Madera y **Bosques** vol. **20**, núm. **2 : 95-110** Verano **2014**

Comparative wood anatomy of *Maytenus* in Northwestern Argentina (South America)

Anatomía comparada del leño de *Maytenus* en el Noroeste de Argentina (Sudamérica)

Ana María Giménez[1], Juana Graciela Moglia[1], M.E. Figueroa[1], J.A. Díaz Zírpolo[1] and Federico Calatayu[1]

1 LAM (Laboratorio de Anatomía de Madera) Facultad de Ciencias Forestales, Universidad Nacional de Santiago del Estero (UNSE), Argentina. amig@unse.edu.ar

Abstract

This paper is a comparative wood anatomy study of four species of the genus *Maytenus* living in Northwest Argentina: *Maytenus vitis-idaea, M. viscifolia, M. spinosa and M. cuezzoi*. The specimens were collected in Santiago del Estero and Salta, Argentina and wood samples are safeguarded in the collection of the LAM (Laboratory of Wood Anatomy), Faculty of Forestry of Santiago del Estero University (UNSE), Argentina. The terminology used followed the IAWA List of Microscopic Features for Hardwood Identification. The diagnostic features of wood anatomical characters were evaluated by employing statistical methods such as Cluster Analysis (CA) and Principal Component Analysis (PCA). PCA showed vessel diameter, fibre wall, and ray width to be significant variables. CA showed *M. cuezzoi and M. viscifolia* to have the highest affinity.

Key words: Celastraceae, Chaco, Hardwoods, Santiago del Estero.

Resumen

El presente trabajo es un estudio de anatomía comparada de madera de cuatro especies del género *Maytenus* del Noroeste Argentino: *Maytenus vitis-idaea, M. viscifolia, M. spinosa y M. cuezzoi*. Las muestras fueron recolectadas en Santiago del Estero y Salta, Argentina y se salvaguardan en la colección del LAM (Laboratorio de Anatomía de Madera), Facultad de Ciencias Forestales de la Universidad de Santiago del Estero (UNSE), Argentina. Se empleó la terminología de IAWA (Lista de caracteres anatómicos del xilema de angiospermas). Los caracteres anatómicos de madera fueron evaluados mediante métodos estadísticos tales como análisis de conglomerados (AC) y el Análisis de Componentes Principales (PCA). El PCA mostró como variables significativas el diámetro de vasos, el espesor de pared de las fibras y el ancho de radios. El CA mostró que *M. cuezzoi y M. viscifolia* tienen alta afinidad específica.

Palabras clave: Celastraceae, Chaco, angiospermas, Santiago del Estero

Introduction

Celastraceae is a widely distributed family in the world, comprising 57 genera with 370 species in both hemispheres. There are several indigenous representatives in Argentina. They are usually small trees or shrubs (Dimitri, 1972). Celastraceae stem xylem anatomy has been described by Record and Hess (1943), Mennega (1997), Archer and Van Wyk (1993a). Mennega (1997) analyzed the anatomy of the subfamily Hippocrateoideae, which is distinguished by thin, long rays. Record and Hess (1943) studied the Genera: *Celastrus*, *Zinowiewia*, *Elaeodendron*, *Goupia*. Archer and Van Wyk (1993a; 1993b) made a comparative anatomical study of mature wood and bark of the subfamily Cassinoideae, comprising mainly southern African species of *Cassine*, *Pleurostylia* (17) and the three monotypic genera, *Allocassine, Hartogiella* and *Maurocenia*.

Metcalfe and Chalk (1983) recorded the presence of numerous small vessels, solitary, in radial multiples of 2-3, ring and semi-ring porous, occasionally with helical thickenings, simple perforation plate, alternate intervascular pits, very small, members of vessels of medium length to moderately long, are typical features. Very weakly defined vestures were seen in Celastraceae (Archer and Van Wyk, 1993a).

Rays are described in some genera to be exclusively uniseriate and homogeneous, in other heterogeneous multiseriate (3-4).

Maytenus is a genus of temperate and warm regions of South Asia (Yemen, Malaysia and Thailand), Africa (Canary Islands, northwest and northeast Ethiopia, and South Africa), and America from Mexico to Tierra del Fuego. It grows in a variety of climates, from tropical (77 sp. in Brazil) to subpolar (Hurrel and Bazzano, 2003).

In Argentina the Genus *Maytenus* comprises about eleven native species. Three are endemic shrubs and small trees (Boelke, 1992), distributed in the subtropical wet forest of Misiones, Yungas, Chaco semiarid forest and Patagonian Andean temperate forests (Zuloaga and Morrone, 1999).

Maytenus boaria (Maitén) is the most important tree of Patagonian Andean forests (Lourteig and Odonell, 1955). The species is used as a natural dye and its branches are an important source of foliage for sheep in the steppe (Tortorelli, 2009). *M. spinosa, M. viscifolia* and *M. vitis-idaea* are species of the semiarid forest of the Chaco region. They are indicative of saline soils and semiarid areas. Giménez and Hernández (2008) found *M. spinosa* in 50% of the areas studied in Santiago del Estero, Province, *M. vitis-idaea* in 36% of them, and *M. viscifolia* at only one site (Sierras de Guasayan). Their uses include dye, fodder, food and to a lesser extent, as timber depending on the size of their trunks (Giménez *et al.*, 2010). *M. cuezzoi* is a threatened endemic species (Cat. 5: restricted distribution plant and sparse populations with restricted distribution and sparse populations).

For the genus *Maytenus*, the outstanding features of the wood are: diffuse porous, small vessels, very numerous (20-40), solitary and in radial multiples, and sometimes helical thickenings. Axial parenchyma is very variable in type and number, commonly scattered or absent, diffuse and multiseriate or thin bands (Metcalfe and Chalk, 1983). Vessels with helical thickenings were cited *M. boaria* (Tortorelli, 2009).

Rays are heterogeneous, frequently with 2-4 vertical rows of cells, 1 to 3 seriate, less than 12/mm (Metcalfe and Chalk, 1983); *M. boaria* (-9 ray/mm) with 3-4 seriates (Tortorelli, 2009).

Mechanical tissue is composed of fibre with distinctly bordered pit (fibre-tracheids), numerous, occasionally septate fibres with simple pits, of medium length, sometimes with helical thickenings (Metcalfe and Chalk, 1983). Is characterized by fibres dimorphic (bands of thick-walled fibres with bordered pits alternating with septate and thin-walled fibres with minutely bordered pits), resembling the axial parenchyma (Joffily *et al.*, 2007).

Fibres with distinctly bordered pits were cited in *M. boaria* (Tortorelli, 2009), *M. acuminata* (Metcalfe and Chalk, 1950), *M. micrantha* (Detienne and Jacquet, 1983).

Fibre-tracheids are elements of transition between tracheids and fibres. They are characterized by the presence of bordered pits, generally located in the radial walls, present in Apocynaceae, Celastraceae (some Genera) Myrtaceae, Sapotaceae, Zygophyllaceae among others. Carlquist (1988) described the imperforate tracheal elements of *Catha, Elaeodendron, Celastrus* and *Maytenus* as septate libriform fibres, septate fibre-tracheids and vasicentric tracheids.

Fibre-tracheid has been cited as an adaptive strategy in species of arid and semiarid areas, such as *Aspidosperma quebracho-blanco* (Apocynaceae) (Moglia *et al.*, 2009); *Monttea aphylla* (Scrophulariaceae) (Giménez *et al.*, 1998); *Tabernaemontana catharinensis* (Apocynaceae) (Giménez, 2004). Carlquist and Hoekman (1985) cite the presence of fibre-tracheids as typical element of the arid flora of California.

Several African species have been described anatomically: *M. acuminata* (Metcalfe and Chalk, 1950); *M. micrantha* (Detienne and Jacquet, 1983), *M. senegalensis*

(Neumann *et al*., 2000). Perforated ray cells (PRC) are present in the stem xylem and in the roots of *M. brasiliensis* and *M. obtusifolia* (Joffily *et al*., 2007).

Sokal and Rohlf (1981) have shown the importance of multivariate statistical techniques in numerical taxonomy. Using multivariate techniques, Robertse *et al*. (1980) solved problems in variation of wood anatomical characters of South African *Acacia*. Somaratne and Heart (2001) established relationships among species of the genus *Calophyllum,* and Wickremasinghe and Heart (2006) did the same for *Diospyros*.

Materials and Methods

The aim of the study is to analyze the comparative wood anatomy of four species which are little known of northwestern Argentina: *Maytenus vitis-idaea*. Griseb.*; M. viscifolia* Griseb.*; M. spinosa* (Griseb.) Lourteig & O'Donell and *M. cuezzoi* Legname.

The characteristics of the species studied are:

Maytenus vitis-idaea Griseb. (monedita) is an unarmed shrub or small tree, 2 m - 5 m high and up to 0,2 m in diameter, with persistent, glabrous foliage. Its geographic distribution in Argentina is the Chaco region, in the following provinces: Jujuy, Salta, Tucumán, Santiago del Estero, Catamarca, La Rioja, San Juan, Formosa, Chaco, Corrientes, Santa Fe, and Córdoba (Legname, 1973). The plant is an indicator of saline soil, and the wood produces a dark reddish dye used to color wool, yarn, etc. (Giménez *et al*., 2007). It is used as food for bees and farm animals, especially for goats at all times of year (Karlin, *et al*. 2010). The ash obtained from burning wood is used as salt for human consumption. It also has anti-inflammatory, disinfectant, astringent and ophthalmic uses. The chewed leaves are used to cure diseases of the mouth (Giménez *et al*., 2010).

Maytenus viscifolia Griseb. (chasqui-yuyo) is an endemic unarmed shrub or small tree, 3 m - 7 m. tall, with a trunk up to 0,3 m in diameter, with persistent foliage. Its geographic distribution in Argentina is the semiarid Chaco region, in the following provinces: Salta, Tucumán, Santiago del Estero, Catamarca, La Rioja, Córdoba, San Juan (Gimenez and Moglia, 2003).

Maytenus spinosa (Griseb.) Lourteig & O´Donell (abriboca) is an endemic shrub with spiny branches and leathery leaves. It is native to Argentina and Uruguay (Digillio and Legname, 1966). The bark produces a pink brown dye (Stramiglioli, 2007).

Maytenus cuezzoi Legname (Legname, 1973; 1982) is an endemic unarmed tree, 3 m - 7 m tall and 0,25 m. in diameter at the base, with entirely glabrous pale green leaves, smooth bark, and red flowers. Its geographic distribution is the Yungas, in the temperate humid upper floor of the montane forest, between 1500 m and 2000 m altitude of the provinces of Salta and Jujuy. (Zuloaga and Morrone, 1999). The species has been found in the Los Toldos valley, Salta province, forming secondary forests dominated by *Ilex argentina, M. cuezzoi* and *Roupala* sp.; these associates indicate degraded forests (Brown and Grau, 2000). Samples were collected by the author of the species, Prof. P. Legname.

We sampled the four species of *Maytenus* from different habitats of northwestern Argentina. *M. vitis-idaea* and. *M. spinosa* were collected in Tala Atun, San Martín department, Santiago del Estero (latitude S 28º 44' 44'', longitude W 63º 11' 34''; altitude: 130 m, mean annual precipitation (MAP): 470 mm; mean annual temperature (MAT): 20 ºC (Saavedra, 2004). *M. viscifolia* was collected in Guampacha, Sierras de Guasayán, (latitude S: 28º 15' 44'', longitude W 63º 34' 55'', altitude: 479 m, MAP: 563 mm; MAT: 19 ºC) of Santiago del Estero province. *M. cuezzoi* was collected in the montane forest of Los Toldos, Salta province (latitude S: 22º 24', longitude W 64º 43', altitude: 1700 m, MAP: 1349 mm, MAT: 19 ºC).

Fresh wood samples were collected along with herbarium vouchers. The material was collected from five wild-growing individuals of each species. 10 cm thick disk was cut from each tree at 0.3 m height. The samples are deposited in Laboratory of Wood Anatomy (LAM), Faculty of Forestry of Santiago del Estero University (UNSE).

Mature wood samples were fixed in 70% alcohol. Transverse, radial and tangential sections (12 µ-18 µ thick) were cut using a sliding microtome. The sections were doubly-stained with 1% fuchsin and astra blue (Roeser,

1972) and mounted permanently by Entellan. Wood material was macerated following Jeffrey's method (Johansen, 1940).

Terminology and determination of quantitative features follow the recommendations of the IAWA Committee (1989) and Tortorelli (2009). For vessel diameters, vessel element lengths, fibre lengths and ray height, 25 measurements were taken from each specimen and averaged.

The influence of environmental conditions on characteristics (vessel diameter and vessel number) associated with water conduction was evaluated through the vulnerability index. The vulnerability index *(VI)* was calculated to estimate susceptibility to damage during water conduction of wood, as proposed by (Carlquist, *1988*): *VI*= Vd / Vmm; where: Vd =vessel diameter and Vmm = vessel per square mm. Numerous, narrow vessels give the plant protection against cavitation, especially in stress environments, while fewer, wider vessels are more susceptible to cavitation.

Multivariate statistical analyses were applied in the present study to trace the possible relationships between anatomical and ecological features. A preliminary approaches to treatment of the subject about which of the quantitative variables are associated with each of the species analyzed follows. Were used seven quantitative variables: vessel per square/ mm (Vmm); tangential diameter of vessel (Vd); vessel element length (Vl); fibre length (Fl); fibre wall thickness (Fw); ray height (Rh); ray width (Rw).

They were evaluated using Principal Component Analysis (PCA) and Cluster Analysis (CA) in order to determine taxonomic patterns and to generate a classification system.

Non parametric analysis of variance (ANAVA) for repeated measures (Cody and Smith, 1991) and the Kruskal Wallis test (α = 0,05) was performed for 7 variables. Professional Program InfoStat was used for statistical analysis (INFOSTAT, 2008).The photomicrographs were taken with Zeiss Axiostar microscope and Sony video camera ExwaveHAD. Small blocks cut to produce transverse, radial and tangential surfaces were used for scanning electron microscopy (SEM).

Results

Anatomical descriptions

Maytenus vitis-idaea (Fig. 1–8)

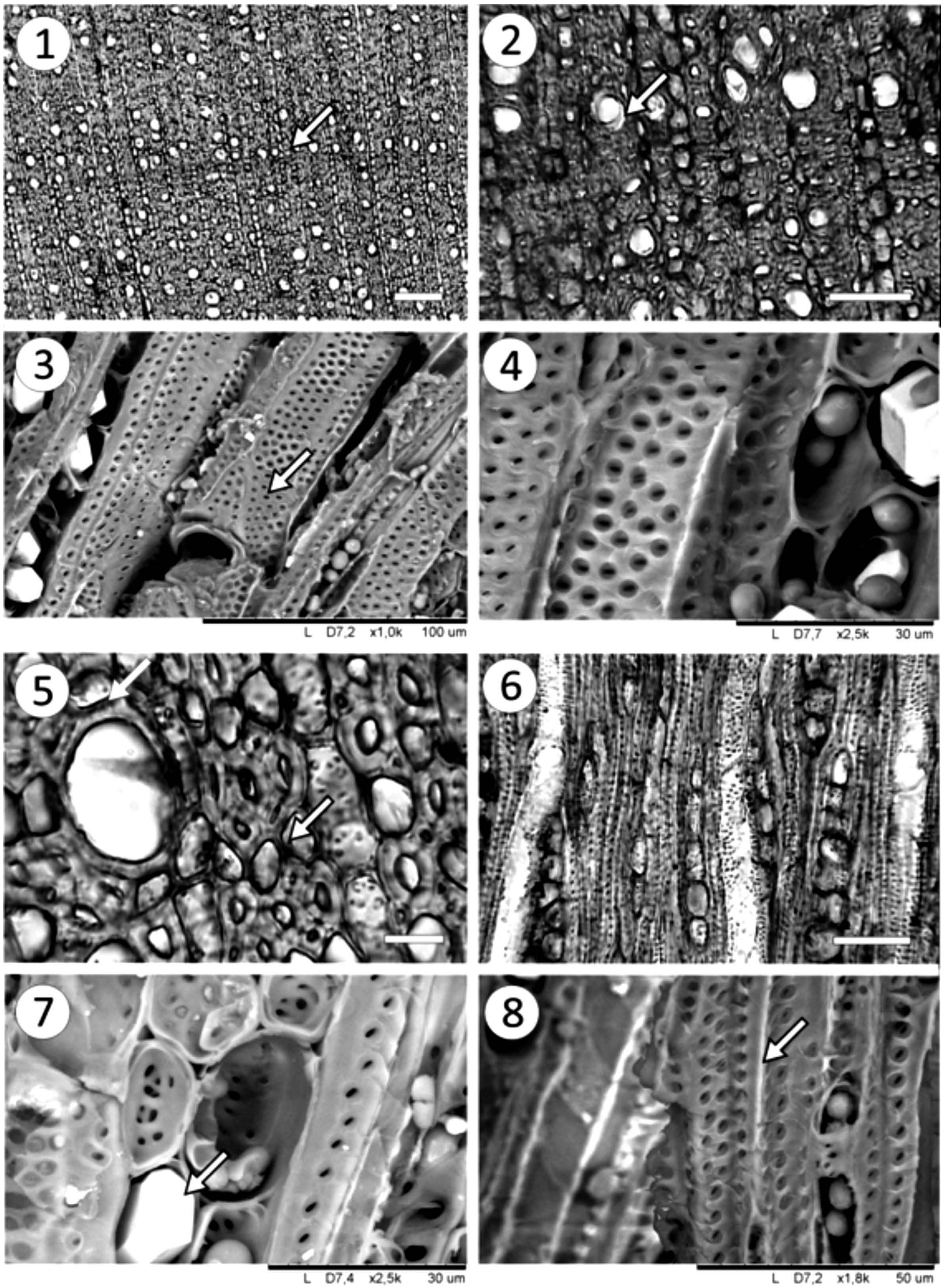
Growth rings distinct, marked by thick-walled fibres. Wood diffuse-porous, vessels solitary (75%) and in radial multiples of 2-4; occasionally with some clusters, 68 (50-85) per mm^2; 28 (20-40) µm in diameter. Vessel element length 77 (45-125) µm. Perforations simple, intervessel pits alternate, small, 4 µm - 6 µm in diameter. Vessel-ray pits with distinct borders, similar to intervessel pits in size and shape. Fibre non-septate, thick- to very thick-walled, 165 (112-262).µm in length, with distinctly bordered pits; pit frequency on radial and tangential walls more or less equal, pits minute (2 µm - 5 µm). Axial parenchyma diffuse-in-aggregates and scanty paratracheal; 1-2 cells per parenchyma strand. Rays heterocellular with 2-4 rows of upright and/or square marginal cells, 13 (7-16) per mm, mostly 1 to 2 (occasionally 3) cells wide, 116 (150- 450) µm in height, not storied. Prismatic crystals occasionally present in upright and/or square ray cells and in short chains in axial parenchyma cells; one crystal per cell or chamber.

Maytenus viscifolia (Fig. 9–20)

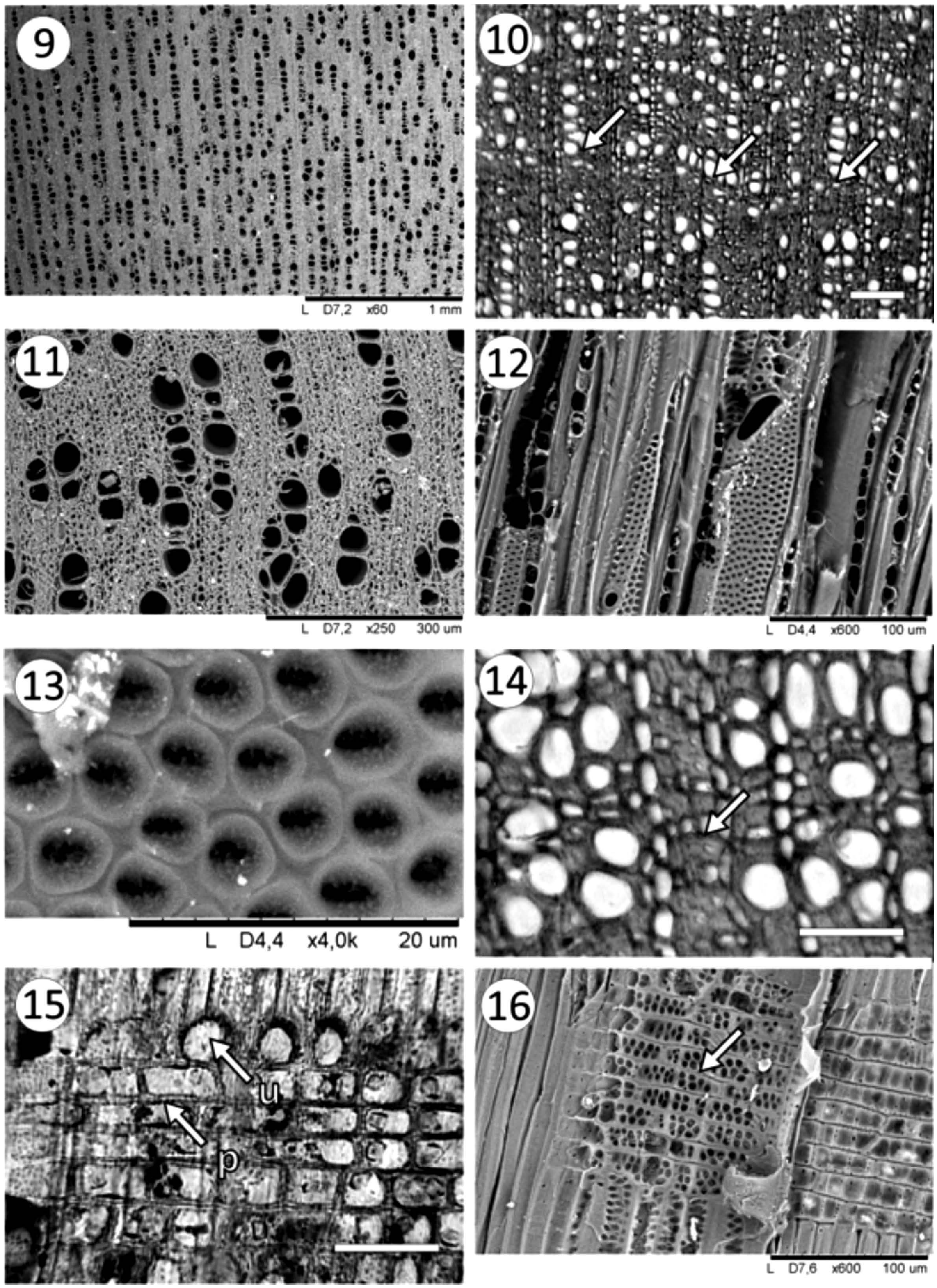
Growth rings distinct, marked by thick-walled fibres. Wood diffuse porous. Vessels solitary (30%) and in radial multiples of 2-6; occasionally with some clusters, 84 (42-117). per mm^2. Vessels 36 (30-40) µm in diameter. Vessel element length 113 (65-172) µm. Perforations simple. Intervessel pits vestured, minute (3 µm - 5 µm), polygonal. Vessel-ray pits rounded with much reduced borders, to apparently simple.

Fibre 227 (135-282) µm in length, with thick to very thick cell walls. Fibre pits mostly conspicuously bordered, 2 µm - 5 µm in diameter, frequency on radial and tangential walls approximately equal. Apotracheal axial parenchyma diffuse-in-aggregates and scanty paratracheal vasicentric.

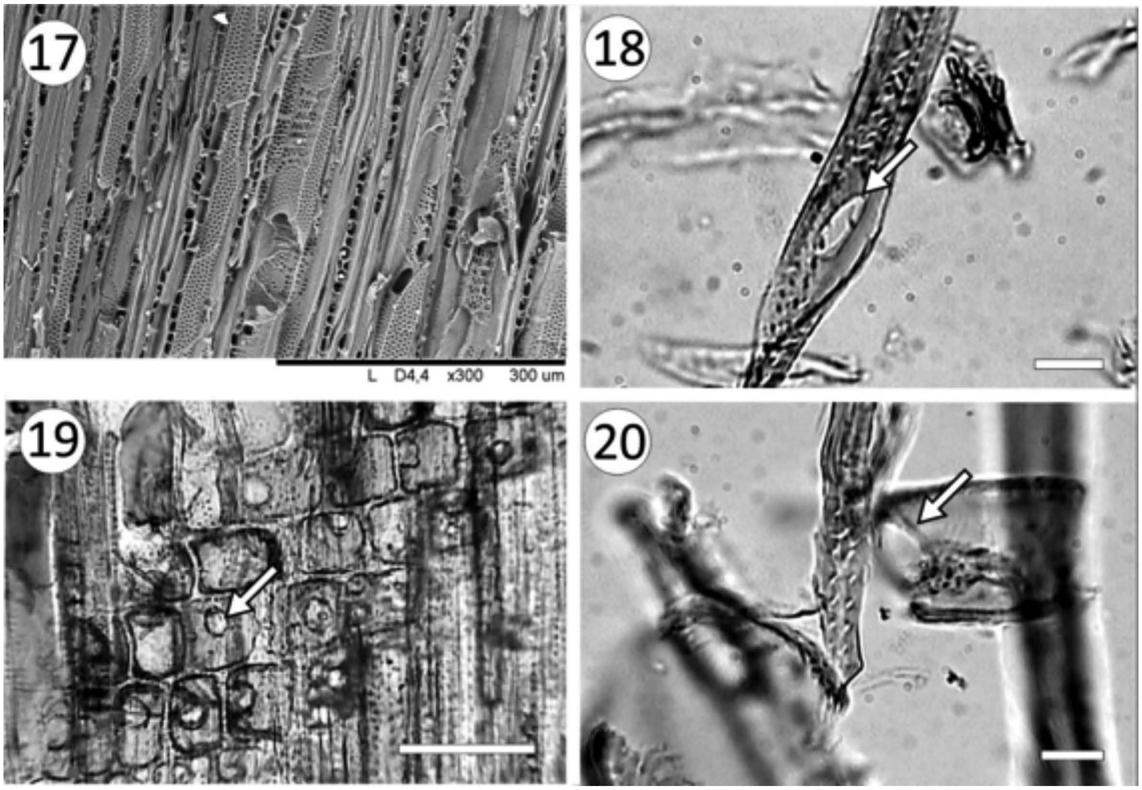
Rays heterocellular with 2-4 rows of upright and/or square marginal cells, 12 (7-16) per mm, 1 to 3 cells wide, 456 (180-850) µm in height, not storied. Perforated ray cells rarely present. Prismatic crystals occasionally present in cells of axial parenchyma.



FIGURES. 1–8: *Maytenus vitis-idaea:* --1. Growth rings distinct marked by thick-walled fibres. --2. Vessels solitary and radial multiples. --3. Vessel with simple perforation. –4. Alternate intervessel pits small. --5. Parenchyma diffuse-in-aggregates. --6. Rays 1 to 2 cells wide.--7. Prismatic crystals present in ray cells. --8. Fibre with bordered pits in one or two rows.
Note: the scale corresponds to 100 um, except in the SEM micrographs which have included its own scale.



FIGURES. 9–16: *Maytenus viscifolia*. --9. Wood diffuse porous. --10 Growth rings distinct marked by thick-walled fibres. --11. Vessels predominantly in radial multiples of 2-6. --12. Vessel with simple perforation. --13. Small alternate intervessel vestured. --14. Parenchyma diffuse-in-aggegates. --15. Rays heterocellular (u: upright cell; p: procumbent cell) --16. Vessel-ray pits.



FIGURES. 17-20: *Maytenus viscifolia*. --17. Rays mostly 1 to 2 cells wide. --18. Vessel with simple perforation. –19 Perforated ray cells. 20. Perforated ray cells in maceration.

Maytenus cuezzoi (Fig. 21–30)

Growth rings distinct, marked by thick-walled fibres. Wood diffuse-porous, rarely appearing semi-ring-porous. Vessels with helical thickenings, in radial multiples of 2-5 (60%), solitary (25%), and occasionally clusters, 99 (62-172) vessels per mm². Vessels 32 (20-20) µm in diameter. Vessel element length 131 (77-182) µm. Perforations simple. Intervessel pits alternate, small (4 µm - 6 µm), vestured. Vessel-ray pits with distinct borders, similar to intervessel pits in size and shape.

Fibre 230 (162-325) µm in length with thick to very thick walls. Fibre pits mostly conspicuously bordered, 2-5 µm in diameter, frequency on radial and tangential walls approximatelyequal.

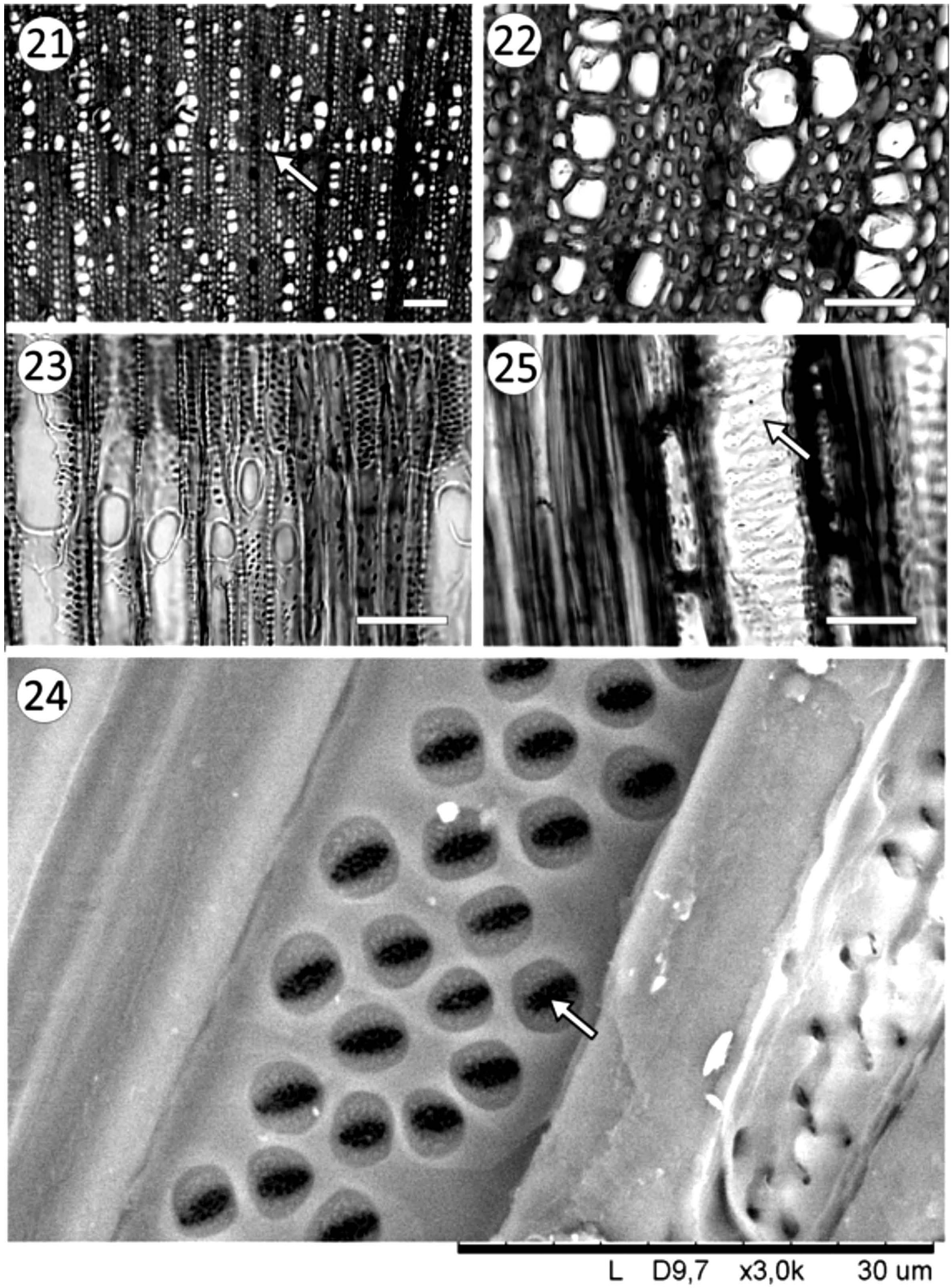
Apotracheal axial parenchyma diffuse-in-aggregates; scanty paratracheal, vasicentric, and unilateral.

Rays heterocellular with 2-4 rows of upright and/or square marginal cells, 13 (9-18) per mm, 1 to 3 cells wide, 460 (240-960) µm in height.

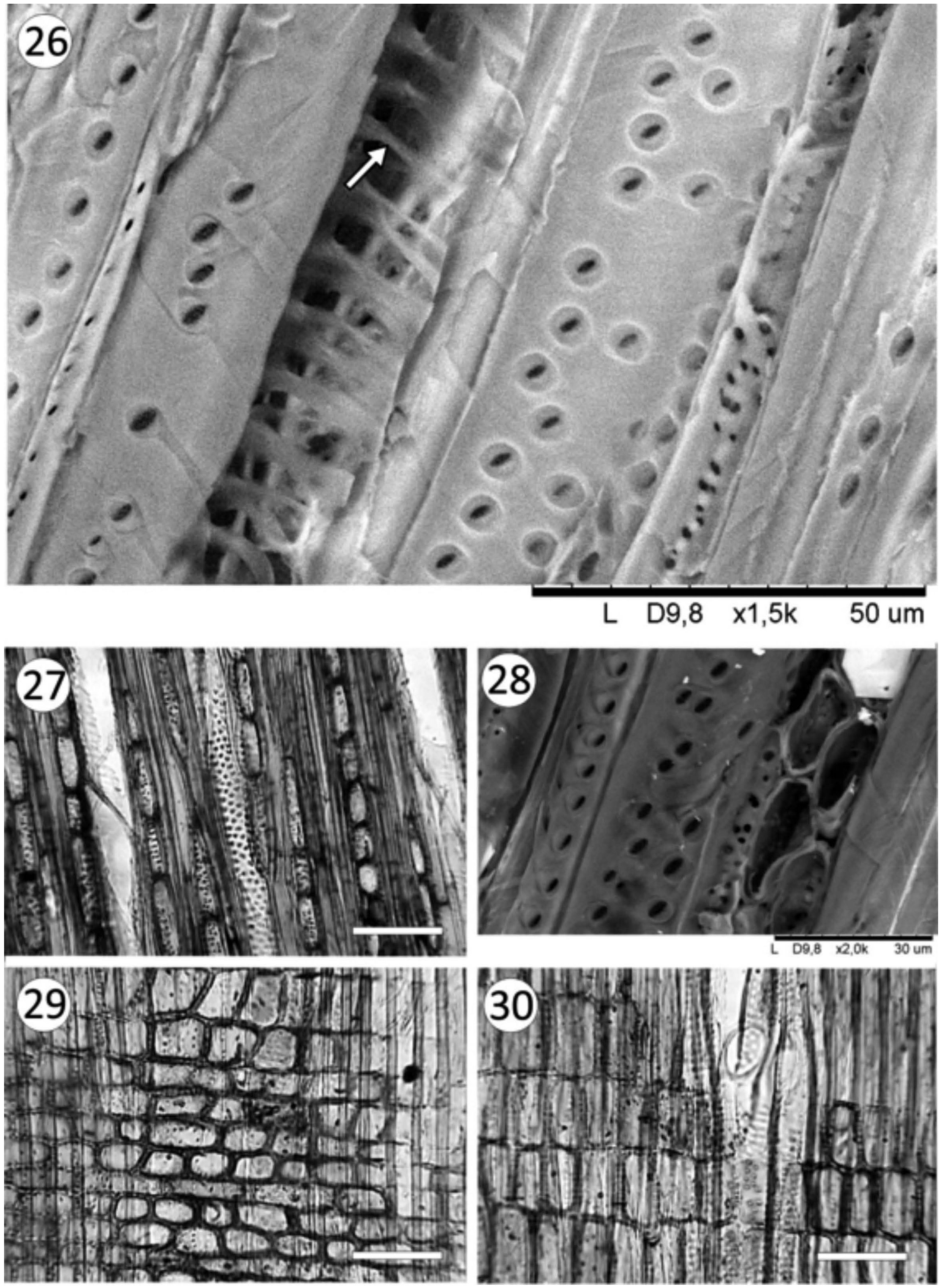
Prismatic crystals occasionally present in upright and/or square ray cells and in short chains in axial parenchyma cells; one crystal per cell or chamber.

Maytenus spinosa (Fig. 31–36)

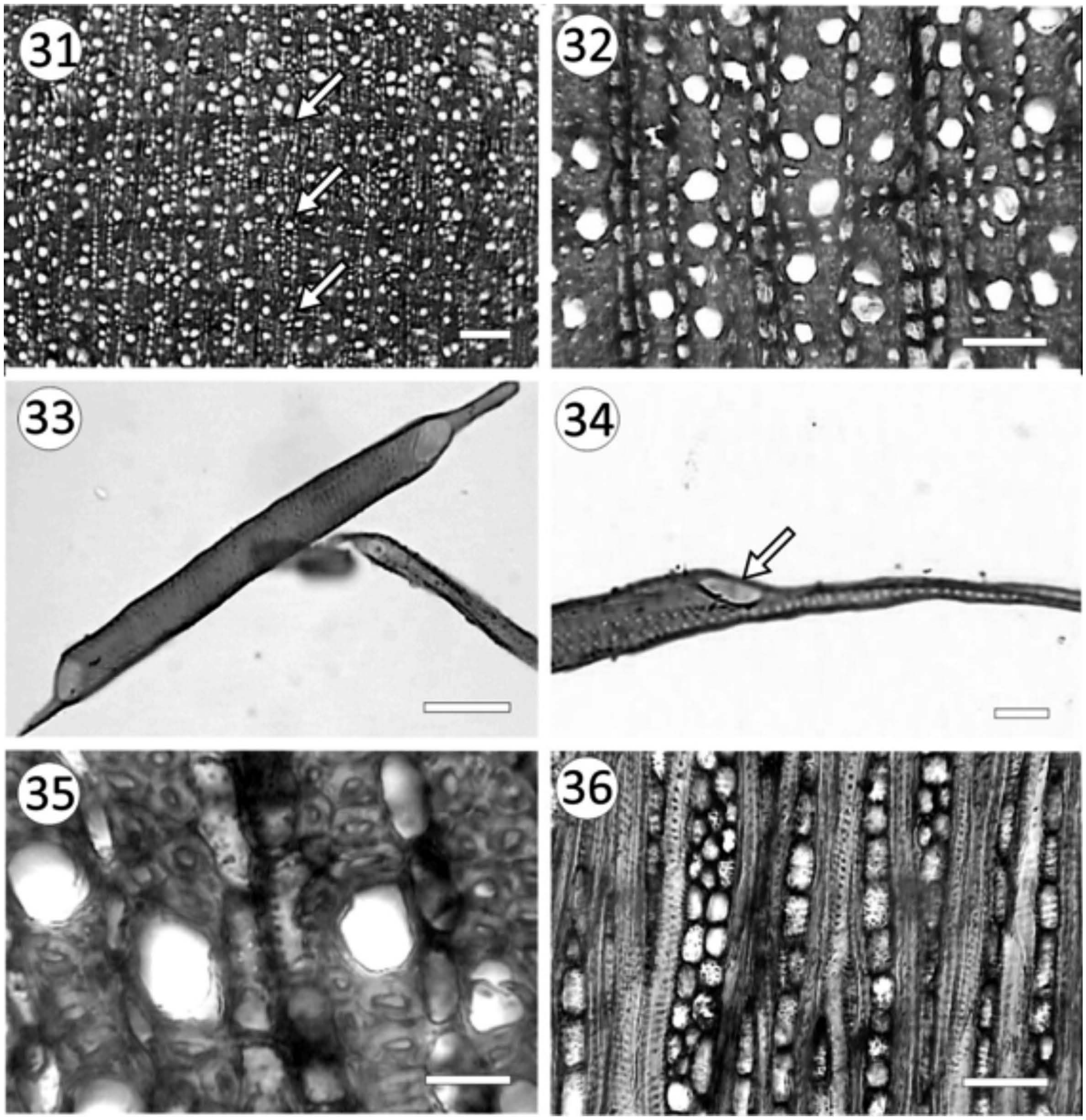
Growth rings distinct, marked by thick-walled fibres. Wood diffuse-porous, rarely appearing semi-ring-porous. Vessels predominantly solitary (84%), in radial multiples of 2, and occasionally some clusters; 136 (87-185) per mm². Vessels 20 (10-30) µm in diameter. Vessel element length 84 (40-117) µm; tails frequent at both ends. Perforations simple. Intervessel pits alternate, small, 4 µm - 6 µm in diameter. Vessel-ray pits with distinct borders, similar to intervessel pits in size and shape.



FIGURES. 21-25: *Maytenus cuezzoi*. --21. Growth rings distinct marked by thick-walled fibres. --22. Vessels predominantly in radial multiples of 2-5. --23. Vessels with simple perforations. --24. Small alternate intervessel pits. --25. Vessels with helical thickenings.



FIGURES. 26-30: *Maytenus cuezzoi*. --26. Vessels with helical thickenings. --27 Rays mostly uniseriate. --28. Rays biseriate with crystal. --29. Rays heterocellular. --30. Vessel-ray pits.



FIGURES. 31-36: *Maytenus spinosa*. --31. Growth rings distinct marked. --32. Vessels predominantly solitary (84%). --33. Vessel with tails at both ends. --34. Vessel with simple plate. --35. Fibretracheids with cell walls thick to very thick. --36. Rays 1, 2 cells wide.

Imperforate tracheary elements consist of non-septate fibre with pits mostly conspicuously bordered, 153 (102-197) µm in length, 2-4 µm in diameter; density on radial and tangential walls approximately equal. Cell walls thick to very thick.

Apotracheal axial parenchyma diffuse-in-aggregates and scanty paratracheal .

Rays heterocellular with 2-4 rows of upright and/or square marginal cells, 20 (14-24) per mm, 1 to 3 cells wide, 330 (130-690) µm in height.

Prismatic crystals occasionally present in upright and/or square ray cells and in short chains in axial parenchyma cells, one crystal per cell or chamber.

The most important anatomical features are summarized in Table 1

TABLE 1. Wood anatomical characters.

Species	*M. vitis-idaea*	*M. spinosa*	*M. viscifolia*	*M. cuezzoi*
Porosity	diffuse-porous	diffuse-porous	diffuse-porous	diffuse-porous
Solitary vessel	75%	84%	30%	25%
Vessel radial multiples of 2-3	16%	11%	40%	31%
Vessel radial multiples (4-5)	0	0	14%	26%
Clusters common	9%	5%	16%	18%
Tangential diameter of vessel lumina µm	28.4 (20-40) S: 6.24	19.6 (10- 30) S:4.55	35.6 (30-40) S:5.07	32 (20-40) S: 5,77
Vessel element length µm	77.10 (45.5-125) S: 19.76	83.6 (40-117.5) S: 22.02	113.4 (65-172.5) S: 30.63	130.7 (77.5-182.5) S: 34.64
Helical thickenings	-	-	-	+
Vestured pits	-	-	+	+
Perforation plate simple	+	+	+	+
Vessel frequency (Vmm^2)	67.7 (50-85) S:10.75	136.2 (87.5-185) S: 30.07	83.6 (42.5-117.5) S: 19.29	99.4 (62.5-172.5) S: 23.98
Ray Uniseriate	30%	43%	44%	49%.
Ray biseriate	56%	38%	50%	28%.
Ray triseriate	14%	19%	6%	23%
Ray height	228.8 (100-430) S:64.1	330.4 (130-690) S:126	456.3 (180-850) S: 184.29	460.4 (240-960) S:186.5
Rays per mm	13.4 (7-16) S: 2.2	19.9 (14-24) S: 2.5	11.7 (7-16) S: 2.5	13.5 (9-18.5) S. 1.9
PRC (perforated ray cell)	-	-	+	-
Fibre length **(**µm**)**	165 (112.5-262.5) S: 30.74	153.2 (102.3-197.5) S: 30.54	227.2 (135-282.5) S: 36.25	229.8 (162.5-325) S: 39.51
Fibre wall thickness (Fw)	4.5 (3.75-5) S: 0.63	3.4 (2.5-3.75) S: 0.57	5.2 (3.75-7.5) S: 0.86	3.35(2.5- 5.0) S:1.07
VI	0.43 (0.24-.70) S: 0.13	0.15 (0.06-0.3) S: 06	0.45(0.28-0.94) S: 0.14	0.34 (0.17-0.57) S: 0.10

Note: S standard deviation

From PCA, factor 1 expresses 58% of the variability, 33% factor 2 and 0,06 factor 3 (Table 2). Factor 1 is considered practically significant, as explaining an important amount of the variability in the data. The variables that load significantly in Factor 1 are: vessel diameter (Vd), fibre length (Fl), and ray width (Rw); on Factor 2: vessel length (Vl), ray height (Rh), and fibre wall (Fw) load significantly. The species separate into different quadrants (Fig. 37).

TABLE 2. Statistics of Eigenvalues (factor) of Principal Component analysis (PCA).

Eigenvalues (Factor)	*Valor*	*Proportion*	*Acumulate Proportion*
1	4,05	0,58	0,58
2	2,55	0,36	0,94
3	0,4	0,06	1
Variables	Factor 1	Factor 2	
Vd	0,49	-0,01	
Vl	0,34	0,45	
Fl	0,44	0,29	
Vmm^2	-0,33	0,40	
Fw	0,32	-0,41	
Rh	0,31	0,47	
Rw	0,38	-0,40	

Note: The variables with the highest value are those that best explain the total variability

Species appear as points and the variables as vectors. Species that appear in the same direction that a variable, may have high values for that variable and low value are plotted in the opposite direction. The correlations between variables can be interpreted through the angles between the vectors. Angles of 90 degrees indicates no correlation, angles (<90°) indicate a positive correlation and angles of > 90° negative correlation, angles close to 180° would show high negative correlation between the variables.

Cluster Analysis (CA) was performed to analyze the behavior of the anatomical variables and species, based on the Euclidean distance. The dendrogram derived from CA based on quantitative wood anatomical features species showed considerable grouping tendency within the genus, *M. cuezzoi* and *M. viscifolia* had the highest affinity (Fig. 38).

The histogram of vessel groupings shows that *M. spinosa and M. vitis-idaea* have more than 70% solitary vessels. *M. cuezzoi* and *M. viscifolia* have solitary, multiple and cluster vessels. *M. vitis-idaea and M. viscifolia* present a predominance of biseriate rays.

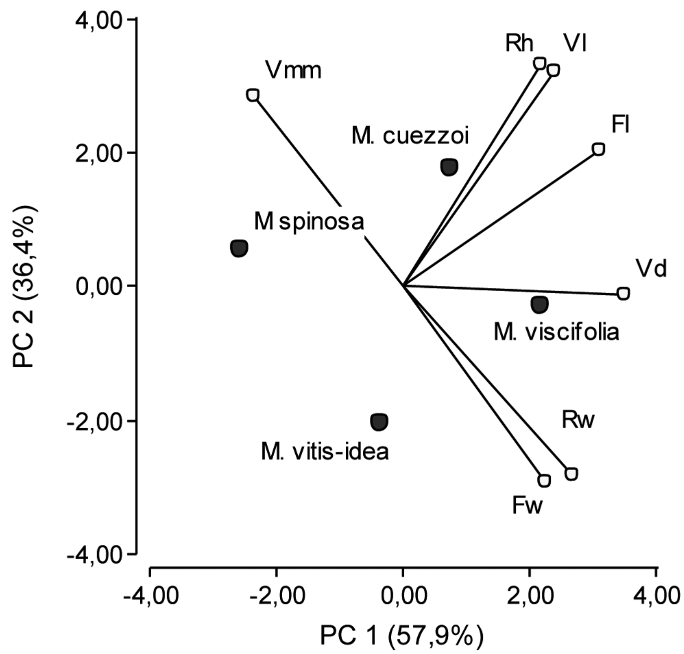


Figure 37. Principal Component Analysis of wood characteristic based on four species.

Variables: Vmm: vessel per square/ mm; Vd: tangential diameter of vessel; Vl: vessel element length; Fl: fibre length; Fw: Fibre wall thickness; Rh: ray height; Rw: ray width; PC1: Factor 1; PC2: factor 2.

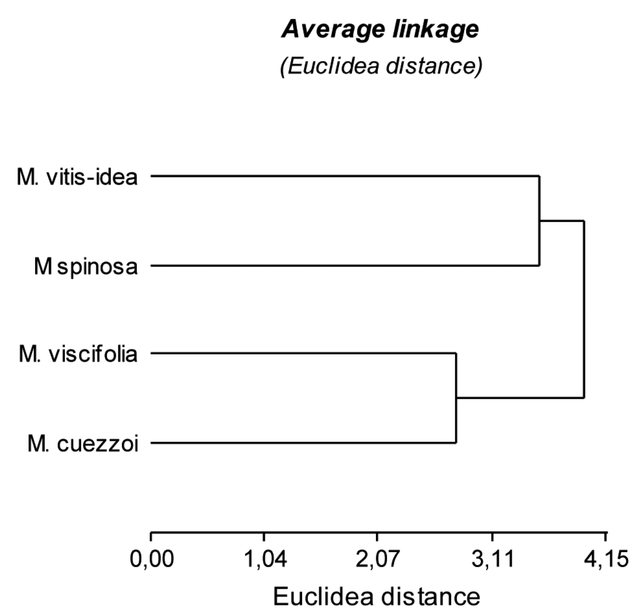


FIGURE 38. Dendrogram resulting from Cluster Analysis of wood features

TABLE 3. ANAVA of anatomical characters and Kruskal Wallis test.

Quantitative wood anatomical features	Variation between sp	M. vitis-idaea	M.spinosa	M. viscifolia	M.cuezzoi
Vessel element length	*	A	A	B	B
Tangential diameter of vessel lumen	*	B	A	C	B C
Vessels frequency	*	A	C	B	B
Fibre wall thikcness	*	A	B	C	C
Fibre length	*	A	A	B	B
Ray height	*	A	B	C	C
Ray width	NS	AB	A	B	A

Note: NS = Not significant. * = Significant (α = 0.05). Different letters indicate significant differences with Kruskal Wallis ´s Test

Discussion

Our observations of *Maytenus* are in accordance with the studies of Metcalfe and Chalk (1983), Tortorelli (2009); Joffily *et al*., 2007.

M. spinosa and *M. vitis-idaea* have wide prevalence of solitary vessels (75%). This character is mentioned for *M. acuminata* (Metcalfe and Chalk, 1983), *M. micrantha* (Detienne and Jacquet, 1983), and *M. senegalensis* (Neumann *et al*., 2000). Vessel multiples of 2-3 is present in *M. cuezzoi*. *M viscifolia* exhibits vessels of all types including multiples of 2-5.

M. boaria had vessels solitary and in multiples of 2-6 (Tortorelli, 2009).

The tangential diameter of vessel varies significantly with the species. The vessels are extremely small, in *M. spinosa* (mean: 19,6 µm); and small in *M. viscifolia*. (35,6 µm).

Vessel elements are extremely short (<350 µ), especially in *M. vitis-idaea and M. spinosa*. Bailey (1957) and Baas (1982) believed that the length of vessel elements and other morphological characters, such as perforation plates and types of pits, reflect the level of specialization of a taxon and further recognized the evolutionary trends of vessel element lengths within angiosperm taxa which came to be known as Baileyane trends. Metcalf and Chalk (1983) also stated that the vessel element length is more significant as a measure of phylogenetic specialization than as a diagnostic character for a taxon. It is the general opinion of Bailey (1957), Baas (1982) and Metcalfe and Chalk (1983) that the less specialized plant taxa have longer vessel elements than the specialized forms. This means high specialization of vessels elements in *Maytenus*.

The vessel frequency show highly significant differences between species; they are extremely numerous in *M. spinosa;* numerous in *M. cuezzoi*, *M. viscifolia and M. vitis-idaea*.

Vessels with helical thickenings were cited *M. boaria* (Tortorelli, 2009) and in *M. cuezzoi*, and vestured pits were observed in *M. cuezzoi* y *M. viscifolia*.

The vulnerability index predicts which species can live in arid (Carlquist, 1988). Xylem efficiency depends on the diameter and frequency of vessels in a given area.

VI index in the four sp is low (0,15/0,45), indicating a high specialization in water transport. Wood samples of *M. spinosa* and *M. vitis-idaea* were collected in Tala Atun (MAP: 470 mm and dry season of 5 months). *M. spinosa*

(VI 0,15), presents a strategy to ensure water conduction with small, short and very numerous vessels.

M. vitis-idaea (IV 0,43) has very small short and moderately numerous vessels.

M. viscifolia living in Chaco serrano (MAP: 563 mm and 5-month dry season), adopts the strategy of increasing vessel diameter (VI: 0,45). The adaptive strategy of *M. cuezzoi* is the increase in vessel length, tangential diameter and vessels frequency, can be interpreted by the greater availability of water in the plant (1340 mm). The differences are statistically significant between the sp. for variables vessel diameter and vessel frequency.

The axial parenchyma in the four species show is diffuse in aggregates.

M. vitis-idaea and *M. viscifolia* have predominantly biseriate rays; *M. spinosa* and *M. cuezzoi, uniseriate rays*. The fibres have distinctly bordered pits, are very short, especially in *M. spinosa, M.vitis-idaea* and *M. viscifolia* have thick walls (over 60% of the outer diameter of the fibres).

In the Celastraceae, the presence of PRCs was only known to data for *Cassine* (Archer and Van Wyk 1993a). However, the authors did not consider the presence of this cell type diagnostic for the genus due to its rare occurrence and it was only found in *M. viscifolia*.

In Celastroideae, the presence of PRCs has so far been restricted to *Maytenus*. Perforated ray cells have been cited in *Maytenus*. Joffily *et al.* (2007), describe the presence of this element in *M. alaternoides, M. boaria, M. brasiliensis, M. communis, M. evonymoides, M. floribunda, M. ilicifolia, M. myrsinoides* and *M. obtusifolia*.

In arid regions, wood must support high negative pressures. In these regions, the morphology of vessels has adaptive value. There is a reduction of vessel diameter and length, increase in vessel frequency and degree of clustering, and presence of qualitative anatomical features, such as simple perforations. These adaptations increase safety against embolisms (Lindorf, 1994). Baas and Carlquist (1985) emphasize the presence of the following characters in xerophytes and halophytes: small vessels (29-53 µ), high vessel frequency (92-150), semi-ring porous, and presence of fibre-tracheids. All of these features (except porosity) are present in the species studied. The anatomical structure of the woods of this study is characteristic of species of arid zones, such as the dry Chaco region in which *Maytenus* is common. The smaller diameter and length of the vessels, and their high frequency, are some of the most notable features of the conductive elements. They are considered signs of adaptation to extreme aridity and tend to increase the safety, given the limited amount of water available (Lindorf, 1994; Carlquist, 1988; Moglia and Giménez, 1998; Giménez, 1993; Roth and Giménez, 1997; Roth and Giménez, 2006).

The sp *M. viscifolia* and *M. cuezzoi* not show statistical differences for 5 of the 7 considered variables (Kruskal Wallis). This is confirmed by the cluster analysis where both sp. form a group.

Conclusions

The species studied show the anatomical features typical of genus *Maytenus*.

The anatomical structure of the woods of this study is characteristic of species of arid zones.

The smaller diameter, shorter vessels and high frequency, are the most notable features of the conductive elements, considered signs of adaptation to extreme aridity

Quantitative variables that best explain the anatomical differences are: vessel diameter, fibre wall thickness, rays width. The distinctive anatomical features are the presence of PRC only in *M. viscifolia,* intervascular vestured pits in *M. cuezzoi* and *M. viscifolia* and helical thickenings in *M. cuezzoi*.

References

Archer, R.H. and A.E. van Wyk. 1993a. Wood structure and generic status of some southern African Cassinoideae (Celastraceae). IAWA *J.* 14:373-389.

Archer, R.H. and A.E. Van Wyk. 1993b. Bark structure and intergeneric relation of some Southern African CASSINOIDEAE (CELASTRACEAE). IAWA *Journal* 14(1):35-53.

Baas, P. 1982. New perspectives in wood anatomy. W. Junk Publ. 252 p.

Baas, P. and S. Carlquist. 1985. A comparison of ecological wood anatomy of the floras of southern California and Israel. IAWA *Journal* 8:245-274.

Bailey, I. 1957. The potentially and limitations of wood anatomy in the study of phylogeny and classification of angiosperms. *Journal of the Arnold Arboretum* 38:243-254.

Boelke, O. 1992. Plantas vasculares de la Argentina nativas y exóticas. Ed. Hemisferio Sur S.A. Buenos Aires.

Brown, A. and A. Grau. 2000. Fortalecimiento de la capacidad productiva bajo condiciones de sustentabilidad. 135 p. Comisión Nacional de la cuenca alta del bermejo.

Carlquist, S. 1988. Comparative wood anatomy. Springer-Verlag, Heidelberg.

Carlquist, S. and Hoekman, D. 1985. Ecological wood anatomy of woody southern California flora. IAWA *Bulletin* 6:319-347.

Cody, R. and J. Smith. 1991. Applied Statistics and the SAS. Programming Language. North Holland. 3 ed. New York, Amsterdan, London. 404 p.

Detienne, P. and P. Jacquet. 1983. Atlas d'identification des bois de l'amazonie et des regions voiseines. Centre Technique Forestier Tropical, Nogent s/Marne. 640 pp

Digillio, R. and R. Legname. 1966. Los árboles indígenas de la provincia de Tucumán. Opera Lilloana XV Tucumán.

Dimitri, 1972. Enciclopedia argentina de agricultura y jardinería. 1a ed. insp. y dirigida por Lorenzo R. Parodi : 1. v.. ACME. Buenos Aires. Ar. l028 p.

Ewers, F.W.; J.M. Ewers, A.L. Jacobsen and J. López Portillo. 2007. Vessel redundancy: modeling safety in numbers. IAWA 28(4):373-388.

Giménez, A. and J. Moglia. 2003. Árboles del Chaco Argentino. Guía para el reconocimiento dendrológico. Secretaría de Ambiente y Desarrollo Sustentable del Ministerio de Desarrollo Social, UNSE. 310 p.

Giménez, A. and P. Hernández. 2008. Biodiversidad en Ambientes naturales del chaco Argentino Vegetación del Chaco Semiárido. Provincia de Santiago del Estero Fascículo 1- Ed. FONCYT. FCF-UNSE. 120 p.

Giménez, A., Gerez, R. and P. Hernández. 2007. Principales leñosas del Chaco Semiárido Argentino con potencialidad de uso tintóreo. Flora Nativa. III Jornadas Nacionales de Flora Nativa; IV Encuentro de Cactáceas. Córdoba. ISBN 978-987-510-079-4. p: 235-246 pp.

Giménez, A.M. 1993. Rasgos estructurales característicos del xilema secundario de las principales especies arbóreas de la región Chaqueña Seca. *Revista Quebracho*: 5-14.

Giménez, A.M. 2004. Anatomía de leño y corteza de *Tabernaemontana catharinensis Adc*. (Apocinaceae). *Revista Quebracho* 11:22-32.

Giménez, A.M.; J.G. Moglia and J.H. Femenia. 1998. Anatomia del leño y corteza de *Monttea aphylla* (Miers) Beneth et Hook, Scrophulariaceae. *Revista Quebracho* 6:42-62.

Giménez, A.M.; P. Hernández, R. Gerez, M.E. Figueroa, I. Barrionuevo, F. Calatayu. 2010. Los arbustos útiles de los bosques del Chaco Semiárido. Eco Productos Forestales No Madereros- Libro de Actas. Trabajo completo p: 66-77.

Hurrel, J. and D. Bazzano, 2003. Arbustos I. Biota Rioplatense Ed. LOLA. Bs. As. Argentina. p:68-69.

IAWA Committee. 1989. IAWA List of microscopic features for hardwood identification. IAWA *Bulletin* 10:219-332.

INFOSTAT 2008. InfoStat, versión 2008. Manual del Usuario. Grupo InfoStat, FCA.

Joffily, A., D.F. Domingues, and R.C. Vieira. 2007. Perforated ray cells in the root and stem of *Maytenus* (Celastroideae-Celastraceae). IAWA *Journal* 28(3):311-314.

Johansen, D.A. 1940. Plant microtechnique. McGraw-Hill Book Co, New York.

Karlin, U.; E. Ruiz Posse and A. Contreras. 2010. Etnobotánica de las Salinas Grandes. *Eco Productos* p:92-104.

Legname, R. 1973. Arboles indígenas de la provincia de Tucumán. Publication: *Lilloa* 33(19):333.

Legname, R. 1982. Árboles indígenas del Noroeste Argentino. Opera Lillona XXXIV. Tucumán.

Lindorf, H. 1994. Eco-anatomical Wood Features of Species from a Very Dry Tropical Forest. IAWA 15(4):361-376.

Lourteig, A. and C. Odonell. 1955. Las celastráceas de Argentina y Chile. *Natura* 1:181-233.

Mennega, A.M.W. 1997. Wood anatomy of Hippocrateoideae (Celastraceae). IAWA *Journal* 18:331-368.

Metcalfe, C. and L. Chalk. 1950. Anatomy of the Dicotyledons. Vol. 1 and 2. Clarendon Press, Oxford.

Metcalfe, C. and L. Chalk. 1983. Anatomy of the dicotyledons, 2nd Ed. Vol. II. Wood structure and conclusion of the general introduction. Clarendon Press, Oxford. 279 p.

Moglia, G. and A.M. Giménez. 1998. Rasgos Anatómicos Característicos del Hidrosistema de las Principales Especies Arbóreas de la Región Chaqueña Seca y Húmeda. *Rev. I.A. Sistemas y Recursos Forestales* 7:53-71.

Moglia, J.G, S.J. Bravo; A.M. Gimenez, A.M. and C.R. Lopez. 2009. ¿Son los caracteres estructurales de la madera de *Aspidosperma quebracho-blanco* Schelkt causantes de su inestabilidad?. *Revista Quebracho* 17:20-31.

Neumann, K., W. Schoch, P. Détienne and F.H. Schweingruber. 2000. Woods of the Sahara and the Sahel. An anatomical atlas. Eidg. Forschungsanstat WSL, Birmendorf, Verlag Paul Haupt.

Record, S.J. and R.W. Hess. 1943. Timbers of the New World. Yale Univ. Press, New Haven.

Robertse, P.J., G. Venter and Janse van Rensberg. 1980. The wood anatomy of the South African *Acacia*. *International Wood Anatomists Bulletin* 1(3):93-103.

Roeser, K.R. 1972. Die Nadel der Schwarz Kiefer-Massenprodukt und Kunstwerk der Natur. *Mikrokosmos* 61:33-36.

Roth, I. and A. Giménez. 1997. Argentine Chaco forests. Dendrology, tree structure, and economic use.1- The semiarid Chaco. Encyclopedia of Plant Anatomy.XIV/5. 120P. Gerbruder-Borntraeger-Berlin-Stuttgart.

Roth, I. and A. Giménez. 2006. Argentine Chaco forests. Dendrology, tree structure, and economic use. 2- The humid Chaco. Encyclopedia of Plant Anatomy.XIV/5. 130p. Gerbruder-Borntraeger-Berlin-Stuttgart.

Saavedra, S.V. 2004. Determinación con base ecológica de la productividad potencial forestal en la provincia de Santiago del Estero. Tesis doctoral Universidad Politécnica de Madrid, Esc. Técnica Superior de Ingenieros de Montes.

Sokal, R. R. and F.R. Rohlf. 1981. Biometry. The Principles and Practice of Statistics in Biological Research, 2nd ed. W.H. Freeman & Co., New York. 880p.

Somaratne, S. and T.R. Heart. (2001). Comparative vegetative Anatomical Study of the Genus *Calophyllum* L. (Clusiaceae) in Sri Lanka. *Ceylon Journal of Sciences (Bio. Sci.)* 28:51-80.

Stramiglioli, C. 2007. Las teleras santiagueñas. Latin Grafica SRL. Bs. As. ISBN 978-987-05-3197-5172 p.

Tortorelli, L. 2009. Maderas y Bosques Argentinos. 2nd ed. Tomo I y II: 1105. ISBN 978-987-9260-68-5. 2000 p.

Wickremasinghe, B. K. L. and T.R. Heart. 2006. A comparative wood anatomical study of the Genus *Diospyros* L. (Ebenaceae) in Sri Lanka. *Cey. J. Sci. (Bio. Sci.)* 35(2):115-136.

Zuloaga, F. O. and O. Morrone,eds.1999. Catálogo de las plantas vasculares de la República Argentina. II. Dicotyledoneae. Monogr. Syst. Bot. Missouri Bot. Gard. 74: St. Louis.

Manuscript received on September 6th 2012.
Accepted on February 27th 2014.

This manuscript must be cited as:
Giménez, A.M., J.G. Moglia, M.E. Figueroa, J.A. Díaz-Zírpolo and F. Calatayu. 2014. Comparative wood anatomy of *Maytenus* in Northwestern Argentina (South America). *Madera y Bosques* 20(2):95-110.