

COMPARATIVE STUDIES OF LEAF VENATION IN SOME SPECIES OF SAPINDACEAE OF MALAYSIA

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ABSTRACT

A study on the variation of leaf venation pattern was undertaken on 43 taxa belonging to 19 genera of Sapindaceae in Malaysia. Results showed that there were 17 venation patterns observed based on the leaf lamina venation, ultimate marginal and veinlet patterns. A total of 15 taxa showed bi-veinlets, 15 taxa uni-veinlets, eight taxa simple veinlets, three taxa tri-veinlet patterns and two other taxa with no ending veinlets. The presence of idioblast cells on the leaf lamina surfaces, presence and localization of simple trichomes on the leaf veins or on the leaf epidermis are the diagnostic characteristics that can be used in identification of *Guioa*, *Harpullia* and *Glenmeia*. Druses observed on the leaves lamina can be very useful for species identification of *Filicium decipiens* (Wight & Arn.) Thwaites. Combination of variation in the leaf venation and diagnostic characteristics found in this study have taxonomic value especially in species and genus identification and differentiation in Sapindaceae in Malaysia.

Key words: Sapindaceae, Leaf venation, Leaf anatomy, Diagnostic characters

INTRODUCTION

Sapindaceae is one of the main angiosperm plant families and includes 150 genera with ca. 2000 taxa which is widespread in tropical and subtropical regions of the world. It is well represented in South America (Adema *et al.*, 1994; van Welzen, 1999) and in Malaysia, a total of 23 genera with 62 taxa can be found in Sabah and Sarawak, and 50 taxa in 18 genera in Peninsular Malaysia (Adema *et al.*, 1994; Yap, 1989). The members of Sapindaceae can be trees and shrubs, including lianas (*Cardiospermum*). Those taxa can be found thriving in primary and secondary rainforests, especially on forest edges, coastal vegetation and roadsides, mainly in lowlands but also on the mountains up to 3000 m (Leenhouts & Muller, 1976).

The family is also important for the regional economy, as a source of edible fruits and seeds

including *Dimocarpus longan* var. *longan* Leenh., *Litchi chinensi* Sonn., *Nephelium lappaceum* L. and *N. ramboutan-ake* (Labill.) Leenh (Adema *et al.*, 1994). Other than that, wood of some taxa of Sapindaceae is useful as timber (Seibert, 1998) and also for medicinal purposes, vegetables, soap or fish poisons (van Welzen, 1992). The family is characterized by alternate and spiral leaves arrangement, mostly paripinnate, sometimes imparipinnate, trifoliate or simple in a few genera; inflorescence axillary to terminal, spike-like to heavy branching; flowers male or bisexual, the latter usually with stamens reduced with filmy appendage; fruits developing from all or one or two of the ovary lobes and seeds covered with sarcotesta, mesocarp or aril. Most genera and species when in sterile conditions are difficult to identify when collected without inflorescence and fruits (Leenhouts & Muller, 1976).

Based on previous studies, leaves are definitely the main characteristic used for identification

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including other morphology, anatomy, phytochemistry and others (Inamdar *et al.*, 1983). In other families' leaf anatomy, have been used for taxa identification, for examples *Euphorbia* (Euphorbiaceae) (Sehgal & Paliwal, 2008), *Bouea*, *Mangifera* and *Spondias* in Anacardiaceae (Mohd Norfaizal & Latiff, 2014), *Macaranga* in Euphorbiaceae (Mohd Norfaizal *et al.*, 2012), *Cardiospermum* in Sapindaceae (Solis & Ferrucci, 2006) and some genera in Dipterocarpaceae (Noraini & Cutler, 2009). All these studies have proved the significance of leaf anatomy in identification of various genera and species, whenever complete specimens are not available. Therefore this study aims to investigate microscopic characteristics of venation patterns and variations of the selected taxa Sapindaceae, as to find out whether these characteristics could be used as a diagnostic characteristic and taxonomic values for the taxa identification.

MATERIALS AND METHODS

Fresh and herbarium samples of a total of 43 taxa of Sapindaceae were used in this study. Details of the taxa and collections are given in Table 1. The fresh specimens used in this study were obtained from many localities in Malaysia, including Sabah, Sarawak, in Peninsular Malaysia includes Taman Negara, Royal Belum State Park and also in Malaysian Agricultural Research and Development Institute (MARDI) Serdang Rare fruit Gene bank. Dried specimens were obtained and analysed from the MARDI Herbarium (MDI), Forest Research Institute Malaysia (KEP) and Universiti Kebangsaan Malaysia, Bangi (UKMB) Herbaria.

The fresh leaf specimens collected were fixed in AA (70% ethanol, 30% acetic acid ratio of 1:3); the dried herbarium samples were boiled depending on the taxa, as thick specimens may take up to 15 minutes of boiling to soften the leaves structure. Approximately 1 x 1 cm sample of the leaf lamina and margin area were cleared using Basic Fuchsin solution (10% Basic Fuchsin and 10% KOH, Sigma Aldrich) in an oven at 60°C for 1 to 2 days, depending on the thickness of the leaf specimen. The cleared leaf specimens were then dehydrated in an alcohol series, cleared in xylene and mounted on slides using Canada Balsam (Sigma Aldrich Chemical, England). The samples were then placed in an oven at 60°C for 2 weeks. The slides were photographed using a digital camera (Olympus BX43F, Tokyo) mounted on an Olympus microscope (Olympus Soft Imaging Solutions GmbH, Münster, Germany). The leaf venation patterns were observed using Cellsens Software (Cellsens, Tokyo Japan)

under 10x, 20x, and 40x magnification. Details of the analysis and descriptions of the leaf venation types followed the classification of Hickey (1979).

RESULTS AND DISCUSSION

The variation of leaf venation patterns of angiosperms was extensively studied and classified by Hickey (1979) and Sun *et al.* (1997), to name the most comprehensive treatments. Leaf architecture is primarily used for classification such as the leaf shape, leaf margin structure and as many as possible characters. Indeed, the first observation and characterization of an angiosperm leaf venation pattern starts by observing the primary veins and then proceeded to the secondary veins that branch off from the primary veins. According to Dickinson (2000), leaf veins are primarily cylindrical bundles of vascular tissue that occur mainly in the mesophyll of leaf lamina and in dicotyledons, it consists of one to more branched major veins and minor veins that usually end with free ending veinlets within the areoles. Veinlet can be branched or unbranched and end in one to three tracheid's.

Leaf venation pattern for a few sub-temperate species of Sapindaceae was studied by Metcalfe and Chalk (1950). It forms the elements that express the leaf structure such as the lamina venation pattern, marginal configuration and gland existence, also serves ultimately for the taxonomists to document the function of leaf venation structure in taxa identification. This is supported by leaf venation patterns have high taxonomic value and suggested that each taxon has a constant number of veins that can be used for identification and for genus confirmation (Sehgal & Phaliwal, 2008).

In Sapindaceae, leaf characters play an important role in supporting identification and classification, such as the size and shape of petiole and leaf blade, the number of nerves and secretory cells and trichomes that are usually diagnostic especially when complete specimens are available for observation (Radlkolfer, 2009). Combination of marginal venation and areolar venation patterns for every taxon are unique, even those taxa that are classified under one genus, for example *Nephelium*. Among the 17 taxa of *Nephelium* studied, the veinlet endings vary greatly among them, namely uni-, simple and linear, bi- or tri-veinlets, with their ultimate marginal venation as complete or incomplete (Table 2). The abundance of idioblast cells on the lamina surface of *Guioa* and *Glenneia* can be a diagnostic character for them (Figure 4D). Druses were also observed in *Filicium decipiens* (Wight & Arn.) Thwaites, a single introduced species of Sapindaceae in Malaysia (Figure 4A). The

Table 1. List of Sapindaceae taxa and samples studied

Taxa	Samples
<i>Allophyllus cobbe</i>	Johor, Kluang, Hutan Simpan Endau Rompin, Rosdi, M. & Angan, A. FRI58782, 25.8.2007 (KEP) Pahang, Pulau Tioman, Kg. Paya, K.M. Wong FRI9275, 19.5.1997 (KEP) Pahang, Taman Negara Kuala Tahan, Ulu Sungai Sat, S.K. Yap FRI63556, 13.7.1970 (KEP) Perak, Chenderoh, Sg. Kerga, Jaamal FRI119285, 9.2.1935 (KEP) Selangor, Puchong, Hutan Simpan Ayer Hitam, Masrom, H. MDI10178, 12.8.2000 (MDI) Pahang, Jerantut, Taman Negara Kuala Tahan, Kuala Sat, Mohd Norfaizal, G. & Masrom, H. MDI12077, 12.4.2015 (MDI)
<i>Amesiodendron chinense</i>	Pahang, Cameron Highlands, Bukit Tapah, Sungai Ketah, Batu 18, T.C. Whitmore FRI 15670, 30.10.1970 (KEP) Selangor, Ulu Gombak, Jalan Lama, B.C. Stone FRI 15972, 4.5.1987 (KEP) Selangor, Hutan Simpan Ulu Gombak, Ang, K.C. FRI27669, 26.4.1983 (KEP) Perak, Gerik, Hulu Perak, Temenggor, Sungai Sigor, Kg. Tekam, Anon. FRI39437, 23.9.1993 (KEP) Perak, Tanjung Malim, Mohd Norfaizal, G. MDI3004, 5.5.2015 (MDI) Selangor, Seri Kembangan, Serdang, Persiaran MAEPS, Mohd Norfaizal, G. MDI2876, 7.1.2015 (MDI)
<i>Arytera littorale</i>	Selangor, Sg. Buloh, Kg. Cubit, K.M. Kochummen FRI29242, 31.3.1981 (KEP) Selangor, Kepong, FRIM, P. Vetherelu FRI32962, 15.1.1986 (KEP) Selangor, Kepong, FRIM, Jalan Arboretum, H.S. Loh, FRI21556, 2.11.1974 (KEP) Selangor, Kepong, FRIM, Zalina, M. ZM3, 8.5.2007 (KEP) Negeri Sembilan, Kuala Pilah, Hutan Simpan Serting, Simpang Pertang, Anon. FRI21658, 17.12.2015 (KEP) Pahang, Bentong, Kg. Janda Baik, Bahari, M. & Amasee. MDI6974, 16.9.1986 (MDI) Pahang, Pekan, Sg. Bebar, Mohd Norfaizal, G. & Masrom, H. MDI12095, 20.5.2015 (MDI)
<i>Cardiospermum halicacabum</i>	Kelantan, Tumpat, Pantai Jubakar, Siti Munirah, M.Y., Imin, K. & Kueh, H.L. FRI144368, 27.1.2011 (KEP) Johor, Mersing, Hutan Simpan Endau Rompin, Julius, A., Sam, Y.Y. & Kueh, H.L. FRI163224, 2.10.2007 (KEP) Selangor, Kajang, Taman Bukit Kajang, Ruth, K. FRI11927, 26.3.1978 (KEP) Terengganu, Kuala Terengganu, Yao, T.L., Ruth, K. & Kueh, H.L. FRI31121, 26.9.2006 (KEP) Selangor, Kajang, Sungai Ramal Dalam, Masrom, H. MDI6494, 10.2.1989 (MDI) Melaka, Alor Gajah, Kampus UiTM Cawangan Lendu, Mohd Norfaizal, G. & Masrom, H. MDI12097, 12.5.2015 (MDI) Selangor, Seri Kembangan, Jalan Puchong, Mohd Norfaizal, G. & Masrom, H. MDI12099, 14.6.2015 (MDI)
<i>Dodonea viscosa</i>	Kedah, Pulau Langkawi, Gunung Raya, M.R. Henderson FRI16013, 13.11.1941 (KEP) Johor, Tuenseh, M.R. Henderson FRI116011, 10.6.1934 (KEP) Kedah, Pulau Langkawi, Tanjung Rhu, E. Soepadmo & Mahmud FRI116014, 18.8.1972 (KEP) Pahang, Kuantan, Pantai Balok, J.G. Watson FRI116010, 13.3.1919 (KEP) Pahang, Kuantan, Teluk Chempedak, Masrom, H. MDI2094, 20.1.1992 (MDI) Pahang, Kuantan, Tg. Lumpur, Masrom, H. MDI2089, 22.1.1992 (MDI)
<i>Ganophyllum falcatum</i>	Pahang, Pulau Tioman, Gunung Kajang, Kg. Paya, Chew, M.Y. T199Sc, 28.4.2012 (KEP) Johor, Johor Baru, Desaru, Mat Asri, N.S. FRI38664, 29.1.1993. (KEP) Pahang, Pulau Tioman, Teluk Dalam, Chew, M.Y. T3016c, 1.5.2012 (KEP) Johor, Mersing, Tanjung Penawar, P.F. Cockburn FRI7598, 22.6.1968 (KEP)
<i>Dimocarpus fumatus</i>	Kedah, Gurun, Sik, Rimba Teloi, S.K. Yap FRI28492, 10.6.1980 (KEP) Perak, Temenggor, Gerik, Sungai Sera, S.K. Yap FRI39973, 10.11.1993 (KEP) Kedah, Sg. Petani, Teo, L.E. & Tarelli KL4615, 19.7.1996 (KEP) Selangor, MARDI Serdang, Mohd Norfaizal, G. MDI1710, 17.4.2015 (MDI) Perak, Gerik, Temenggor, Taman Negeri Di Raja Belum, Sungai Kejar, Masrom, H. MDI9809, 12.8.2008 (MDI)
<i>Dimocarpus longan</i> var. <i>longan</i>	Perak, Lenggong, Gunung Runtuh, S.R. Henderson FRI23812, 11.6.1930 (KEP) Selangor, FRIM Kepong, F.S.P. Ng. FRI22811, 23.9.1982 (KEP) Selangor, FRIM Kepong, F.S.P. Ng. FRI22689, 13.11.1980 (KEP) Selangor, MARDI Serdang, Masrom, H. MDI1458, 13.5.1995 (MDI) Johor, Muar, Parit Pinang Seribu, Mohd Norfaizal, G. MNFG1879, 21.1.2015 (MDI) Johor, Batu Pahat, Seri Merlong, Mohd Norfaizal, G. MNFG1882, 22.1.2015 (MDI)
<i>Dimocarpus longan</i> ssp. <i>malesianus</i>	Perak, Gerik Temenggor, Sg. Bekek, A. Latiff, A. Zainuddin, S. Muzni, Ikram, M.S. & Wahid, S. 4020, 1.9.1993 (UKMB) Negeri Sembilan, Kuala Pilah, S.K. Yap FRI116028, 6.5.1976 (KEP) Selangor, FRIM Kepong, F.S.P. Ng FRI91105, 10.6.1974 (KEP) Melaka, Ayer Keroh, F.S.P. Ng FRI91107, 10.6.1974 (KEP) Sarawak, Serian, Kg. Kakeng, Masrom, H. MDI1281, 2.2.1999 (MDI) Sabah, Kota Belud, Mohd Norfaizal, G. & Masrom, H. MNFG1678, 23.5.2010 (MDI) Selangor, Seri Kembangan, Jalan Puchong, Mohd Norfaizal, G. & Masrom, H. MNFG1759, 18.5.2014 (MDI)

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<i>Filicium decipiens</i>	Katagawan Timur, Sg. Mentaya, P. Wildie F94162, 23.3.1994 (KEP) Selangor, Jalan Puchong, Masrom, H. MDI8448, 7.1.1995 (MDI)
<i>Glenneia penangensis</i>	Negeri Sembilan, Kuala Pilah, Hutan Simpan Pasoh, Mat Asri FRI91501, 4.8.1976 (KEP) Kedah, Hutan Simpan Bukit Enggang, Mohd Shah & A. Tan FRI55682, 5.5.1993 (KEP) Johor, Bukit Jelaloi, P.F. Bungess FRI166503, 20.10.1969 (KEP) Johor, Kluang, Ismail Ishak FRI166504, 9.7.1959 (KEP) Johor, Kluang, K.M. Kochummen FRI2832, 21.10.1969 (KEP) Kedah, Langkawi, Masrom, H., Tuan Othman, T.A. & Yahaya, M. MDI 8864, 28.12.1995 (MDI) Kedah, Pulau Payar, Masrom, H., Tuan Othman, T.A. & Yahaya, M. MDI1654, 26.12.1985 (MDI)
<i>Guioa bijuga</i>	Hutan Simpan Lesong, Ulu Sungai Pukin, T. Suppiah FRI11881, 16.2.1971 (KEP) Kelantan, Kuala Krai, Hutan Simpan Gunung Stong, Rusdi, M., Phoon, S.N. & Ong, P.T. FRI66254 (KEP) Kedah, Ulu Muda, P.S. Bray. FRI11785, 20.1.1969 (KEP) Pahang, Kuantan, Cherating, Masrom, H. & Tuan Othman, T.A. MDI 8860, 26.12.1985 (MDI) Terengganu, Dungun, Pantai Sura, Mohd Norfaizal, G. MNFG1801, 11.2.2015 (MDI) Pahang, Pulau Tioman, Kg. Genting, Mohd Norfaizal, G. MNFG1802, 11.3.2015 (MDI)
<i>Guioa pleuropteris</i>	Terengganu, Marang, Kamarul Hisham, M. Lim, C.L. & Mohd Nazri, A. FRI67055, 24.2.2009 (KEP) Hutan Simpan Panti, Jutta, M. & Hamidi, A.M. FRI54235, 17.4.2007 (KEP) Terengganu, Bukit Bauk, Yao, T.L., Lim, C.L. & Angan, A. FRI65442, 8.4.2009 (KEP) Pahang, Pulau Tioman, Kg. Asah, Chew, M.Y. T3387A, 2.5.2012 (KEP) Terengganu, Kemaman, Pasir Gajah, Imin, K. Phoon, S.N. Pannell, C.M. & Mohd Nazri, A. FRI76165, NIL (KEP) Pahang, Pulau Tioman, Gunung Kajang, Mohd Norfaizal, G. Masrom, H., Omar, Y. & Aishah-Farhana, S. MDI12415, 5.4.2011 (MDI)
<i>Guioa diplopetala</i>	Sabah, Sandakan, Talip, Hoya & Lolli SAN80738, 21.2.1976 (SAN) Lanjak Entimau, Bukit Masum, Ulu Sungai Lelap, Paul Chail et al. S68837, 30.1.1999 (UKMB) Hap Seng Land, Kelabakan, Fedilis, K. SAN91944, 23.3.1982 (SAN)
<i>Harpullia arborea</i>	Sabah, Jalan Bukit Tawau, Batu 15, Abon Gibott FRI17, 11.2.1962 (KEP) Sabah, Jalan Bukit Tawau, Batu 15, Abon Gibott FRI18, 13.9.1962 (KEP) Sabah, Tambunan, Puasa Angian FRI19, 19.2.1934 (KEP) Sabah, Kota Belud, Masrom, H. MDI0989, 13.4.1989 (MDI)
<i>Lepisanthes amoena</i>	Pahang, Jerantut, Sungai Pahang, Burkill, I.H. FRI118693, 7.12.1924 (KEP) W.P. Kuala Lumpur, Taman Awam Kuala Lumpur, Ahmad, C. FRI118695, 7.7.1919 (KEP) Selangor, Ladang Kepong, Abdul Hamid FRI118648, 1.3.1934 (KEP) W.P. Kuala Lumpur, Taman Awam Kuala Lumpur, Jaamal FRI118696, 5.4.1926 (KEP) Pahang, Kuala Lipis, Kg. Awah, Mohd Norfaizal, G., Masrom, H. MDI2513, 8.4.2011 (MDI) Perak, Tanjung Malim, Shohimee, S. MDI4405, 17.7.1984 (MDI) Selangor, MARDI Serdang, Mohd Norfaizal, G. MNFG7676, 21.7.2015 (MDI)
<i>Lepisanthes fruticosa</i>	W.P. Kuala Lumpur, Hutan Simpan Bukit Nanas, Abdul Rahman FRI118690, 26.2.1918 (KEP) Johor, Gunung Panti, B. Everett FRI8684, 21.1.1970 (KEP) Johor, Gunung Panti, K.M. Kochummen FRI115591, 5.3.1980 (KEP) W.P. Kuala Lumpur, Jalan Nakhoda Yusoff, K.M. Kochummen FRI119270, 15.2.1981 (KEP) Terengganu, Kuala Berang, Mohd Norfaizal, G. MNFG2323, 18.5.2015 (MDI) Johor, Pontian, Mohd Norfaizal, G. MNFG2324, 20.6.2015 (MDI) Selangor, MARDI Serdang, Mohd Norfaizal, G. MNFG2328, 19.7.2015 (MDI)
<i>Lepisanthes rubiginosa</i>	Johor, Pulau Aur, M.R. Henderson FRI115558, 28.4.1927 (KEP) Kedah, Yan, Gunung Jerai, L.G. Saw FRI85678, 29.3.2011 (KEP) Perak, Hutan Simpan Piah, Mohd Isa & Jaamal FRI11554, 15.2.1935 (KEP) W.P. Kuala Lumpur, Jalan Belengkok, Hamid FRI11556, 20.8.1919 (KEP) Terengganu, Kuala Berang, Mohd Norfaizal, G. MNFG2310, 18.5.2015 (MDI) Selangor, Serdang, Mohd Norfaizal, G. MNFG1963, 9.5.2014 (MDI) Selangor, Seri Kembangan, jalan Puchong, Mohd Norfaizal, G. MNFG1964, 9.5.2014 (MDI)
<i>Lepisanthes senegalensis</i>	Negeri Sembilan, Bahagian 8, Gunung Angsi, Loh Hong Shing FRI17357, 21.2.1971 (KEP) Perak, Hutan Simpan Gunung Bubu, T.C. Chan FRI17595, 21.3.1971 (KEP) Pahang, Kampung Aur, T. Suppiah FRI14769, 18.2.1971 (KEP) Negeri Sembilan, Hutan Simpan Pasoh, Mat Asri FRI21664, 2.3.1976 (KEP) Johor, Pontian, Benut, Kamaruddin Salleh MDI6175, 10.9.1988 (MDI)

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<i>Lepisanthes tetraphylla</i>	Negeri Sembilan, Jelebu, Kg. Pantai, J.V. La Frank FRI6006, NIL (KEP) Terengganu, Ulu Terengganu, Kuala Petang, Sungai Trenggun, P.F. Cockburn FRI8427, 3.6.1968 (KEP) Terengganu, Bukit Bauk, Bahagian 20B, S. Chelliah FRI104370, 19.6.1967 (KEP) Hutan Simpan Gunung Lesong, S.K. Yap FRI15491, 24.8.1928 (KEP) Perak, Manong, Bukit Bubu, S. Anthony FRI3914, 7.5.2005 (KEP) Terengganu, Tasik Kenyir, Pulau Tekak Besar, Mohd Norfaizal, G. & Masrom, H. MDI7457, 8.7.2012 (MDI) Terengganu, Tasik Kenyir, Pulau Tekak Besar, Mohd Norfaizal, G. & Masrom, H. MDI7458, 9.7.2012 (MDI)
<i>Litchi chinensis</i>	Negeri Sembilan, Hutan Simpan Bukit Tampin, S.K. Yap FRI82228, 23.9.1982 (KEP) Negeri Sembilan, Hutan Simpan Bukit Tampin, Loh Hong Shing FRI82225, 29.5.1970 (KEP) Selangor, Serdang, Plot C, Arboretum MARDI, Mohd Norfaizal, G. MDI 7896, 27.2.2015 (MDI)
<i>Nephelium costatum</i>	Selangor, Hulu Langat, Batu 18, Baharudin Alias FRI118955, 8.12.1971 (KEP) Pahang, Hutan Sekunder Tasik Bera, Y.C. Chan FRI16920, 20.7.1972 (KEP) W.P. Kuala Lumpur, Ramli, Z. KEP98852, NIL (KEP) Negeri Sembilan, Kuala Pilah, Mat Asri FRI25652, 2.8.1976 (KEP) Negeri Sembilan, Hutan Simpan Ulu Bendul, MDI1207 (MDI) Selangor, Bukit Cherakah, MASrom, H. MDI7539, 7.4.1993 (MDI)
<i>Nephelium cuspidatum</i> var. <i>robustum</i>	Sabah, Iahad Datu, KM 63, Masrom, H. FRI46627, 7.4.1993 (KEP) Sarawak, Kapit, Bukit Raja, E. Wright FRI202756, 23.10.1965 (KEP) Negeri Sembilan, Hutan Simpan Pasoh, S.K. Yap FRI100422, 7.3.1976 (KEP) Sabah, Tawau, Hutan Simpan Membawa, F. Krispinus FRI10, 7.4.1977 (KEP) Sabah, Tenom, Kg. Batu-batu, Mohd Norfaizal, G. MNFG3001, 4.4.2012 (MDI)
<i>Nephelium cuspidatum</i> var. <i>eriopetalum</i>	Negeri Sembilan, Hutan Simpan Pasoh, Mat Asri FRI91124, 3.8.1976 (KEP) Kedah, Gunung Jerai, F.S.P. Ng FRI117269, 2.6.1978 (KEP) Selangor, Hutan Simpan Ampang, Ang Khor Cheng FRI116604, 20.5.1989 (KEP) Negeri Sembilan, Hutan Simpan Pasoh, S.K. Yap FRI117270, 24.3.1976 (KEP) Perak, Tapah, Hutan Simpan Chikus, Wong, S.M. FRI117281, 9.1.1972 (KEP) Sarawak, Serian, Kg. Kakeng, Mohd Norfaizal, G. MNFG3003, 3.2.2012 (MDI)
<i>Nephelium cuspidatum</i> var. <i>multinerve</i>	Sabah, Padawan, Stabut, James Dawos Mamit FRI11, 9.1.1970 (KEP) Sarawak, Sibuti, Masrom, H. MDI9490, 16.9.2009 (KEP)
<i>Nephelium cuspidatum</i> var. <i>ophoides</i>	Negeri Sembilan, Rembau, J.V. La Frankie FRI103164, 28.2.1988 (KEP) Negeri Sembilan, Hutan Simpan Pasoh, S.K. Yap FRI118609, 14.3.1962 (KEP) Negeri Sembilan, Hutan Simpan Pasoh, Mohd Bin Mohd Sakat FRI118607, 4.8.1976 (KEP) Pahang, Jengka, Khairuddin FRI116618, 16.3.1989 (KEP) Sabah, Papar, Kg. Merchang, Masrom, H. MDI-4346-GEF, 25.3.2013 (MDI)
<i>Nephelium uncinatum</i>	Pahang, Jengka, Khairuddin FRI33812, 15.3.1989 (KEP) Kedah, Changloon, Hutan Rekreasi Bukit Wang, Marzalina Mansor FRI37752, 18.7.1989 (KEP) Selangor, Hutan Simpan Ulu Gombak, Batu 19, S.K. Yap FRI28994, 26.8.1980 (KEP) Sabah, Papar, Masrom, H. MDI4347, 10.10.2013 (MDI)
<i>Nephelium juglandifolium</i>	Perak, Kuala Kangsar, Kota Lama Kanan, Kg. Batang Kulim, Ahamd Damanhuri FRI35690, 15.2.1986 (KEP) Kelantan, Gua Musang, Hutan Simpan Galas, Loh Hong Shing FRI19280, 24.2.1972 (KEP) Negeri Sembilan, Seremban, S.K. Yap FRI64451, 29.7.1987 (KEP) Negeri Sembilan, Kuala Pilah, Bukit Putus, Masrom, H. MDI2356, 7.8.2014 (MDI)
<i>Nephelium hamumalatum</i>	Negeri Sembilan, Port Dickson, Hutan Simpan Sungai Menyala, S.K. Yap, FRI64551, 17.9.1987 (KEP) Negeri Sembilan, Port Dickson, Hutan Simpan Sungai Menyala, S.K. Yap, FRI100415, 17.9.1987 (KEP) Negeri Sembilan, Hutan Simpan Pasoh, S.K. Yap FRI25630, 15.7.1976 (KEP) Pahang, Hutan Tasik Bera, S.K. Yap FRI16973, 26.7.1972 (KEP) Selangor, Hutan Simpan Bangi, Mohd Norfaizal, G. MNFG1567, 9.9.2012 (MDI)
<i>Nephelium lappaceum</i> var. <i>lappaceum</i>	Kelantan, Gua Musang, Kg. Seta, Husmady, H., Ridzuan, A.H. & Boya, B. FRI39707, 26.3.1992 (KEP) Johor, Muar, Simpang Jeram, Husmady, H., Ridzuan, A.H. & Boya, B. FRI85085, 17.6.1992 (KEP) Hutan Simpan Sungai Menyala, Wyatt, Smith FRI64805, 17.6.1947 (KEP) Melaka, Tangga Batu, Mohd Norfaizal, G. MDI2358, 9.8.2014 (MDI) Johor, Muar, Jalan Temenggong Ahmad, Parit Keroma, Mohd Norfaizal, G. MDI6578, 31.8.2014 (MDI) Selangor, Kajang, Sg. Ramal Dalam, Mohd Norfaizal, G. MDI6600, 9.11.2015 (MDI)
<i>Nephelium melanomiscum</i>	Sarawak, Divisi 7, Ulu Sungai Belaga, Illias Paie S43820, 2.11.1981 (KEP) Sarawak, Limbang, Ulu Sungai Medamit, E. Wright & Othman Ismail S32264, 10.10.1972 (KEP) Sarawak, Serian, Kg. Kakeng, Masrom, H. & Mohd Norfaizal, G. MDI5413-GEF, 12.5.2012 (MDI)

Table 1 continued...

<i>Nephelium laurinum</i>	Johor, Kota Tinggi, Sungai Sedili Kechil, E.J.H. Corner FRI28572, 18.6.1934 (KEP) Kelantan, Rantau Panjang, NIL FRI17108, 8.5.1929 (KEP) Perak, Tanjung Malim, Mohd Norfaizal, G., Masrom, H. & Salmaniza, S. MDI345, 6.7.2015 (MDI)
<i>Nephelium maingayi</i>	W.P. Kuala Lumpur, Kg. Datuk Keramat, F. Remy & L.E. Teoh KL4075, 16.8.1991 (KEP) Johor, Mersing, Ahmad Abdullah KL77856, NIL (KEP) Negeri Sembilan, Seremban, Hutan Simpan Berembun, Ang Koon Cheong FRI27878, 5.2.1965 (KEP) Selangor, MARDI Serdang, Arboretum Plot C, Mohd Norfaizal, G., Masrom, H. & Salmaniza, S. MNFG4349-GEF, 5.5.2015 (MDI) Selangor, Seri Kembangan, Arboretum Jalan Puchong, Mohd Norfaizal, G., Masrom, H. & Salmaniza, S. MNFG3003, 5.5.2015 (MDI)
<i>Nephelium melliferum</i>	Terengganu, Gunung Kerbat, T.C. Whitmore FRI20336, 30.6.1976 (KEP) Kelantan, Gua Musang, C. Wiart & L.E. Teo KE4526, 3.8.1995 (KEP) Perak, Seberang Perak, Kg. Gajah, NIL KEP93323, 6.4.1959 (KEP) Selangor, Seri Kembangan, Arboretum Jalan Puchong, Mohd Norfaizal, G., Masrom, H. & Salmaniza, S. MNFG3006, 6.5.2015 (MDI)
<i>Nephelium ramboutan-ake</i>	Selangor, Bukit Lanjan, P.F. Cockburn FRI82306, 20.10.1967 (KEP) Terengganu, Hulu Terengganu, Kg. Tersat, Husmady, H. Ridzuan, A. & Ayau, A.H. FRI82305, 17.7.1992 (KEP) Ulu Kelantan, Hutan Simpan Ulu Lebir, T. Suppiah FRI13.8.1970, 13.8.1970 (KEP) Selangor, Sungai Ramal Dalam, Mohd Norfaizal, G. MNFG2007, 23.4.2014 (MDI) Selangor, Seri Kembangan, Arboretum Jalan Puchong, Masrom, H. MDI5679, 7.3.2013 (MDI)
<i>Mischocarpus sundaicus</i>	Terengganu, Pantai Gong Badak, Mohd Shah & Sidek, FRI48219, 23.11.1978 (KEP) Pahang, Pekan, Burkill, I.H. & Haniff FRI167900, 30.11.1924 (KEP) Perak, Hutan Pangkor, Saw 167894, 21.7.1953 (KEP) Perak, Pangkor, Lumut, Aziz Budin FRI167901, 30.9.1952 (KEP) Selangor, Hulu Bernam, Mohd Norfaizal, G. MNFG2009, 6.4.2015 (MDI)
<i>Mischocarpus pentapedalus</i>	Selangor, FRIM Kepong, S.K. Yap FRI2495, 7.7.1987 (KEP) Johor, Segamat, Hutan Simpan Labis, L.G. Saw FRI34228, 1.5.1980 (KEP) Perak, Gerik, G. Bront KL4327, 1.2.1994 (KEP) Kelantan, Tanah Merah, Kuala Rek, S.K. Yap FRI10183, 10.1.1987 (KEP) Selangor, Serdang, Bukit Datuk, Masrom, H. MDI5467, 16.5.2015 (MDI)
<i>Paranephelium macrophyllus</i>	Perak, Kuala Kangsar, Keledang Siong, NIL FRI30491, 23.2.1982 (KEP) Perak, Perak Utara, Hutan Simpan Bintang Hijau, Y.C. Chan FRI13317, 28.2.1970 (KEP) Perak, Ipoh, Ng. FRI1603, 15.10.1966 (KEP) Perak, Temenggong, Kuala Sungai Tiang, Mohd Norfaizal, G., Masrom, H. & Mohd Khairuddin MNFG3017, 10.9.2015 (MDI) Selangor, MARDI Serdang, Arboretum Plot B, Mohd Norfaizal, G. & Salmaniza, S. MNFG2989, 17.6.2015 (MDI) Selangor, MARDI Serdang, Arboretum Plot C, Mohd Norfaizal, G. & Salmaniza, S. MNFG2990, 19.6.2015 (MDI)
<i>Pometia pinnata</i> f. <i>pinnata</i>	Johor, Segamat, Hutan Simpan Labis, Ahamd Damanhuri FRI36651, 12.7.1991 (KEP) Pahang, Jerantut, Hutan Simpan Som, L.e.Teo & Din KL5739, 23.7.2010 (KEP) Selangor, Gombak, Ulu Gombak, F.S.P. Ng FRI22101, 24.7.1974 (KEP) Selangor, Cyberjaya, Taman Tasik Perdana Barat, Mohd Norfaizal, G. MNFG2990, 19.6.2015 (MDI) Selangor, MARDI Serdang, Mohd Norfaizal, G. MNFG3231, 17.6.2015 (MDI)
<i>Pometia pinnata</i> f. <i>glabra</i>	Kedah, Baling, Mohd Norfaizal, G. MNFG3232, 20.7.2015 (MDI) Johor, Muar, Mohd Norfaizal, G. MNFG3240, 31.8.2015 (MDI) Johor, Muar, Sg. Mati, Mohd Norfaizal, G. MNFG3241, 31.8.2015 (MDI)
<i>Pometia pinnata</i> f. <i>macrocarpa</i>	Selangor, Serdang, Arboretum Plot B, Mohd Norfaizal, G. MNFG3243, 2.9.2015 (MDI) Negeri Sembilan, Seremban, Mohd Norfaizal, G. MNFG3245, 4.9.2015 (MDI)
<i>Trigonachras acuta</i>	Pahang, Balok, Sungai Belong, A, Berhaman FRI134464, 28.2.1992 (KEP) Sabah, Hutan Simpan Sepilok, Amin Gambaling FRI94580, 21.5.1982 (KEP) Sabah, Kota Belud, NIL FRI49371, 22.4.1966 (KEP) Sabah, Sandakan, Sg. China, Termiji Rasid SAN88083, 12.4.1978 (SAN) Pahang, Pekan, Sg. Bebar, Mohd Norfaizal, G. MNFG6709, 3.1.2015 (MDI) Perak, Tanjung Malim, Mohd Norfaizal, G. MNFG6890, 3.2.2015 (MDI)
<i>Xerospermum noronhianum</i>	Pahang, Rompin, Hutan Simpan Lesong, Rohana Idris FRI47591, 3.7.1974 (KEP) Perak, Gunung Bubu, Y.C. Chan FRI17566, 16.3.1971 (KEP) Terengganu, Dungun, Bukit Besi, K.M. Kochummen FRI2396, 18.6.1987 (KEP) Pahang, Taman Negara Kuala Tahan, Ang Khoon Cheng FRI23376, 25.4.1975 (KEP) Selangor, MARDI Serdang, Arboretum Plot C, Mohd Norfaizal, G. MNFG8767, 13.6.2015 (MDI) Selangor, Puchong, Hutan Simpan Ayer Hitam, Masrom, H. MDI2890, 5.5.2000 (MDI)

Table 2. Variation in the areolar and marginal venation pattern in Sapindaceae taxa studied

Taxa	Type of marginal venation		Type of veinlets				
	Incomplete	Closed	None veinlet	Simple (linear to curved)	uni-veinlet	bi-veinlet	tri-veinlet
<i>Allophylus cobbe</i>	+					+	
<i>Amesiodendron chinense</i>	+			+			
<i>Arytera littorale</i>	+				+		
<i>Cardiospermum halicacabum</i>	+			+			
<i>Dimocarpus longan</i> ssp. <i>malesianus</i>		+				+	
<i>Dimocarpus longan</i> var. <i>longan</i>		+				+	
<i>Dimocarpus fumatus</i>		+		+			
<i>Dodonaea viscosa</i>		+		+			
<i>Filicium decipiens</i>	+					+	
<i>Ganophyllum falcatum</i>	+					+	
<i>Glenea penangensis</i>	+			+			
<i>Guioa bijuga</i>	+				+		
<i>Guioa pleuopteris</i>	+				+		
<i>Guioa diplopetala</i>	+				+		
<i>Harpullia arborea</i>	+						+
<i>Lepisanthes amoena</i>	+				+		
<i>Lepisanthes rubiginosa</i>	+				+		
<i>Lepisanthes senegalensis</i>	+			+			
<i>Lepisanthes fruticosa</i>	+						+
<i>Lepisanthes tetraphylla</i>		+		+			
<i>Litchi chinensis</i>	+		+				
<i>Mischocarpus pentapendalus</i>		+		+			
<i>Mischocarpus sundaicus</i>		+			+		
<i>Nephelium cuspidatum</i> var. <i>robustum</i>	+						+
<i>Nephelium cuspidatum</i> var. <i>eriopetalum</i>	+					+	
<i>Nephelium cuspidatum</i> var. <i>multinerve</i>		+		+			
<i>Nephelium cuspidatum</i> var. <i>ophoides</i>	+			+			
<i>Nephelium laurinum</i>	+				+		
<i>Nephelium juglandifolium</i>	+				+		
<i>Nephelium lappaceum</i>	+					+	
<i>Nephelium maingayi</i>	+						+
<i>Nephelium hamumalatum</i>	+					+	
<i>Nephelium melanomiscum</i>	+						+
<i>Nephelium melliferum</i>	+			+			
<i>Nephelium ramboutan-ake</i>	+					+	
<i>Nephelium uncinatum</i>	+						+
<i>Paranephelium macrophyllum</i>	+			+			
<i>Pometia pinnata</i> f. <i>glabra</i>	+						+
<i>Pometia pinnata</i> f. <i>macrocarpa</i>	+						+
<i>Pometia pinnata</i> f. <i>pinnata</i>	+						+
<i>Trigonacharas acuta</i>	+					+	
<i>Xerospermum noronhianum</i>		+		+			

presence of swollen veinlets or swollen tracheid's, cystolith cells and trichomes can also be used as additional characters for the differentiation of taxa among groups. For example, swollen veinlets are present in *Allophylus cobbe* (L.) Raeusch (Figure 4B) and trichomes on the leaf venation can be observed in *Cardiospermum halicacabum* L. (Figure 4C).

A total of 43 taxa belonging to 19 genera were extensively studied for their leaf venation patterns and the results are summarised in Table 4. Five veinlet patterns were observed from this study,

namely no ending veinlets, simple and linear veinlets, uni-veinlets, bi-veinlets and tri-veinlets. In particular, two species include *Litchi chinensis* Sonn. and *Dimocarpus fumatus* Leenh. showed no ending veinlets and this is diagnostic for them. While others showed either uni-, or simple and linear, or bi- or tri-veinlets and these can be the diagnostic characters for taxa identification.

Two types of ultimate marginal venation were observed in this study. Type 1 is an incomplete ultimate marginal venation, consisting of freely ending veinlets directly adjacent to the margin and

this is showed by 34 taxa (Figure 1A-H). Type 2 is a complete or closed ultimate marginal venation, which refers to higher vein order fused into a vein running just inside the margin and showed by only nine taxa (Figure 2A-H). From the areolar venation observed, it also showed clearly two types of areolar venation, namely Type 1, for which the majority of the leaf venation which consists of incomplete ending veinlets (Figures 3A, B, C & E) and Type 2,

a closed venation (Figure 3D), that is observed only in *Litchi chinensis* Sonn. and *Dimocarpus fumatus* Leenh.

Cluster analysis using *Gower General Similarity Coefficient* was performed using 11 characters such as the leaf marginal venation, areolar venation and diagnostic characters (Table 3). It is clearly shown that two main clusters were obtained with similarity index 0.5. Cluster I contain 9 taxa and can be further

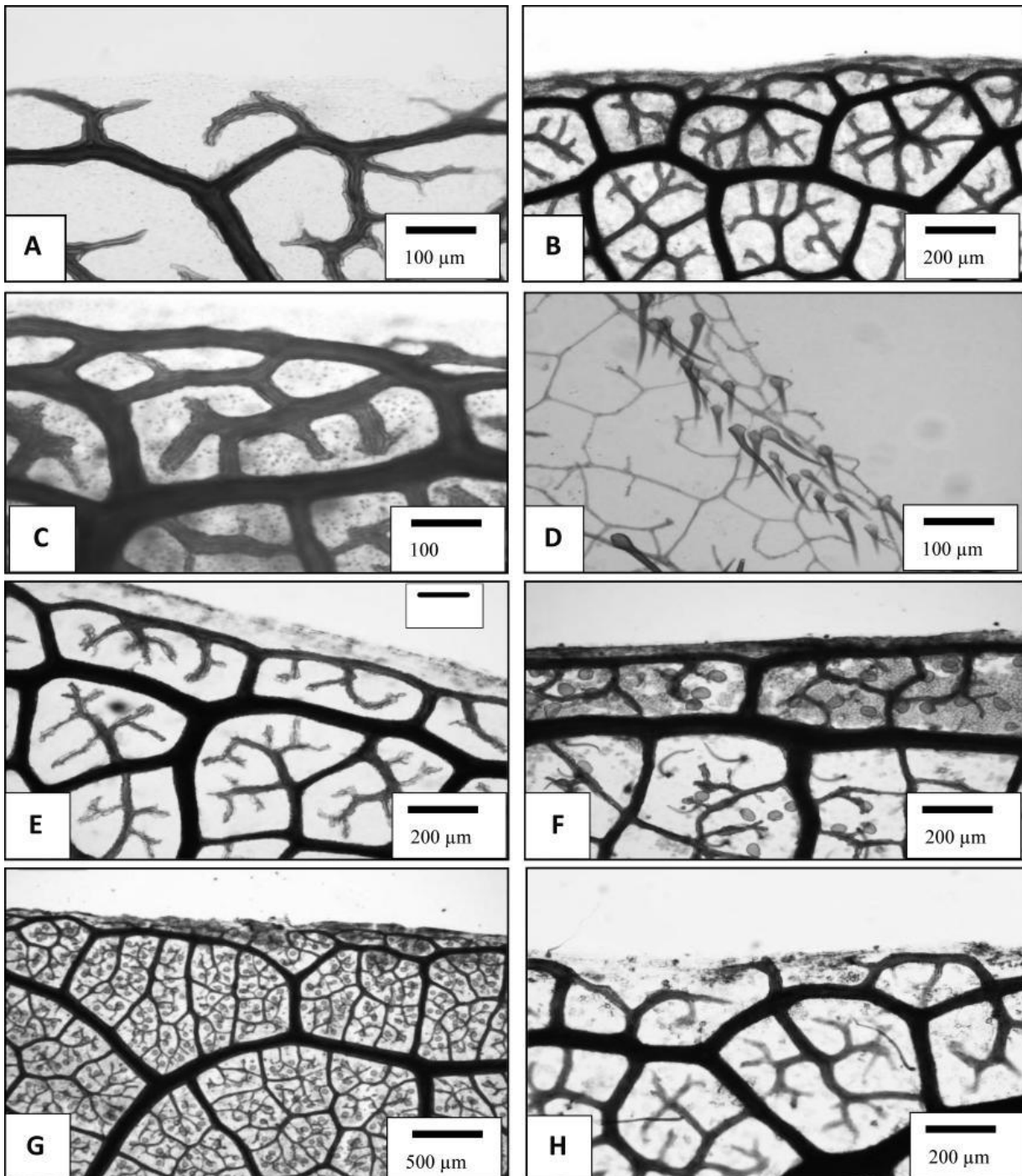


Fig. 1. Ultimate marginal venation in Sapindaceae. A. *Allophylus cobbe*, B. *Amesiodendron chinense*, C. *Arytera littorale*, D. *Cardiospermum halicacabum*, E. *Lepisanthes amoena*, F. *Guioa bijuga*, G. *Guioa pleuropteris* and H. *Paranephelium macrophyllum*.

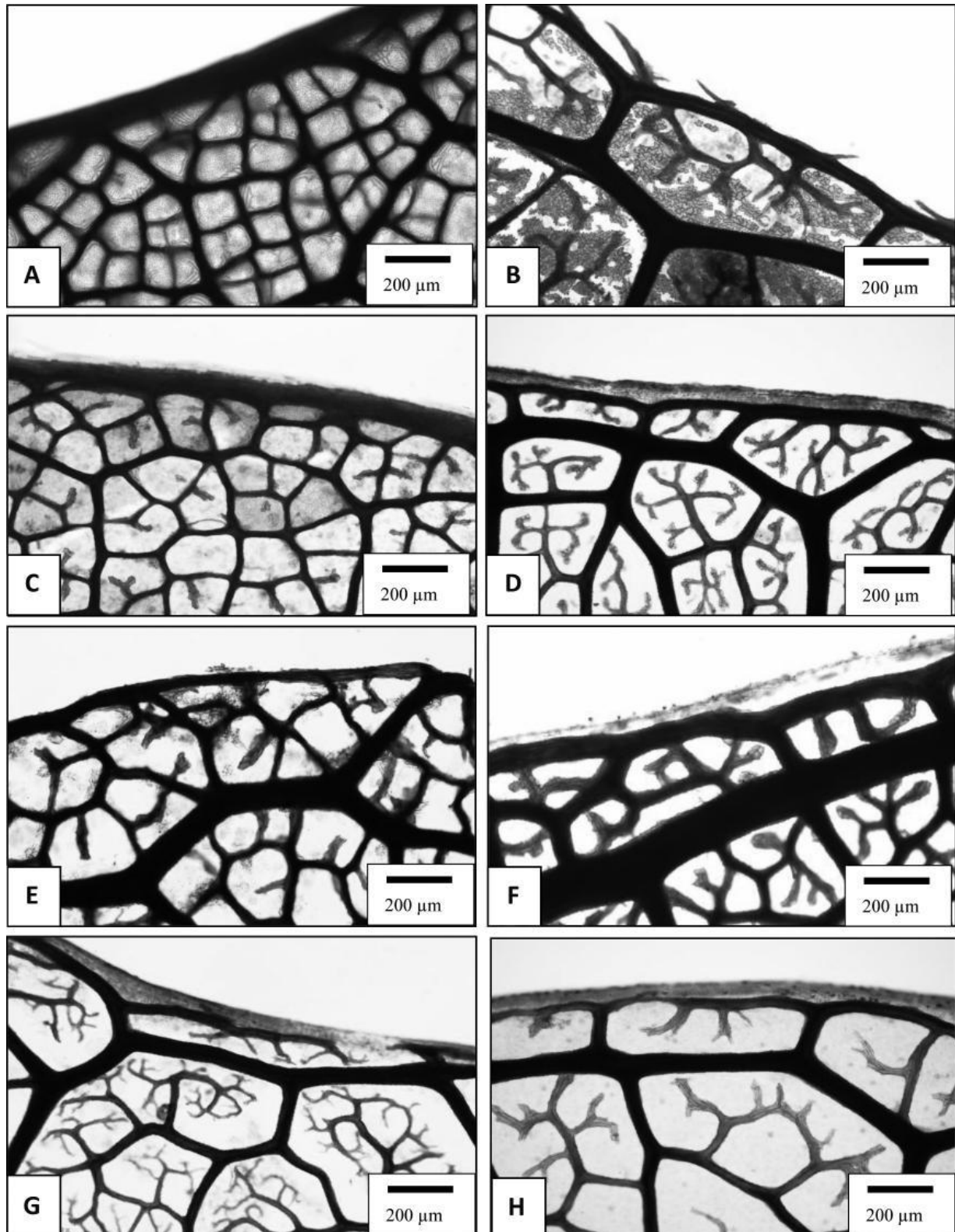


Fig. 2. Ultimate marginal venation in Sapindaceae (continued) A. *Litchi chinensis*, B. *Lepisanthes tetraphylla*, C. *Mischocarpus pentapetalus*, D. *Mischocarpus sundaicus*, E. *Nephelium cuspidatum* var. *multinerve*, F. *Nephelium cuspidatum* var. *eripetalum*, G. *Pometia pinnata* and H. *Xerospermum noronhianum*.

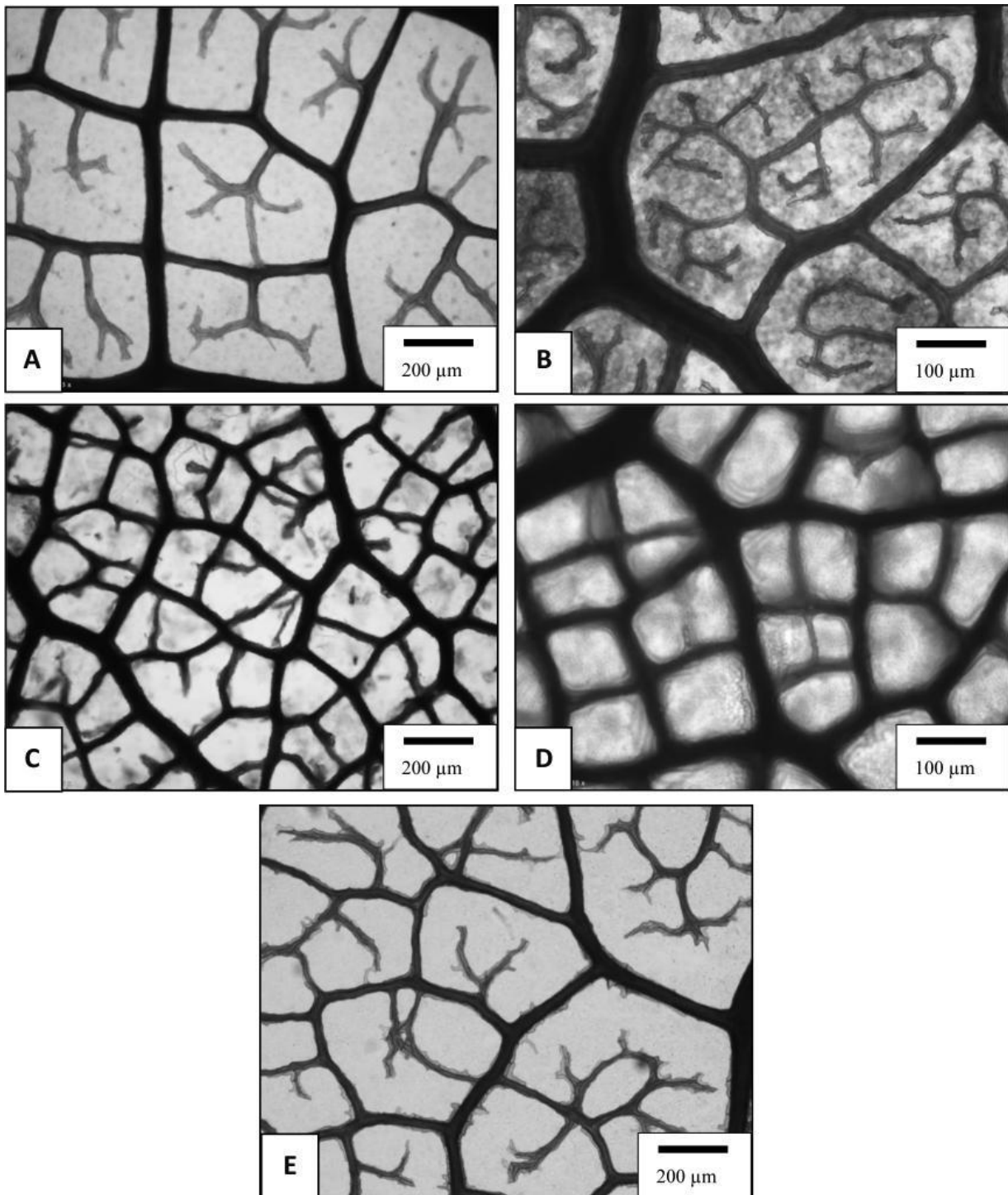


Fig. 3. Areolar venation in Sapindaceae A. Uni-veinlets, B. Tri-veinlets, C. Simple and uni-veinlets, D. No ending-veinlet and E. Bi-veinlets.

discerned into 4 sub clusters IA-ID with similarity index 0.72. Sub cluster IA consists of *Lepisanthes tetraphylla* (Vahl.) Radlk., sub cluster IB consists of *Nephelium cuspidatum* var. *multinerve* (Radlk.) Leenh., *Mischocarpus sundaicus* Blume, *M. pentapetalus* (Roxb.) Radlk. and *Dodonaea viscosa* Jacq., sub cluster IC consists of *Litchi chinensis* Sonn. and *Dimocarpus fumatus* Leenh. while sub

cluster ID contains *Dimocarpus longan* var. *longan* Leenh. and *D. longan* var. *malesianus* Leenh. All those taxa clustered in Cluster I shared the same character of closed marginal venation type.

Cluster II with similarity index 0.71 also consists of 4 subclusters too, IIA – IID. Subcluster IIA (similarity index 0.85) consists of *Para-nephelium macrophyllum* King, *Nephelium*

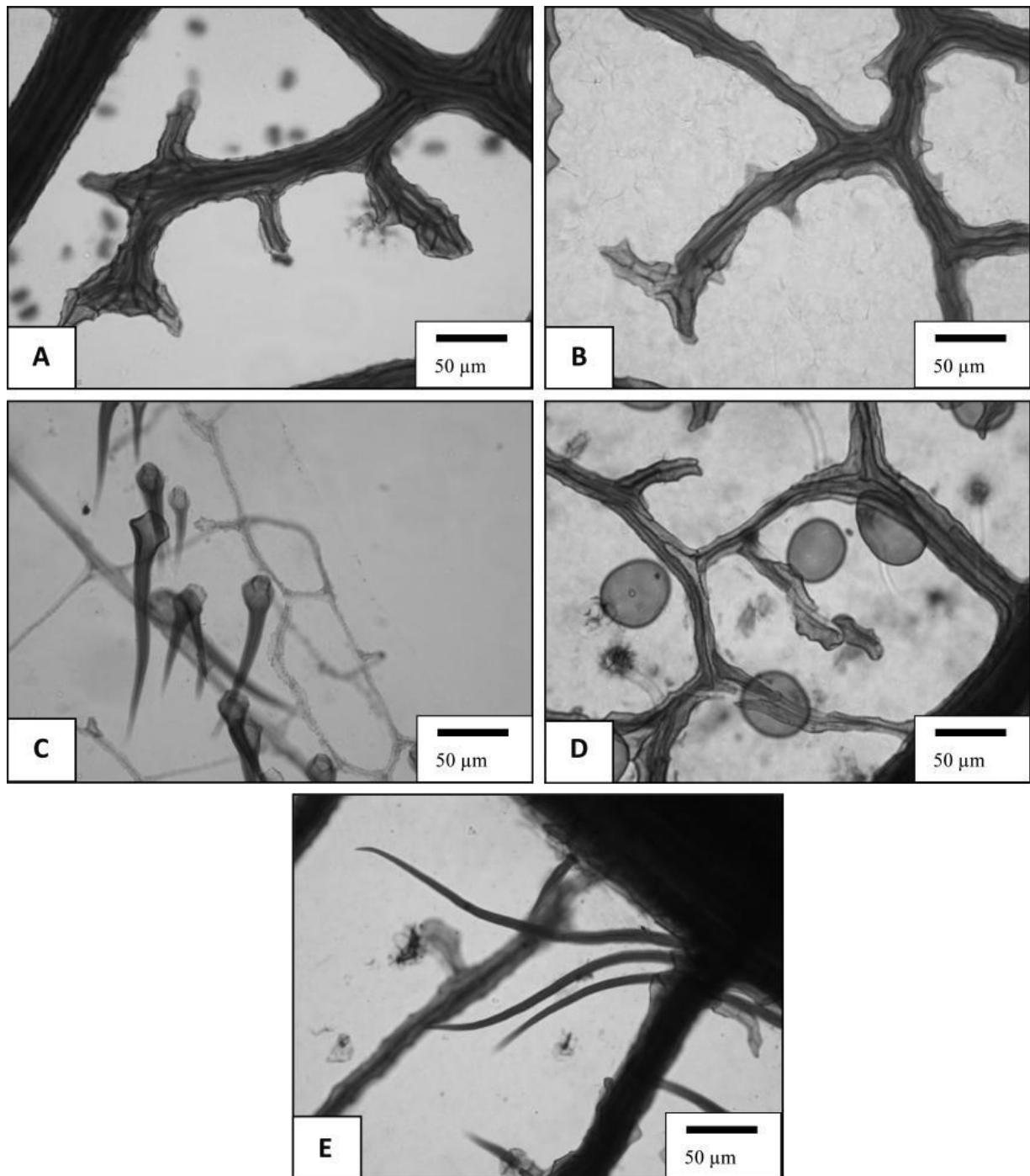


Fig. 4. Other anatomical characters in the veins of Sapindaceae. A. Druses on the leaf lamina surface observed in *Filicium decipiens*, B. Swollen tracheid's in *Allophyllus cobbe*, C. Simple trichomes restricted on the leaves margin in *Cardiospermum halicacabum*, D. Idioblast cells observed in *Guioa* spp. and E. Simple trichomes observed on leaves lamina of *Glennia penangensis*.

melliferum Gagnep., *N. cuspidatum* var. *ophoides* Blume, *Lepisanthes senegalensis* (Poir.) Leenh., *Cardiospermum halicacabum* L. and *Amesiodendron chinense* (Merr.) Hu, Subcluster IIB (similarity index 0.73) contains *Pometia pinnata* f. *pinnata* J.R. Forst. & G. Forst., *P. pinnata* f. *glabra* J.R. Forst. & G. Forst., *P. pinnata* f. *macrocarpa* J.R. Forst. & G. Forst., *N. uncinatum* Radlk. ex Leenh.,

N. melanomiscum Radlk., *N. maingayi* Hiern., *N. cuspidatum* var. *robustum* Blume, *Harpullia arborea* (Blanco.) Radlk. and *Lepisanthes fruticosa* (Roxb.) Leenh., Subcluster IIC (similarity index 0.85) consists of *Xerospermum noronhianum* (Blume) Blume, *N. juglandifolium* Blume, *N. laurinum* Blume, *Lepisanthes rubiginosa* (Roxb.) Leenh., *L. amoena* (Hassk.) Leenh., *Guioa diplopetala* (Hassk.)

Table 3. Leaf venation characteristics used in MVSP analysis

Type of characteristics	Scoring details	Analysis
Ultimate marginal venation	1. Complete or closed	Yes (1) No (0)
	2. Incomplete	Yes (1) No (0)
Areolar venation	3. Incomplete	Yes (1) No (0)
	4. Complete or Closed	Yes (1) No (0)
	5. No veinlet	Yes (1) No (0)
Type of veinlets	6. Simple veinlets (linear-curved)	Yes (1) No (0)
	7. Bi-veinlets	Yes (1) No (0)
	8. Tri-veinlets	Yes (1) No (0)
Other characters	9. Idioblasts appearance	Yes (1) No (0)
	10. Druses present	Yes (1) No (0)
	11. Trichomes present	Yes (1) No (0)

Radlk., *G. pleuropteris* (Blume) Radlk., *Filicium decipiens* (Wight & Arn.) Thwaites and *Arytera littoralis* Blume and finally subcluster IID (similarity index 0.70) consists of *Trigonachras acuta* (Hiern.) Radlk., *N. ramboutan-ake* (Labill.) Leenh., *N. hamulatum* Radlk., *N. cuspidatum* var. *eriopetalum* Blume, *Ganophyllum falcatum* Blume and *Allophyllus cobbe* (L.) Raeusch. A single species of *Guioa bijuga* (Hiern.) Radlk. was observed forming subcluster IIA.

Variation in types of veinlet combined with diagnostic characters such as idioblast and presence of druses or trichomes on the leaf surface observed in each taxon play important role in clustering all the taxa in Cluster II. There is no clear resolution in the clusters that delimit those taxa having complete or closed marginal venation or their areolar leaf venation type. Hence, it is suggested to combine these results with other anatomical and morphological evidences to get a better classification of Malaysian Sapindaceae.

However, delimitation for subfamilies was detected. Cluster I contain Sapindoideae, Nepheliaeae and Dodonoideae, while Cluster II consists members of Sapindoideae, Paullianaeae,

Nepheliaeae, Doratoxyleae and Thouinaeae. It is also showed that *Litchi*, *Dimocarpus* and *Nephelium* which are the closely related were clustered in Cluster I and support the close venation morphological relationship between these genera.

CONCLUSION

The observation of variable patterns of leaf venation is taxonomically significant in the Malaysian Sapindaceae because it can be used as additional evidences, mainly in the group (subfamilies and tribes) identification of taxa and also to directly differentiate Malaysian Sapindaceae taxa such as the genera *Guioa*, *Harpullia*, *Glenea* and species such as *Litchi chinensis*, *Xerospermum noronhianum* and *Dimocarpus fumatus* and the introduced *Filicium decipiens*. However, other taxa may require more anatomical characters such as petioles, midribs, lamina, margin, epidermal surfaces, stomata, anticlinal walls, amongst others and in combination with morphology they may be more useful in both generic and species identification and classification.

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