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Systematic Significance of Stipe Anatomy of *Selaginella* (Selaginellaceae) in Peninsular Malaysia

(Kepentingan Sistematik Anatomi Stip *Selaginella* (Selaginellaceae) di Semenanjung Malaysia)

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ABSTRACT

An anatomical study was carried out on 14 taxa belonging to Selaginellaceae in an attempt to study their stipe anatomical characteristics and to provide anatomical data for the selected taxa in Selaginellaceae. Out of 29 taxa of Selaginellaceae recorded in Peninsular Malaysia, 14 taxa have been selected namely *Selaginella alutacia*, *S. argentea*, *S. frondosa*, *S. intermedia* var. *intermedia*, *S. intermedia* var. *dolichocentrus*, *S. mayeri*, *S. morganii*, *S. ornata*, *S. plana*, *S. polita*, *S. roxburghii* var. *roxburghii*, *S. stipulata*, *S. wallichii* and *S. willdenowii*. Method used in this study was sectioning using sliding microtome. Findings in this study have shown that Selaginellaceae species studied can be clustered into two groups based on the stipe stellar systems, which are monostelic and tristelic groups. There are some variations exist in the cross sections of the stipes of the same species due to the presence and absence of the leaf trace. Each species is proved to have distinct stipe anatomical characteristics that can be used to differentiate species in Selaginellaceae.

Keyword: Anatomy; Peninsular Malaysia; Selaginellaceae; stele; stipe

ABSTRAK

Kajian anatomi telah dilakukan ke atas 14 takson daripada famili Selaginellaceae untuk melihat ciri anatomi stip dan menyediakan data anatomi untuk takson terpilih daripada famili Selaginellaceae. Sejumlah 14 daripada 29 takson Selaginellaceae yang terdapat di Semenanjung Malaysia telah dipilih iaitu *Selaginella alutacia*, *S. argentea*, *S. frondosa*, *S. intermedia* var. *intermedia*, *S. intermedia* var. *dolichocentrus*, *S. mayeri*, *S. morganii*, *S. ornata*, *S. plana*, *S. polita*, *S. roxburghii* var. *roxburghii*, *S. stipulata*, *S. wallichii* dan *S. willdenowii*. Kaedah yang digunakan dalam penyelidikan ini ialah hirisan dengan mikrotom gelongsor. Hasil kajian menunjukkan spesies Selaginellaceae boleh dikelompokkan kepada dua kumpulan berdasarkan sistem stel pada stip iaitu kumpulan monostelik dan tristelik. Terdapat variasi pada ciri anatomi keratan rentas stip dalam spesies yang sama disebabkan kehadiran dan ketidakhadiran kesan daun pada stip. Setiap spesies kajian dibuktikan mempunyai ciri anatomi stip yang berbeza yang boleh digunakan untuk pembezaan spesies dalam famili Selaginellaceae.

Kata kunci: Anatomi; Selaginellaceae; Semenanjung Malaysia; stel; stip

INTRODUCTION

The spikemoss family Selaginellaceae is an ancient group of lycopods which is a sister group to a clade of all living plants (Korall et al. 1999). The Selaginellaceae is classified together with Lycopodiaceae and Isoetaceae under the phylum Lycopphyta, while the remaining fern families are categorized into the phylum Monilophyta. Selaginellaceae is a monotypic heterosporous group of ferns comprising the genus *Selaginella*, which composed of an estimated 750 extant species. Most species in *Selaginella* are small and delicate and mainly occur in abundance in the tropical zones of the world (Foster & Gifford 1974). In Peninsular Malaysia, *Selaginella* is represented by 29 taxa, nine of which are endemic to the area (Parris & Latiff 1997; Wong 2010). The morphology of *Selaginella* has been studied and reviewed by Wong (1983, 2010). The identification of *Selaginella* depends much on the minute leaves which make it hard to differentiate because of the

rather similar leaf morphology. Hence, the anatomical data could be useful to identify and to distinguish species in the genus. The objectives of this research were to study the anatomical characteristics of the stipe of the selected species of *Selaginella* in Peninsular Malaysia and to find the useful anatomical characteristics that can be used in the identification of the species.

MATERIALS AND METHODS

A total of 14 taxa of *Selaginella* have been used in this study namely, *S. alutacia*, *S. argentea*, *S. frondosa*, *S. intermedia* var. *intermedia*, *S. intermedia* var. *dolichocentrus*, *S. mayeri*, *S. morganii*, *S. ornata*, *S. plana*, *S. polita*, *S. roxburghii* var. *roxburghii*, *S. stipulata*, *S. wallichii* and *S. willdenowii* (Table 1). The stipe of each species was sectioned using sliding microtome. The method used for sectioning was according to the protocol by Johansen

TABLE 1. The specimens collected for this study and their specific location is listed below

Species	Collectors & Collection No.	Locality
<i>Selaginella alutacia</i>	Razali Jaman, Masnoryante & Hazwani, NHA2011-09 (UKMB)	Selangor, Ulu Gombak
	Razali Jaman, Masnoryante & Hazwani, NHA2011-11, NHA2011-13 (UKMB).	Selangor, Sg. Semungkis
<i>Selaginella argentea</i>	Razali Jaman & Hazwani, NHA2011-29 (UKMB).	Selangor, Hutan Simpan Kekal UKM
<i>Selaginella frondosa</i>	Razali Jaman & Hazwani, NHA2011-30 (UKMB).	Selangor, Hutan Simpan Kekal UKM
<i>Selaginella intermedia</i> var. <i>dolichocentrus</i>	Razali Jaman, Masnoryante & Hazwani, NHA2011-20, NHA2011-21 (UKMB)	Selangor, Fraser's Hill, Pinetree Trail
<i>Selaginella intermedia</i> var. <i>intermedia</i>	Razali Jaman, Masnoryante & Hazwani, NHA2011-23 (UKMB).	Pahang, Cameron Highlands, Hutan Lipur Parit Fall
<i>Selaginella mayeri</i>	Razali Jaman, Masnoryante & Hazwani, NHA2011-03, NHA2011-04, NHA2011-05 NHA2011-06 (UKMB)	Selangor, Ulu Gombak
	Razali Jaman, Masnoryante & Hazwani, NHA2011-14 (UKMB).	Selangor, Sg. Semungkis
<i>Selaginella morganii</i>	Razali Jaman, Masnoryante & Hazwani, NHA2011-24 (UKMB).	Pahang, Cameron Highlands, Hutan Lipur Parit Fall
<i>Selaginella ornata</i>	Razali Jaman, Masnoryante & Hazwani, NHA2011-18, NHA2011-19 (UKMB)	Selangor, Fraser's Hill, Jeriau
	Razali Jaman, Masnoryante & Hazwani, NHA2011-22 (UKMB)	Pahang, Cameron Highlands, Hutan Lipur Parit Fall
<i>Selaginella plana</i>	Razali Jaman & Hazwani, NHA2011-31 (UKMB).	Selangor, Hutan Simpan Kekal UKM
<i>Selaginella polita</i>	Razali Jaman, Masnoryante & Hazwani, NHA2011-27 (UKMB).	Pahang, Cameron Highlands, Gunung Brinchang
<i>Selaginella roxburghii</i> var. <i>roxburghii</i>	Razali Jaman, Masnoryante & Hazwani, NHA2011-08 (UKMB)	Selangor, Ulu Gombak
	Razali Jaman, Masnoryante & Hazwani, NHA2011-12 (UKMB)	Selangor, Sg. Semungkis,
	Razali Jaman, Masnoryante & Hazwani, NHA2011-15, NHA2011-17 (UKMB).	Selangor, Ulu Kemensah
<i>Selaginella stipulata</i>	Razali Jaman, Masnoryante & Hazwani, NHA2011-16 (UKMB).	Selangor, Ulu Kemensah
<i>Selaginella wallichii</i>	Razali Jaman, Masnoryante & Hazwani, NHA2011-01 (UKMB).	Selangor, Ulu Gombak
<i>Selaginella willdenowii</i>	Razali Jaman, Masnoryante & Hazwani, NHA2011-02 (UKMB)	Selangor, Ulu Gombak

(1940) and Sass (1958) with some suitable modifications. The slide preparations were observed under light microscope and images were analysed using Analysis Docu Software.

RESULTS AND DISCUSSION

Based on the stipe anatomical characteristics, the *Selaginella* species studied can be clustered into two groups based on the number of stele in the cross section namely, monostelic and tristelic group (Figure 1). In the monostelic group, the stipes outline is variable from circular (*S. argentea*, *S. intermedia* var. *dolichocentrus*, *S. intermedia* var. *intermedia*, *S. morganii*, *S. ornata*, *S. polita* and *S. roxburghii* var. *roxburghii*), to elliptical (*S. alutacia*) and tetragonal (*S. frondosa*) in shape. In the

tristelic group, the stipes outline is variable from circular (*S. willdenowii*) and elliptical (*S. mayeri*, *S. plana*, *S. stipulata* and *S. wallichii*). Interspecific variations also occur in the stelar shapes, sizes and arrangements. Most species in the current study have flat or ribbon-shaped stele while in *S. mayeri* and *S. willdenowii*, both have circular and flat steel. The stele of *S. frondosa* shows a different shape where the both ends curve upwards and possess four protoxylems in the lower part of cross sections instead of two as in most of the species.

The cross sections of the stipe showed the presence of a large cortex. In some species, the cortex seems to be larger on the abaxial side than the adaxial side. Generally, the position of the stele in the monostelic group is at the center of the stipe or located at 1/3 from the adaxial side of the stipe. Likewise, the position of the stele in the tristelic

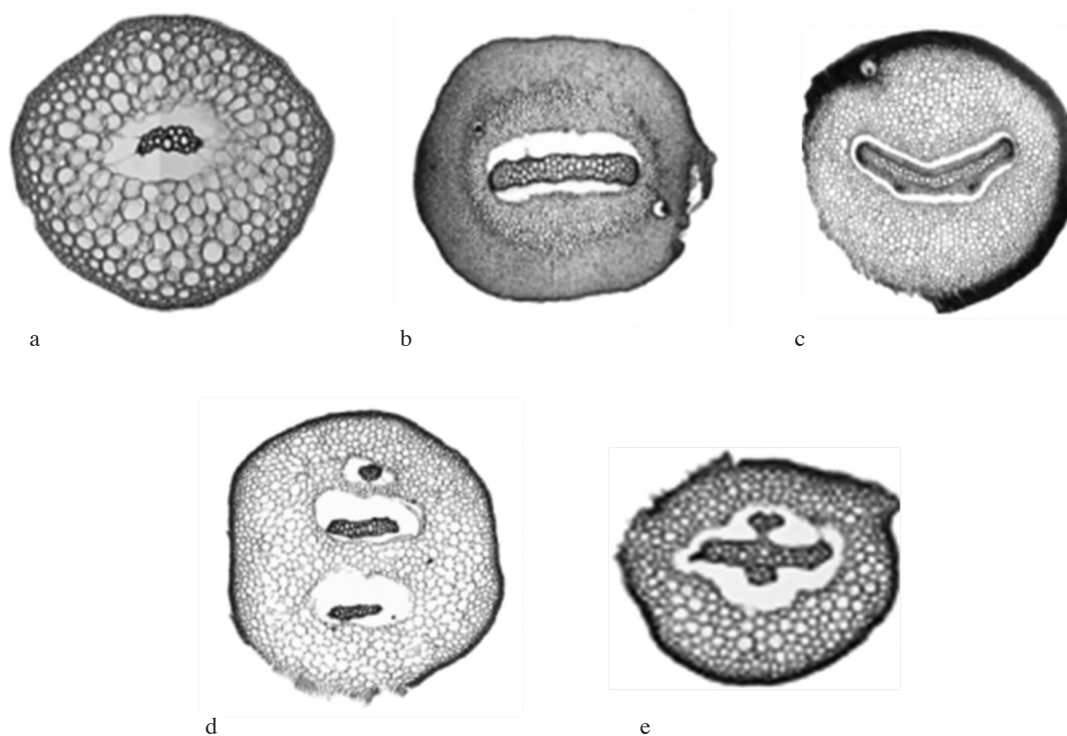


FIGURE 1. Monostelic group a) *S. argentea*, b) *S. alutacia* and c) *S. frondosa*;
Tristelic group d) *S. mayeri* and e) *S. willdenowii*

group is also at the center of the stipe where the meristemes are arranged parallel to each other, of which two external ones are somewhat shorter than those in the middle or the position of the stele can also be at the distance of 1/3 from the adaxial side, making the size of the cortex larger at abaxial than the adaxial side. The cortex in *Selaginella* is separated from the stele by a conspicuous intercellular spaces or lacuna. Each stele in monostelic and tristelic group is enclosed by the lacuna. For the tristelic group, each meristeme is enclosed by its very own lacuna except for *S. willdenowii* where the three meristemes shared one large lacuna.

The cross sections of the stipe of all species studied showed the epidermal layer consisting of one layer of thick walled cells. Trichome and stomata seems to be absence in all species studied. This result was found to be similar to those stated by Bold (1973), Ogura (1972) and Parihar (1965).

The cortex is composed of thin-walled, green, angular parenchymatous cells as a whole without intercellular air spaces. In most species with a rigid stipes, the cortex may be partially sclerenchymatous by forming a hypodermal sclerenchyma (Parihar 1965). According to Ogura (1972), the hypodermal layer can be found only in erect or sub-erect species and lacking in the creeping ones. However, in the current study, the hypodermal layers were also observed in the creeping stipes in *S. alutacia*. The collenchyma cells were absence in *Selaginella* species studied and are actually rare in most pteridophytes and

has only been reported in the stipe of *Tmesipteris* of the Psilotaceae (Ogura 1972).

The xylem consists of metaxylem and protoxylem. The pericycle is composed of single layer of large cells which lies in the phloem. The phloem is composed of parenchyma and sieve cells. Stipe anatomical features were reported to be suitable for the systematic study of fern because of the variations in shape of steles and the presence of sclerenchyma (Bidin & Anita 1995; Bidin & Aryati Masturi 1996; Ogura 1972).

CONCLUSION

Problems in species identification in *Selaginella* due to the similarities in morphological characteristics could be solved using anatomical characteristics. Based on the stipe anatomical characteristics, the *Selaginella* species studied were classified into the monostelic and tristelic groups. The stele observed in all species studied is of the primitive protostelic type. The monostelic stelar type is in the form of dorsiventral protostele where the flat xylem is provided with protoxylems at both ends.

The stele shape and size of the upper part and the lower part of the stipes belongs to the same species are found to be variable in some species. By combining the morphological and anatomical features of each species in this family, an identification key to species will make the identification process becomes easier with the more available data provided to distinguish each species in this family.

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