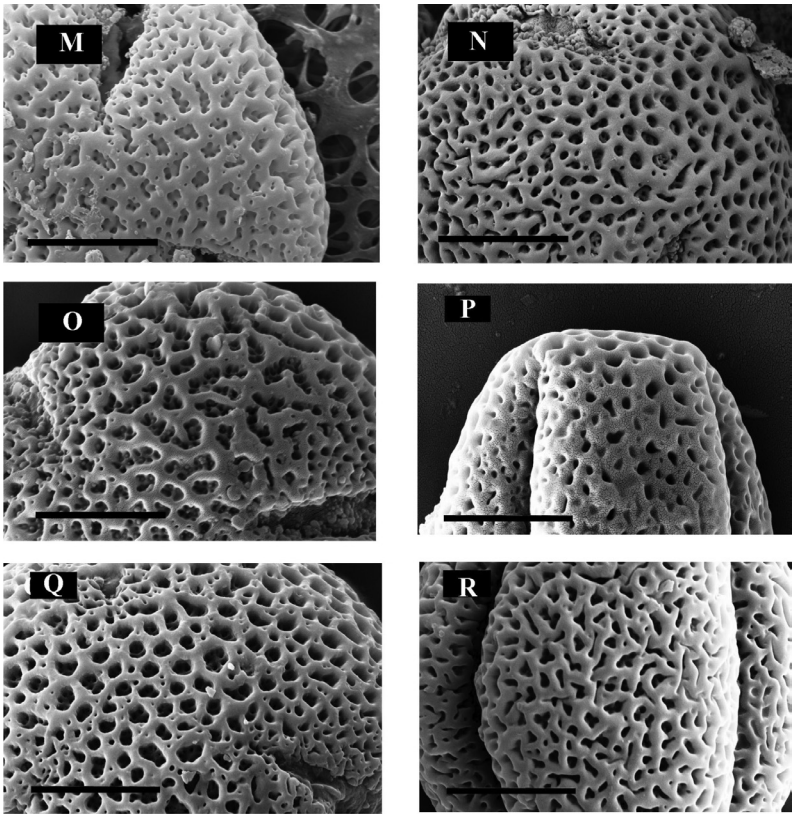

FIGURE 2 (continue). Scanning electron micrographs of the sculpture of pollen grains: *V. pallida*: M, *V. pauciflora*: N, *V. pedicellata*: O, *V. perakensis*: P, *V. rassak*: Q, *V. ridleyana*: R. (Scale bar = 5 μm)

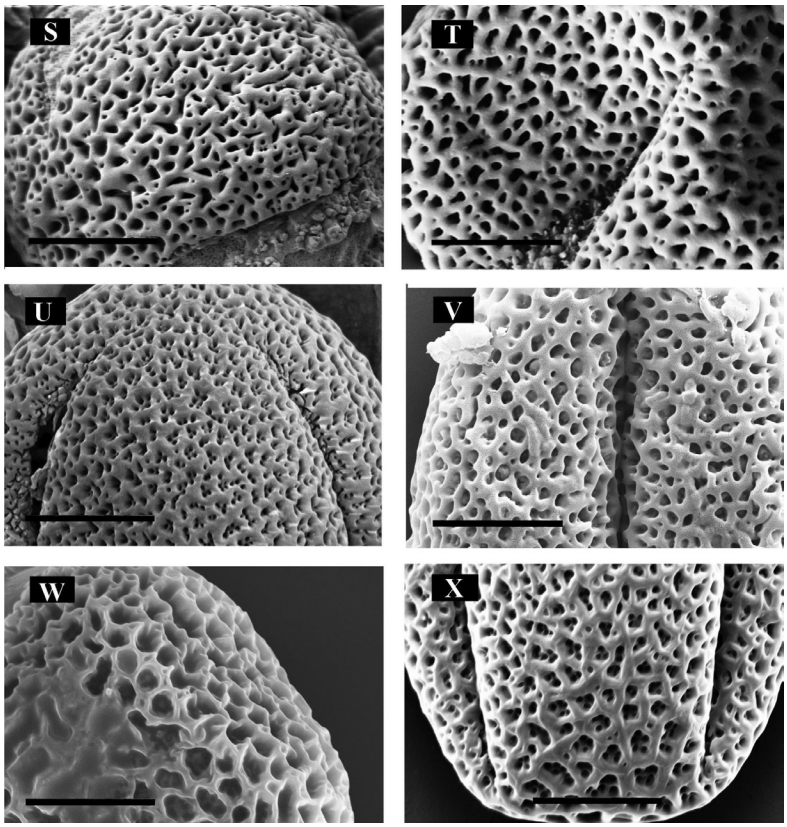

FIGURE 2 (continue). Scanning electron micrographs of the sculpture of pollen grains: *V. sarawakensis*: S, *V. stapfiana*: T, *V. acrocarpa*: U, *V. umbonata*: V, *V. yeechongii*: W, *V. scortechinii*: X. (Scale bar = 5 μm)

TABLE 3. Exine ornamentation characters of the 24 species of *Vatica*

Species	Size of big lumina in μm	Size of small lumina in μm	Width of muri in μm	Number of small lumina in 9 μm^2
V. bella	1.2 (1.28) 1.36	0.19 (0.24) 0.28	0.27 (0.39) 0.52	4(6)8
V. cinerea	0.67 (0.77) 0.84	0.14 (0.17) 0.2	0.3 (0.43) 0.5	7 (13) 17
V. cuspidata	0.6 (0.86) 1.1	0.07 (0.08) 0.1	0.49 (0.6) 0.72	13 (15.33) 19
V. flavida	0.92 (1.09) 1.29	0.16 (0.27) 0.47	0.10(0.14) 0.20	4(8.5)16
V. havilandii	0.55 (0.79) 1.1	0.17 (0.19) 0.2	0.43 (0.48) 0.55	8(9)11
V. hullettii	0.66 (0.88) 1.12	0.1 (0.14) 0.22	0.35 (0.44) 0.56	20(23)28
V. lobata	0.93 (1.01) 1.05	0.12 (0.14) 0.17	0.24 (0.35) 0.45	5(6)8
V. lowii	0.49 (0.51) 0.54	0.15 (0.16) 0.17	0.19 (0.37) 0.52	7(9.33)11
V. maingayi	0.79 (0.96) 1.16	0.17 (0.2) 0.22	0.45 (0.64) 1	2(5.33)8
V. mangachapoi	0.74 (0.89) 1.16	0.14 (0.15) 0.15	0.37 (0.43) 0.49	5(6.67)10
V. nitens	0.85 (1.14) 1.3	0.14 (0.16) 0.18	0.33 (0.4) 0.45	5(6)8
V. odorata	0.84 (0.98) 1.15	0.14 (0.16) 0.17	0.39 (0.46) 0.52	3(7.33)11
V. pallida	0.76 (0.97) 1.23	0.08 (0.1) 0.11	0.36 (0.5) 0.6	4(6.67)9
V. pauciflora	0.73 (1.02) 1.32	0.1 (0.11) 0.13	0.21 (0.45) 0.62	1(3.67)7
V. pedicellata	1.63 (2) 2.42	0.14 (0.14) 0.15	0.35 (0.53) 0.63	4(6)10
V. perakensis	0.75 (0.83) 0.92	0.14 (0.15) 0.17	0.47 (0.61) 0.83	7(8)9
V. rassak	1.18 (1.25) 1.33	0.11 (0.14) 0.17	0.39 (0.52) 0.65	8(8.67)9
V. ridleyana	0.64 (0.76) 1.09	0.1 (0.12) 0.15	0.38 (0.45) 0.5	3(5.33)8
V. sarawakensis	0.7 (0.84) 1.01	0.1 (0.15) 0.21	0.37 (0.56) 0.87	7(13.33)18
V. scortechinii	1.23 (1.28) 1.36	0.17 (0.24) 0.29	0.28 (0.5) 0.72	4(4.67)6
V. stapfiana	0.58 (0.74) 0.92	0.15 (0.2) 0.24	0.33 (0.43) 0.5	5(7.67)10
V. acrocarpa	0.81 (0.86) 0.96	0.13 (0.15) 0.17	0.34 (0.44) 0.5	2(4)6
V. umbonata	0.65 (0.83) 0.96	0.08 (0.12) 0.17	0.21 (0.52) 0.88	3(4.33)5
V. yeechongii	1.03 (1.44) 1.79	0.15 (0.18) 0.21	0.18 (0.33) 0.42	2(6)10

The general morphological pollen characters, polar axis (P), equatorial diameter (E), P/E, shape, colpus length, colpus width and total exine thickness and exine ornamentation, big lumina size, small lumina size, width of muri and number of small lumina in 9 μm^2 can be used to separate the species studied or to classify them into groups. The P/E or the shape of pollen has significant value that can divide *Vatica* species into two groups Group; I with shape prolate or subprolate and Group II with shape suboblate, oblate or oblate spheroidal. Similarly, the polar axis (P) has taxonomic value within each group to distinguish some species, such as in Group I, *V. bella, V. cuspidata, V. lowii* and *V. perakensis* have (P) less than 21 μm. while *V. lobata, V. ridleyana* and *V. stapfiana* have (P) more than 24 μm. The equatorial diameter (E) has taxonomic value too to distinguish some species such as *V. pallida* and *V. sarawakensis* which have (E) less than 21 μm, while *V. yeechongii* has (E) more than 24 μm. The colpus length in *Vatica* is longer within the prolate group than those with oblate group therefore supports the division of *Vatica* into two groups, while colpus width doesn't have much taxonomic value. The total exine thickness is helpful to diagnose some species such as that of *V. bella, V. perakensis* and *V. ridleyana* which have the total exine thickness less than 1.5 μm while *V. odorata, V. nitens and V. mangachapoi* have the total exine thickness more than 2.5 μm; the size of big lumina has some taxonomic value too that it can be used to distinguish *V. yeechongii* from *V. flavida* which has similar ornamentation, while the size of small lumina doesn't have much taxonomic value. The width of muri can distinguish *V. yeechongii* from *V. flavida* which has thin muri. *V. cuspidata* and *V. hullettii* can be diagnosed by high number of small lumina. Generally, all the Peninsular Malaysian *Vatica* species are relatively homogenous as far as the pollen characters are concerned. The measurements in this study were quite in agreeable with the previous studies except that of Nor Nafizah (2006) who stated the size of the pollen grains bigger by about 30% than this study. The dendrogram produced from the numerical analysis is shown (Figure 3).

From the dendrogram the genus *Vatica* is divided into two clusters namely Group I and Group II at ca. 70% similarity (Figure 3). Further, Group I may be subdivided into two subgroups I and II at 75% similarity, Subgroup I comprises of *V. umbonata, V. ridleyana, V. stapfiana* and *V. lobata* and Subgroup II comprises of *V. maingayi* to *V. bella*. Similarly Group II may be divided into three subgroups I, II and III at 78% similarity, Subgroup I comprises of *V. flavida*, Subgroup II comprises of *V. pallida* to *V. hullettii* and Subgroup III comprises of *V. yeechongii* to *V. acrocarpa*. These groupings were compatible with the groupings of the studied species based on pollen shapes. It is worthy to note that *V. flavida* appeared on its own as a subgroup in Group II as its exine ornamentation is different from the rest of the species and this character could be used to distinguish the species.

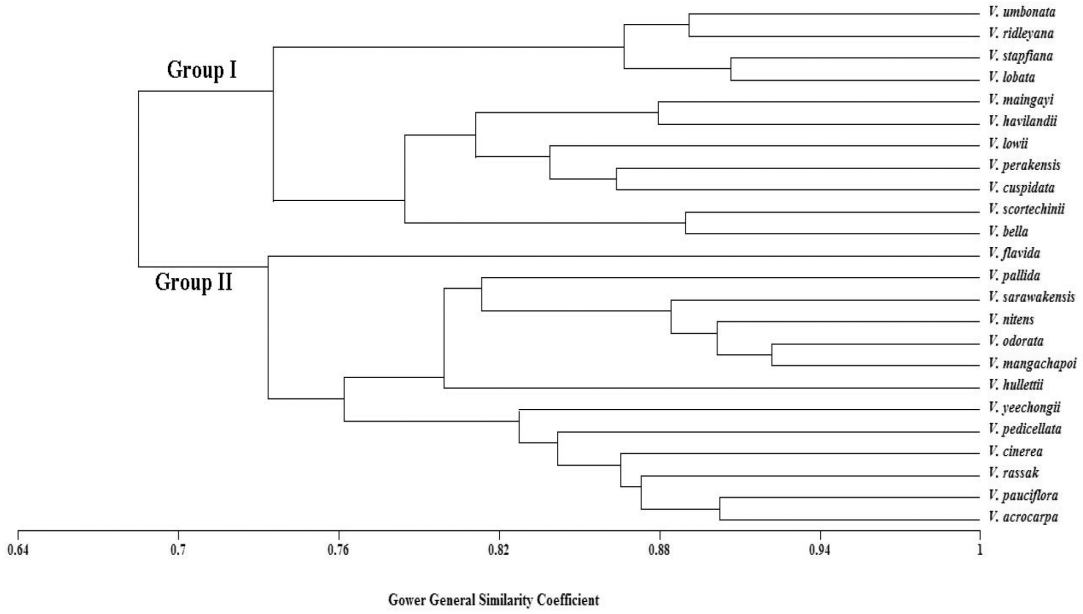

FIGURE 3. Dendrogram based on UPGMA for pollen characters of *Vatica*

IMPLICATIONS

Based on the calyx morphology the genus *Vatica* has been divided into two sections namely, Sect. *Vatica* and Sect. *Sunaptea* (Ashton 1982; El-Taguri & Latiff 2011). The species, *V. havilandii, V. bella, V. scortechinii, V. stapfiana, V. ridleyana,V. umbonata* and *V. lobata* agreed with the grouping in Sect. *Vatica,* whereas some of the species in Sect. *Vatica* such as *V. odorata, V. lowii, V. cuspidata* and *V. perakensis* are embedded in the other cluster. Some species of Sect. *Sunaptea* such as *V. yeechongii, V. flavida, V. hullettii, V. pallida, V. pauciflora* and *V. pedicellata* are clustered within the same clade, i.e. within sect. *Vatica*. Similarly, the recognition of *V. acrocarpa* as a species is also supported by pollen studies (El-Taguri & Latiff 2012). The variation within the pollens are so wide that they could be employed to construct key to identification of the species below.

KEY TO THE SPECIES USING POLLEN CHARACTERS

A key to the species of some *Vatica* species in Peninsular Malaysia based on pollen morphological characters is presented below.

1. Shape suboblate, oblate or oblate spheroidal 2
   Shape prolate or subprolate 13
2. Total exine thickness mostly 2 µm or less 3
   Total exine thickness mostly more than 2 µm 5
3. Size of big lumina less than 1 µm, oblate, polar axis (P) less than 17 µm, colpus width less than 2.5 µm ..... *V. pallida*
   Size of big lumina more than 1 µm, suboblate, polar axis (P) more than 19 µm, colpus width more than 3 µm 4
4. Width of muri more than 0.5 µm, number of small lumina in 9 µm^2 more than 8 ..... *V. rassak*
   Width of muri 0.5 µm or less, number of small lumina in 9 µm^2 less than 5 ..... *V. pauciflora*
5. Size of big lumina less than 1 µm 6
   Size of big lumina more than 1 µm 10
6. Width of muri more than 0.5 µm 7
   Width of muri 0.5 µm or less 8
7. Number of small lumina in 9 µm^2 mostly 13, width of muri more than 0.5 µm, suboblate, colpus length less than 12 µm ..... *V. sarawakensis*
   Number of small lumina in 9 µm^2 mostly 4, width of muri less than 0.5 µm, oblate spheroidal, colpus length more than 14 µm ..... *V. acrocarpa*
8. Number of small lumina in 9 µm^2 10 or less ..... *V. mangachapoi* and *V. odorata*
   Number of small lumina in 9 µm^2 more than 10 9
9. Colpus more than 15 µm long, number of small lumina in 9 µm^2 less than 17..... *V. cinerea*
   Colpus less than 13 µm long, number of small lumina in 9 µm^2 more than 20 ..... *V. hullettii*
10. Width of muri more than 0.5 µm, size of big lumina more than 2 µm ..... *V. pedicellata*
    Width of muri less than 0.5 µm, size of big lumina 1.5 µm or less 11
11. Width of muri less than 0.2 µm, size of small lumina more than 0.2 µm, number of small lumina in 9 µm^2 more than 8, oblate spheroidal, total exine thickness less than 0.2 µm ..... *V. flavida*

Width of muri more than 0.2 μm, size of small less than 0.2 μm, number of small lumina in 9 μm² less than 6, suboblate, total exine thickness more than 0.2 μm 12

12. Lumina shape mostly long oblong, polar axis (P) 17 μm, equatorial diameter (E) 20.5 μm ..... *V. nitens*

Lumina shape mostly round, polar axis (P) 22 μm, equatorial diameter (E) 26.5 μm ..... *V. yeechongii*

13. Total exine thickness mostly more than 2 μm 14

Total exine thickness mostly 2 μm or less 15

14. Size of big lumina less than 1 μm, polar axis (P) more than 20 μm, prolate, colpus more than 15 μm long ..... *V. maingayi*

Size of big lumina more than 1 μm, polar axis (P) less than 20 μm, subprolate, colpus less than 15 μm long ..... *V. scortechinii*

15. Size of big lumina more than 1 μm 16

Size of big lumina less than 1 μm 17

16. Polar axis (P) less than 22 μm, subprolate, colpus less than 16 μm long, total exine thickness mostly less than 1.5 μm ..... *V. bella*

Polar axis (P) more than 25 μm, prolate, colpus more than 21 μm long, total exine thickness mostly more than 1.5 μm ..... *V. lobata*

17. Width of muri 0.5 μm or less 18

Width of muri more than 0.5 μm 20

18. Polar axis (P) more than 23 μm, prolate ..... *V. stapfiana*

Polar axis (P) less than 23 μm, subprolate 19

19. Size of big lumina more than 0.55 μm, colpus length more than 15 μm ..... *V. havilandii*

Size of big lumina less than 0.55 μm, colpus length mostly less than 14 μm ..... *V. lowii*

20. Number of small lumina in 9 μm² 10 or less, size of small lumina 0.1 μm or more 21

Number of small lumina in 9 μm² mostly 15, size of small lumina less than 0.1 μm ..... *V. cuspidata*

21. Polar axis (P) less than 20 μm, colpus length less than 16 μm, number of small lumina in 9 μm² more than 7 ..... *V. perakensis*

Polar axis (P) more than 22 μm, colpus length more than 19 μm, number of small lumina in 9 μm² less than 7 ..... *V. ridleyana* and *V. umbonata*

ACKNOWLEDGEMENTS

We thank the curators of herbaria KEP, SING, UKMB, KLU and the School of Forestry Kepong, Malaysia for allowing the senior author to study their specimens and the School of Environmental and Natural Resource Sciences, Faculty of Science and Technology for the research facilities. This work is supported by Grant UKM-OUP-2012-056 to which the authors are grateful.

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Hoessin, M. A. El-Taguri
Faculty of Science, Benghazi University
Box 1308, Benghazi
Libya

Hoessin, M. A. El-Taguri & A. Latiff*
Faculty of Science and Technology
Universiti Kebangsaan Malaysia
43600 Bangi, Selangor
Malaysia

*Corresponding author; email: latiff@ukm.edu.my

Received: 6 March 2013
Accepted: 3 January 2014