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PERFORATED RAY CELLS IN BATHYSA MERIDIONALIS (RUBIACEAE)

by

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SUMMARY

This paper describes the morphology and size of perforated ray cells in *Bathysa meridionalis* Smith & Downs and compares its features with the adjacent ray cells and vessel elements. The perforated ray cells are much bigger and more voluminous than normal ray cells. Their shapes vary from ellipsoid to polygonal. The perforation plates may be solitary to tree per wall, round to reniform. The dimensions of perforated ray cells suggest that they are at least as effective for water flow as axial vessel elements.

Key words: Rubiaceae, *Bathysa*, perforated ray cells, perforation plates.

INTRODUCTION

The genus *Bathysa* Presl (Rubiaceae) comprises 10 species (Mabberley 1987), distributed over Brazil and Peru. *Bathysa meridionalis* Smith & Downs can be found in both, the Atlantic rain forest and in the mesophytic deciduous forest in Southeast Brazil (Rossi 1994).

The wood anatomy of *Bathysa* is poorly known; *B. nicholsonii* had its microscopic features described by Luchi (1990), while *B. meridionalis* had its macroscopic features investigated by Mainieri (1973). The microscopic features of *B. meridionalis* were considered in a study of the tribes of the Rubiaceae (Koek-Noorman & Hogeweg 1974), but a detailed characterization is not available. This species was chosen for our study of perforated ray cell morphology because these cells are relatively abundant and are easily distinguished from vessel elements.

Perforated ray cells were first described by Chalk & Chattaway (1933). Their distribution through angiosperm families has been reviewed in many subsequent works (McLean & Richardson 1973; Nazma & Vijendra Rao 1981; Giraud 1983; Dayal et al. 1984; Vijendra Rao et al. 1984; IAWA Committee 1989; and others).

Chalk and Chattaway (1933) stated that perforated ray cells are much larger than surrounding cells, but later they were defined by the IAWA Committee (1989) as “cells of the same dimensions or larger than the adjacent cells, but with perforations …” In more recent works Eom & Chung (1996), Nagai et al. (1994) and Rudall (1985)

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also reported that perforated ray cells are larger than normal ray cells, but only Otegui (1994) gave measures of perforated ray cells. None of the cited works gives accurate information on the dimensions of the perforated ray cells and their relationship with other ray cells and vessel elements. The size of perforated ray cells seems to be relevant since cell dimensions may influence a possible role in water transport. This study aims at more detailed information on size and morphology of perforated ray cells.

MATERIAL AND METHODS

Three trees of *Bathysa meridionalis* were sampled with an increment borer at breast height in a semi-deciduous mesophytic forest at the Forest Reserve of the University of São Paulo (Reserva da 'Cidade Universitária Armando de Sales Oliveira'). The trees used were 25–40 cm in diameter at breast height (dbh) and 6–10 m tall. The material studied is kept at the Xylarium of the Instituto de Biociências da Universidade de São Paulo (samples numbered SPFw 003, 357, 358).

General observations were made on 10–20 mm sections stained with safranin and iodine green. For detailed examination of the perforated ray cells and perforation plates, thick sections (30–80 mm) with double staining (saffranin and Delafield's hematoxilin) were used. Macerations were prepared by using the modified Franklin's method (Berlyn & Miksche 1976) and stained in astrablue and Delafield's hematoxilin.

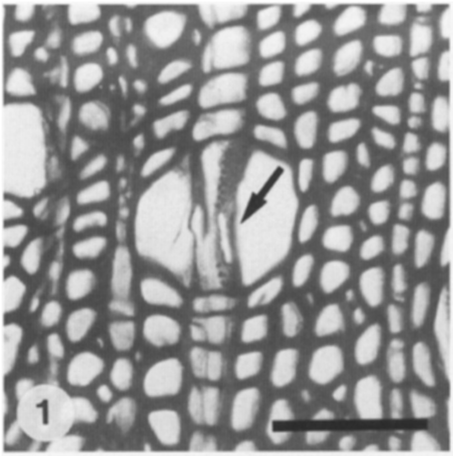
To measure the frequency of the perforation plates, 50 perforated ray cells were examined. Macerations were used to measure height and radial length of the normal and perforated ray cells**.** The lengths were measured from radial longitudinal sections, while width was measured from tangential longitudinal sections.

To compare perforated ray cells with ordinary cells, volume was used since it combines their length, width and height in one value. This method may be criticized since some cells do not resemble the shape of a six-sided polyhedron. On the other hand, it did not seem appropriate to calculate the ellipsoid volume. The other cells of the ray also present irregularities in such a way that the errors are regularly distributed, which makes the comparison of magnitudes valid.

A rough estimate of the cell volume (V) was given by: $V = RL \times H \times W$, where RL = radial length, H = height and W = width; the maximum dimensions were considered.

The estimate of the minimum number of measurements was made as suggested by Freese (1967) and Eckblad (1991). The means of the cell dimensions were compared with the t test (Costa-Neto 1977). Perforated ray cells were compared only with the square and upright marginal ray cells, since they do not occur adjacent to procumbent cells.

Fig. 1–6. *Bathysa meridionalis.* – 1: TS, perforated ray cell (arrow) in a uniseriate ray. – 2: TLS, perforated ray cell between two vessel elements (arrow). – 3: RTS, perforated ray cell with reniform perforation plate and pits in the rim. – 4: RTS, perforated ray cell with elliptical perforation plate. – 5: RTS, group of perforated ray cells in a thick section (arrows). Perforation reniform and elliptical. – 6: Maceration, vessel element with two elliptical perforation plates. — Scale bar for Fig. 1, 2, 5 & 6 = 100 μm; for 3 & 4 = 50 μm.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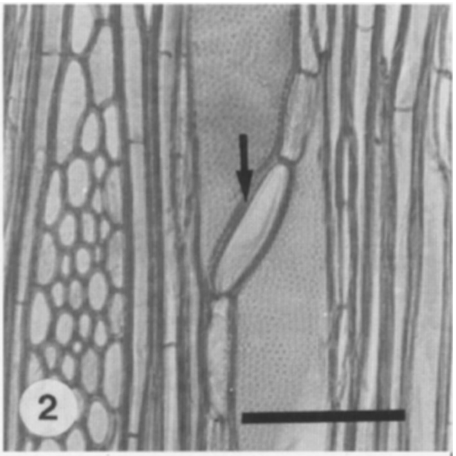
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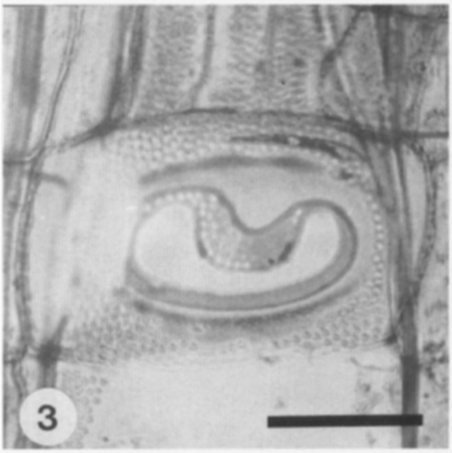
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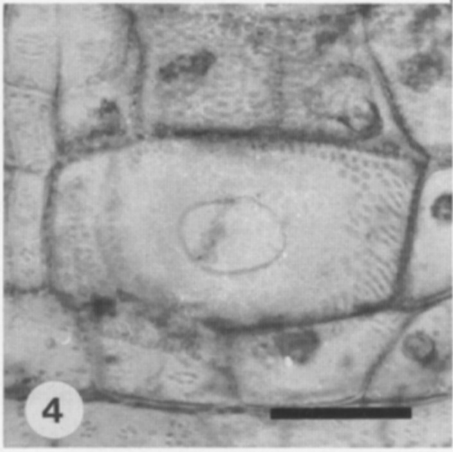
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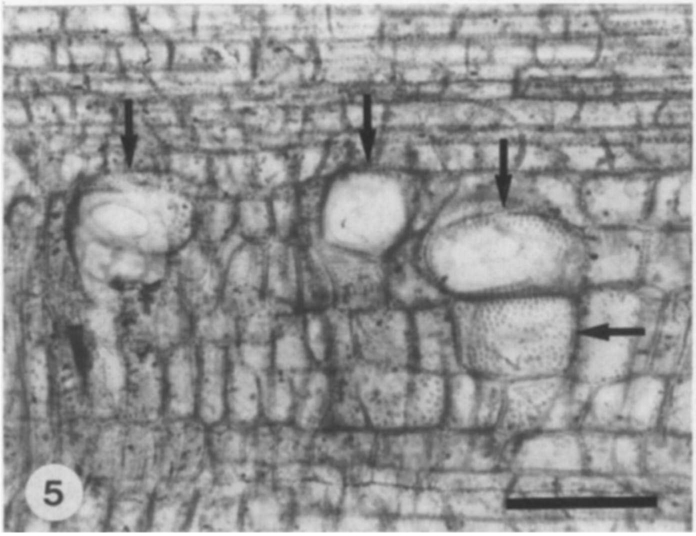
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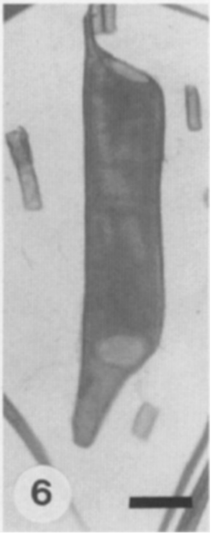
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Table 1. Linear dimensions of ray cells (μm) and statistical data. AVG = average; SD = standard deviation of the sample; VC = variation coefficient (SD / AVG × 100) in %.

Variable	AVG	SD	VC	Range	Variable	AVG	SD	VC	Range
Perforated ray cell					*Upright cells*				
Height	76	25	38	47–131	Height	76	15	20	78–103
Width	35	11	32	16–66	Width	18	3	18	13–25*
Length	125	47	38	49–299	Length	33	6	19	26–47
Square cells					*Vessel elements*				
Height	45	10	22	31–69	Diameter	67	12	18	45–91
Width	18	3	18	13–25*	Length	989	143	15	589–1344
Length	50	9	18	39–61					

* Values measured without distinction between square and upright cells.

Table 2. Estimated volume (μm^3) of ray cells.

Cell kind	AVG	SD	VC	Range
Perforated ray cells	301455	140078	46	110646 – 556679
Square cells	43352	19426	45	27966 – 69822
Upright cells	45622	12080	26	20885 – 43352

RESULTS

Perforated ray cells were found only in uniseriate rays (Fig. 1) or in the uniseriate portion of multiseriate rays. These regions are composed of square and upright cells.

Perforated ray cells of *Bathysa meridionalis*, from radial view, vary in shape from elliptic to square (Fig. 3–5). In macerations most of the perforated ray cells exhibit the approximate shape of a six-sided polyhedron, with fairly regular sides.

Perforated ray cells are usually isolated with a frequency of less than two cells per radial section (about 1 cm^2). They were occasionally found in groups, as in Figure 5

The perforation plates in perforated ray cells are simple, shapes ranging from circular to elliptic (52%) (Fig. 4, 5), reniform (kidney-shaped) (44%) (Fig. 3, 5) or irregular (4%). Most perforated ray cells (65%) have only one perforation plate per radial wall, but two (25%) and even three perforation plates (10%) can also be found. The reniform plates show a pitted rim around each perforation (Fig. 3). The dimensions of both the perforated ray cells and the adjacent ray cells are presented in Table 1. Estimates of ray cell volumes are given in Table 2.

DISCUSSION

Comparison of perforation plates of vessel elements and perforated ray cells shows that only the perforated ray cells have reniform perforations with a ring of pits

(Fig. 3). This feature resembles those found by Rudall (1982) in *Canthium barbatum* (Rubiaceae), but in *B. meridionalis* pits rarely occur in the rims of the circular or elliptical plates. No perforation plates have been found on the tangential or transverse walls of the perforated ray cells in any of the preparations.

As for the number of perforations per contact region, there is a significant difference between the perforated ray cells and the vessel elements. Ceccantini and Angyalossy-Alfonso (unpublished data) found only one perforation on each end of 96% of the vessel elements and two perforations in 4% of them. On the other hand, 65% of the perforated ray cells have one, 25% have two, and 10% have three perforations per radial wall. The low frequency of vessel elements with two perforations suggests that they are the most frequent connection with the perforated ray cells, since the occurrence of the latter is also small.

The thickened rim of the perforation plate in perforated ray cells, with pits on it, stands out as a dark purple ring in double-stained preparations. Nagai et al. (1994) also showed resembling pits near the perforation plate in *Xylosma longifolium*. These pits probably enable only a negligible water flow when compared with the flow through the perforation. The purpose of those pits (if there is a purpose) remains obscure.

Analysing the sizes of perforated ray cells in relation to the vessel elements in Table 1, it is possible to think that since the widths of the perforated ray cells may reach about half of the vessel element diameter, they will be more resistant to water flow than vessel elements. In fact, the vessel perforation plates of *Bathysa meridionalis* are smaller than the vessel diameter, being the most important factor for restricion of the water flow. Even without measuring the perforation plates that showed irregular shapes, one would expect that hydraulic conductivity of perforated ray cells is higher than that of the vessels, since their perforation plates are bigger than those of the vessel elements. This contradicts Nagai et al. (1994), who found perforation plates in perforated ray cells to be smaller than those found in vessel elements.

The average length of the perforated ray cells is at least twice the average length of other ray cell classes (Table 1), while the average height is intermediate between that of square and upright cells. Chalk & Chattaway (1933) noted that the difference between the widths of perforated ray cells and adjacent cells is negligible, but in *B. meridionalis* this difference is very relevant because one is about twice that of the other ray cells. The high coefficients of variation (CV) of the dimensions of the perforated ray cells are also relevant – about 30–40% – showing that perforated ray cells are more variable than ordinary ray cells.

The average volume of the perforated ray cells is about seven times larger than that of the other cells, and the volume of the smallest perforated ray cells is ~70% higher than the largest volume measured for the ordinary ray cells.

Combretum species (IAWA Committee 1989, and personal notes) have perforated ray cells of the same size as the surrounding ray cells. Why are these perforated ray cells different and why does their volume remain the same? Is it related to the vessel diameter? Does it help on water transport? Many questions remain about the function of perforated ray cells. To understand their physiological role, it is not sufficient to know their dimensions; it is necessary to establish their function experimentally.

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