Cretaceous Research 56 (2015) 388-398

Contents lists available at ScienceDirect

Cretaceous Research

journal homepage: www.elsevier.com/locate/CretRes

The first record of Lauraceae fossil woods from the Cretaceous Puerto Yeruá Formation of eastern Argentina and palaeobiogeographic implications

María Jimena Franco^{a, *}, Mariana Brea^a, Esteban Passeggi^a, Leandro Martín Pérez^b

^a Centro de Investigaciones Científicas y Transferencia de Tecnología a la Producción — Consejo Nacional de Investigaciones Científicas y Técnicas (CICYTTP—CONICET), Dr. Matteri y España SN, E3105BWA Diamante, Entre Ríos, Argentina

^b División Paleozoología Invertebrados, Museo de La Plata, Paseo del Bosque SN, B1900FWA La Plata, Argentina

A R T I C L E I N F O

Article history: Received 6 January 2015 Received in revised form 18 May 2015 Accepted in revised form 19 May 2015 Available online xxx

Keywords: Fossil wood Persea Mill. Lauraceae Cretaceous Palaeobiogeography Argentina Gondwana

ABSTRACT

In this paper, a new species of fossil wood, *Paraperseoxylon septatum* sp. nov. (Lauraceae), from the Cretaceous of Puerto Yeruá Formation, is described. The fossil wood herein studied has features of the Lauraceae family, and particularly resembles the extant genus *Persea* Mill. The possible climatic conditions of the Puerto Yerúa Formation were inferred using the Vulnerability Index, Mesomorphy ratios and the Taxon Independent Approach of the anatomical features present in the fossil wood described, suggesting a warm and humid to seasonally dry context. This material is the first record known from the Cretaceous of Northeastern Argentina and the earliest occurrence in the Southern Hemisphere of a fossil taxon with feature closest to *Persea*, and clearly establishes the presence of Lauraceae in Northeastern Argentina during the Cretaceous. Nowadays the genus *Persea* has a tropical and subtropical disjunct distribution in the Americas, Asia, and the Canary Islands. The present study provides information pertinent to understanding its phylogenetic context and biogeographic history.

© 2015 Elsevier Ltd. All rights reserved.

1. Introduction

The Lauraceae is a large family of woody plants (except for the herbaceous parasite *Cassytha*), with about 50 genera and 2500 to 3000 species distributed throughout tropical to subtropical latitudes (Chanderbali et al., 2001; Taylor et al., 2009). These plants represent an important part of the ecosystem of the tropical and subtropical forest regions in the Old and the New World (Richter, 1981). They are particularly diverse in American and Asian tropics and they also have a large number of species in Australia and Madagascar, but poorly represented in Africa (Cronquist, 1981; Werff and Richter, 1996).

This family is among the most speciose basal angiosperm families (APG III, 2009) and has an extensive fossil record including leaves, woods, pollen, fruits, seeds, and flowers from the Cenozoic, with some reports as early as the Cretaceous (Herendeen et al., 1994; Taylor et al., 2009; Takahashi et al., 2014).

Wood assignable to the Lauraceae is relatively easy to recognize based on the presence of variable vessel-ray pitting, predominantly solitary small to medium vessels, alternate intervascular pitting, heterocellular rays, mostly one to three cells wide, vasicentric paratracheal parenchyma and oil cells (Metcalfe and Chalk, 1950; Scott and Wheeler, 1982; Richter, 1987).

In this contribution, we have erected a new Lauraceae fossil wood species which resembles the extant genus *Persea* Mill., *Paraperseoxylon septatum* sp. nov, recovered in the Puerto Yeruá Formation (Cretaceous), Entre Ríos Province, Argentina and we provided new evidence of the diversity of the Lauraceae family during the Cretaceous. This is the first *Persea*-like wood known from the Cretaceous of Northeastern Argentina.

2. Geological setting

The Puerto Yeruá Formation (De Alba and Serra, 1959) is a Cretaceous succession exposed along the right margin of the





CrossMark

^{*} Corresponding author.

E-mail addresses: jimenafr@gmail.com (M.J. Franco), cidmbrea@gmail.com (M. Brea), estebanpasseggi@cicyttp.org.ar (E. Passeggi), pilosaperez@gmail.com (L.M. Pérez).

Uruguay River, between the cities of Concordia and Colón, in the northeast of Entre Rios Province, Argentina.

It is an intercalated set of fluvial siliciclastic rocks and calcrete horizons with alpha fabric (Tofalo and Pazos, 1999, 2002). These rocks were deposited from tractive-unidirectional currents with high to moderate energy, originated from rivers of sinuosity with lateral channel migration (Tofalo, 1986).

The significant thicknesses of the calcretes present in the Puerto Yeruá Formation is a very important tool for paleoclimate inferences and indicates that the sediments were possibly deposited in intermediate moisture conditions with marked seasonal rains (Tofalo, 1986).

The analyzed locality is near the Puerto Yeruá Village in the Department of Concordia (Fig. 1). Red sedimentary rocks from the Cretaceous unit lie exposed at this locality. This section is approximately two metres thickness, composed of fine to medium, reddish and silicified sands, fine to medium conglomerates and scarce greenish muds. The presence of mud and sand matrix-supported conglomerate is frequent. The top of the sequence is covered by vegetation (Figs. 2 and 3A).

The age of this unit is difficult to determine beyond a Cretaceous age (De Valais et al., 2003). However, this formation was assigned to the Upper Cretaceous based on presence of dinosaur remains *sensu* de Carles pers. com. (in Huene, 1929; pag. 81). Titanosaurid bones were found on the lenticular mud bed of the Uruguay River in Entre Ríos Province (Huene, 1929; Powell, 2003). A few materials analyzed by De Valais et al. (2003), a conical scute probably belonging to an Ankylosauria gen. and sp. indet., a small fragment of tooth from a Theropoda gen. and sp. indet. and a fragment of eggshells, cf. *Sphaerovum erbeni* Mones, do not provide sufficient data to estimate a more accurate age beyond the Cretaceous.

The Puerto Yerúa Formation is correlated with the Guichón Formation (Bossi, 1966) from Uruguay. In the latter, bones belonging to a derived titanosaurian (Eutitanosauria) and eggshells referred to the oogenus? *Sphaerovum* sp. indet. were described (Soto et al., 2009). This material is considered a fine indicator of the Upper Cretaceous for the Campanian–Maastrichtian range

(Casadío et al., 2002). If the presence of *Sphaerovum erbeni* can be confirmed, this would be solid evidence of a Late Cretaceous age (Campanian–Maastrichtian) for the Guichón Formation.

3. Material and methods

The fossil specimen was collected from the Puerto Yeruá fossiliferous Locality, situated in Puerto Yeruá, Entre Ríos Province, Argentina. The outcrop of the Puerto Yeruá Formation is situated at 31° 31′ 55.23″ S, 58° 1′ 34.93″ W (Fig. 1).

The material was preserved by siliceous cellular permineralization and has well-preserved secondary xylem. It was thinsectioned (transversal, radial longitudinal and tangential longitudinal) using standard petrographic techniques. The wood was described and measurements undertaken in accordance with the IAWA recommendations (IAWA Committee, 1989). The quantitative values provided in the anatomical description are averages of 25 measurements. The average is cited first, followed by minimum and maximum values (in parentheses).

The Vulnerability Index (V) and Mesomorphy ratios (M) were calculated using the equations developed by Carlquist (1977). The taxon independent approach (TIA) was used in order to derive clearer insight into the paleoclimate (Martínez-Cabrera et al., 2014). The anatomical characteristics of wood were analyzed in terms of their associated palaeoecological requirements, including: vessel diameter, vessel density, percentage of solitary vessels, vessel arrangement, length of vessel elements, perforation plate types, porosity, axial parenchyma distributions, presence of septate fibers, parenchyma strand and growth rings (Carlquist and Hoekman, 1985; Wheeler and Baas, 1991, 1993; Lindorft, 1994).

The identification of the fossil wood samples was based on reference to wood classical descriptions of extant and fossil plants (Record and Hess, 1942; Metcalfe and Chalk, 1950; Tortorelli, 1956; Richter, 1987; Rancusi et al., 1987; Scott and Wheeler, 1982; Richter and Dallwitz, 2000; León, 2002; Wheeler and Manchester, 2002; InsideWood, 2004-onwards; Dupéron-Laudoueneix and Dupéron, 2005; Wheeler and Dillhoff, 2009).



Fig. 1. Location map showing Puerto Yeruá fossiliferous locality, Entre Ríos, Argentina.



Fig. 2. Schematic profile at the Puerto Yeruá fossiliferous locality, Entre Ríos, Argentina.

The fossil sections were studied with a Nikon Eclipse E200 light microscope (using $40 \times$, $100 \times$, $400 \times$ and $1000 \times$ magnification levels) and the photomicrographs were taken with a Nikon Coolpix 990 digital camera. In addition, a scanning electron microscope (SEM) was used. The material was prepared for SEM by cutting a 1 cm³ block of wood that was mounted on SEM stubs without coating and then observed in a low vacuum using a SEM LEO

1450VP at the Universidad Nacional de San Luis, San Luis, Argentina and a SEM Jeol JSM-580 OLV at the Universidad Nacional del Nordeste, Corrientes, Argentina.

The macrofossil wood holotype is housed in the Museo de Antropología y Ciencias Naturales de Concordia, Concordia, Entre Ríos Province, Argentina, under the acronym MACNC-Pb 2513, and the isotype and thin-section slides were kept in the repository of



Fig. 3. A. Puerto Yerúa Formation. B-D. Paraperseoxylon septatum sp. nov. Holotype: MACNC-Pb 2513.

the Laboratorio de Paleobotánica, CICYTTP-CONICET, Diamante, Entre Ríos Province, Argentina, under the acronyms CIDPALBO-MEG 161 and CIDPALBO-MIC 1739 (a-c).

4. Systematic palaeobotany

Superorder Magnolianae Takht., 1967

Order Laurales Juss. ex Bercht. and J.Presl, 1820

Family Lauraceae Jussieu, 1788

Genus Paraperseoxylon Wheeler and Manchester, 2002.

Type species. *Paraperseoxylon scalariforme* Scott and Wheeler, 1982, p. 140, Figs. 23–27, by subsequent designation of Wheeler and Manchester 2002, p. 65, Fig. 16.

Paraperseoxylon septatum sp. nov.

Figs. 3-6.

Derivation of name. The specific epithet refers to the occurrence of septa in fibers and parenchyma.

Holotype. MACNC-Pb 2513.

Isotype. CIDPALBO-MEG 161 and CIDPALBO-MICmic 1739 (a–c). *Type locality.* Puerto Yeruá, near Concordia city, in Entre Ríos Province, Eastern Argentina.

Stratigraphic horizon. Puerto Yeruá Formation (Cretaceous).

Diagnosis. Diffuse porous wood; solitary vessels, in radial multiples and rarely in clusters, mean tangential diameter of \leq 100 µm; simple and scalariform perforation plates; alternate and subopposite intervessel pits; vessel-ray parenchyma pits with distinct borders, similar to intervessel pits; non-septate and septate fibers; vasicentric, aliform to confluent axial parenchyma; 1–2 seriate rays, homocellular to weakly heterocellular, idioblastic secretory cells ("oil or mucilage cells") common in ray parenchyma and among the fibers.

Description. The fossil specimen consists of an 8 cm long and 15.5 cm wide fragment and is very well preserved (Fig. 3B–D). The species is based on a piece of secondary wood. The pith, primary xylem, cortex and secondary phloem are absent. Growth rings are demarcated by larger radially compressed fiber walls and by terminal parenchyma (Fig. 4A). The wood shows diffuse porosity (Fig. 4A). Vessels are commonly solitary (68%), occasionally in radial multiples of 2-4 (30%) and rarely in clusters (2%) (Fig. 4A and D). The solitary vessels are circular to oval in outline and have thin walls (Fig. 4D). Vessels have a radial diameter of 66 (30-99) μ m and a tangential diameter of 59 (20–78) μ m. The mean vessel density is 7 $(5-12)/mm^2$. The vessel element length is 173 $(110-235) \mu m$, with oblique end walls (Fig. 4B and G). Perforation plates are simple (Figs. 4F and 6E); some are scalariform with 2 or 3 bars (Fig. 4E). Intervessel pits are very small, bordered, rounded, alternate and sub-opposite (Figs. 5E, I and 6E). Their diameters are 7 (6–8) um.

The fibers are polygonal in outline, abundant, non-septate and sometimes septate, with poor preservation, with a diameter of 12 (10–15) μ m and with a wall thickness of 3 (2–5) μ m (Figs. 5B, D, H and 6F).

The axial parenchyma is paratracheal, vasicentric, lozengealiform to confluent, and has strands of seven to eleven cells (Figs. 4D, 5A, H and 6D).

The rays are commonly uniseriate (72%) and rarely biseriate (28%) (Figs. 4B, G–H, 5A–B and 6C–F). The number of rays per mm linear is 7 (5–9 per mm linear). They are homocellular, composed exclusively of procumbent cells (Figs. 4C, E–F and 6A) and rarely partially heterocellular with one row of upright and/or square cells (Figs. 4I and 5C). The rays' width of is 20 (15–30) μ m. The rays' height is 194 (100–370) μ m and 12 (3–25) cells high. They are Homogeneous type III of Kribs or Heterogeneous type III of Kribs. There are oil or mucilage cells associated with ray parenchyma (Figs. 4J, L, 6A and F) and among fibers (Figs. 4K and 5G).

Vessel-ray parenchyma pits, with distinct borders, are similar to intervessel pits in size and shape throughout the ray cell (Fig. 5F and J).

5. Discussion

5.1. Comparison with extant species

Oil and mucilage cells are diagnostic character and are limited to very few woody dicotyledons: Annonaceae, Aristolochiaceae, Burseraceae, Canellaceae, Dilleniaceae, Hernandiaceae, Lauraceae, Magnoliaceae, Monimiaceae, Myristicaceae, Piperaceae, Rutaceae, Saurauiaceae, Schisandraceae, Winteraceae (Metcalfe and Chalk, 1950). Of these families, only the Lauraceae have growth ring boundaries distinct, simple and scalariform perforation plates, vasicentric axial parenchyma, ray width of 1–3 cells, oil and/or mucilage cells associated with ray parenchyma and present among fibers (InsideWood, 2004 onwards).

Richter (1987) found three classes of vessel-ray parenchyma pits in the Lauraceae, which closely relate to diameter classes of intervessel pits:

Class a: intervessel pits with a diameter of 8 (3–7) μ m and vessel-ray parenchyma pits of similar size and shape as intervessel pits, sometimes opening into compound pits which are extended horizontally or vertically or are curved.

Class b: intervessel pits with a diameter of 15 $(8-12) \mu m$ and vessel-ray parenchyma pits variable in shape, round to oval, to elogated horizontally, vertically or diagonally.

Class c: intervessel pits from 10 to 15 μ m with vessel-ray parenchyma pits very large and window-like.

The fossil studied has *class a* vessel-ray parenchyma pits *sensu* Richter (1987). The extant Lauraceae taxa that have this kind of vessel-ray parenchyma pits are *Actinodaphne* Nees., *Chlorocardium rodiei* (Schomb.) Rohwer, H.G.Richt. & van der Werff, *Laurus* L., *Lindera* Thunb., *Litsea chinensis* Lam., *Neolitsea* (Benth.) Merr., *Persea* Mill. (North American species), *Sassafras* J. Presl and *Umbellularia* (Nees) Nutt. The fossil wood was compared with these genera in Table 1 and it is most closely related with *Persea*.

The wood of *Persea* is similar to most of the other members of the Lauraceae in some characters. However, *Persea* differs from other Lauraceae in having the combination of simple and scalariform perforation plates, homogeneous or heterogeneous rays, vasicentric, lozenge-aliform, confluent and in strand parenchyma, and idioblast present in parenchyma and among the fibers (Record and Hess, 1942; León, 2002).

The extant species of *Persea* are indistinguishable in terms of wood anatomy. Therefore, we cannot assign the Cretaceous fossils to a single extant species.

5.2. Comparison with fossil species

The fossil wood described herein was compared with other fossil genera assigned to Lauraceae (Table 2). *P. septatum sp. nov.* has simple and scalariforms perforation plates. This character is only present in *Cinnamomoxylon* Gottwald, *Laurinoxylon* (Felix) emend Duperón, Duperón-Laudoueneix, Sakala and Franceschi, *Paraperseoxylon* Wheeler and Manchester, and *Sassafrasoxylon* Brezinová and Süss (Table 2).

Dupéron-Laudoueneix and Dupéron (2005) reviewed fossil woods assigned to Lauraceae and most of Lauraceae fossil woods have been assigned to the genus *Laurinoxylon* Felix, 1883. The diagnostic characters of this genus are the following: solitary vessels and in radial multiples, simple and scalariform perforation plates, paratracheal parenchyma, 1–5 seriate rays, weakly heterocellular, vessel-ray parenchyma pits very large and elongated, and



Fig. 4. *Paraperseoxylon septatum sp. nov.* Holotype: MACNC-Pb 2513. A. General view in transverse section (ts), the arrow indicate a growth ring. B. General view in tangential longitudinal section (tls). C. General view in radial longitudinal section (rls). D. Solitary and radial multiples vessels, the arrow indicate confluent parenchyma (ts). E. Homocellular rays (white arrow) and scalariform perforation plate (black arrow; rls). F. Simple perforation plate (white arrow; rls). G. Rays and vessels, the arrow indicates an oblique end wall (tls). H. Uni-biseriate rays (tls). I. Heterocellular ray (rls), the arrow indicates an upright cell. J. Oil or mucilage cells (black arrow) associated with ray parenchyma (white arrow), rls. K. Oil or mucilage cell (black arrow) present among fibers, rls. L. Oil or mucilage cell (white arrow) associated with ray parenchyma (black arrow), tls. Scale bar in A–C = 200 μ m; in D–I = 100 μ m; in J–L = 30 μ m.

oil or mucilage cells (Duperón et al., 2008). *P. septatum* sp. nov. has homocellular and heterocellular narrower rays and the vessel-ray pits are similar to intervessel pits in size and shape (Table 2).

P. septatum sp. nov. differs from *Cinnamomoxylon* Gottwald in the type of ray (Table 2; Dupéron-Laudoueneix and Dupéron, 2005). *Sassafrasoxylon* Brezinová and Süss has ring-porous wood, with multiple rings of earlywood pores; parenchyma sparsely paratracheal; 1–4 seriate rays; vessel-ray pits enlarged, rounded to horizontally elongated and unilaterally bordered which differ from those of the fossil specimen studied herein (Table 2; Poole et al., 2000).

P. septatum sp. nov. is assigned to *Paraperseoxylon* Wheeler and Manchester based on the presence of *class a* vessel-ray parenchyma pits *sensu* Richter (1987), both simple and scalariform perforation plates and idioblasts scattered among the fibers and occurring in

rays (Wheeler and Manchester, 2002; Wheeler and Dillhoff, 2009). This fossil genus was erected by Wheeler and Manchester (2002) who described a lauraceous fossil, *P. scalariforme* (Scott and Wheeler) Wheeler and Manchester, from the middle Eocene of the Nut Beds Flora of the Clarno Formation, with anatomical characters closest to those of the extant genera *Actinodaphne, Laurus, Lindera, Persea* and *Neolitsea*. This material was originally described as *Ulminium scalariform* Scott and Wheeler (Scott and Wheeler, 1982). The fossil material described herein is very similar to the type species, but differ from it in the presence of distinct growth ring boundaries, septate and non-septate fibers, homocelullar and heterocelullar rays, and in the type of axial parenchyma (Wheeler and Manchester, 2002).

In Argentina, a fossil wood, *Laurinoxylon atlanticum* (Romero) Dupéron-Laudoueneix and Dupéron 2005, with closest affinities



Fig. 5. *Paraperseoxylon septatum* sp. nov. Holotype: MACNC-Pb 2513. A. Biseriate ray (black arrow) and parenchyma strand (white arrow), tls. B. Uniseriate ray (black arrow) and septate fibers (white arrows), tls. C. Detail of a heterocellular rays with procumbent (black arrow) and upright cells (white arrow), rls. D. Detail of the fibers in ts. E. Vessels with alternate intervessel pits (white arrow) in tls. F. Vessel ray pits with distinct borders, similar to intervessel pits (white arrow). G. Detail of oil or mucilage cell (black arrow) present among fibers in tls. H. Detail of a septate fiber (black arrow) next to parenchyma strand (white arrow) in tls. I. Detail of intervessel pits (black arrow). J. Detail of vessel ray pits (white arrow) Scale bar in A–F = 30 µm; in G–J = 10 µm.

with the genus *Persea*, specially *P. lingue* (Miers ex Bertero) Nees is reported from the Eocene of Patagonia (Romero, 1970) and upper Oligocene of Neuquén, Argentina (Brea et al., 2015). The material described by Romero (1970) is characterized by diffuse porous wood; solitary vessels, in radial multiples; simple perforation plates; short vessel members with narrow diameters and with mostly alternate intervessel pits; vasicentric parenchyma, sometimes aliform and locally confluent; low rays, 1–2 seriate, heterocellular; narrow fibers with thin walls and few cells with contents, only present in ray cells. The differences between *P. septatum* sp. nov. and *Laurinoxylon atlanticum* are in the type of the perforation plates, ray type and in the absence of oil cells among fibers.

In addition, several fossil woods with Lauraceae affinity in the Cenozoic of Chubut and Entre Ríos in Argentina were studied: *Laurinoxylon chubutense* (Romero) Dupéron-Laudoueneix and Dupéron, *Laurinoxylon artabeae* (Brea) Dupéron-Laudoueneix and Dupéron, *Curtiembreoxylon poledrii* Franco, *Laurinoxylon mucilaginosum* (Brea) Dupéron-Laudoueneix and Dupéron and *Beilschmiedioxylon parataubertiana* Ramos, Brea and Kröhling (Brea, 1995, 1998; Franco, 2012; Ramos et al., 2012). These materials do not have *Persea*-like wood and are different from the new fossil wood studied here.

5.3. Palaeoecology and palaeobiogeographic implications

The Persea group sensu Rohwer et al. (2009) consists of seven currently recognized genera: Alseodaphne Nees, Apollonias Nees, Dehaasia Blume, Machilus Rumphius ex Nees, Nothaphoebe Blume, Persea Mill. and Phoebe Nees, including a total of c. 400 to 450 species. About 80% of these species are distributed in tropical to subtropical Asia, the rest are found in warm-temperate to tropical regions of the New World (Li et al., 2011). These occur mainly in montane forests in Central and South America and range from Mexico to Chile, reaching the Atlantic coastal forests in southeastern Brazil (Chanderbali et al., 2001). Only two species, Apollonias barbujana (Cav.) Bornm. and Persea indica (L.) Spreng., are distributed in the Macaronesian Islands (Li et al., 2011).

The genus *Persea* has a tropical and subtropical disjunct distribution in the Americas, Asia and the Canary Islands (Raven and Axelrod, 1974; Rohwer, 1993). This is due to its extinction in Europe and Africa, with only *P. indica* surviving as endemic in the laurel forests of the northern coast of the Canary Islands (Raven and Axelrod, 1974).

In South America, *Persea* is found chiefly in the montane forests of east central to southern Brazil. There, some species are native. Most of the remaining South American species populate the upper rainforests on the slopes of the Andes. In addition, two endemic species are present in the Guayana Highlands, and *P. lingue* (Nees) reaches into the temperate zones of Chile and Argentina. From the mountain chains of Central America, the genus continues along the Sierra Madre Occidental to the Sierra Madre Oriental of Mexico. Only *P. caerulea* (Ruiz and Pavon) Mez occurs in both South and Central America (Scora and Bergh, 1992). The presence of *P. septatum* sp. nov, in the Argentinian Mesopotamic region implies that



Fig. 6. *Paraperseoxylon septatum* sp. nov. Holotype: MACNC-Pb 2513. A. Oil or mucilage cells (white arrow) associated with ray parenchyma (black arrow) in rls. B. Vessels (white arrow) and homocellular rays in rls. C. Uniseriate (white arrow) and biseriate (black arrow) rays in tls. D. Biseriate ray (black arrow) and parenchyma strand (white arrow) in tls. E. Vessel with a simple perforation plate (black arrow) and intervessel pits (with arrow) in tls. F. Septate fiber (black arrow) and oil or mucilage cell (white arrow) associated with ray parenchyma, tls. Scale bar in A = 15 μ m; in B = 25 μ m; in C = 20 μ m; in D-F = 40 μ m.

this taxon was more widespread in the geological past and has experienced extinction in this region.

Lauraceae fossils are common in Cretaceous and Cenozoic deposits of both the Northern and Southern Hemisphere (Poole et al., 2000 and references therein). *Persea* fossil distribution is different from its present range. It grew in regions that are now temperate and even polar (Scora and Bergh, 1992). Fossil record of *Persea*-like organs is known in North America from from the Eocene onwards (Schroeder, 1968; Herendeen et al., 1994; Wheeler and Manchester, 2002), and wood very similar to that of this genus is known from the Eocene of Patagonia (Romero, 1970). This fossil wood from the Cretaceous Puerto Yeruá Formation of the Argentinian Mesopotamic Region is the earliest record of Persea-like wood.

The history of the Cretaceous vegetation in the Argentinian Mesopotamic Region is not known. This is the first paleobotanical Cretaceous record for this region. However, the presence of Lauraceae fossils was confirmed in the Cenozoic of this region in several formations by fossil woods, leaf compressions and cuticles: Ocotea sp. and Laurophyllum sp. (leaves) in the Paraná Formation (upper Miocene); Nectandra sp. 1, Nectandra sp. 2, Nectandra sp.? and Ocotea sp.? (leaves), Laurinoxylon artabeae (Brea) Dupéron-Laudoueneix and Dupéron and C. poledrii Franco (fossil woods) in the Ituzaingó Formation (upper Cenozoic), Laurinoxylon mucilaginosum (Brea) Dupéron-Laudoueneix and Dupéron, Laurinoxylon artabeae (Brea) Dupéron-Laudoueneix and Dupéron and B. parataubertiana Ramos, Brea and Kröhling (fossil woods) in the El Palmar Formation (Upper Pleistocene) (Anzótegui, 1980; Aceñolaza and Aceñolaza, 1996; Brea, 1998; Anzótegui and Aceñolaza, 2008; Franco, 2012; Ramos et al., 2012).

Many of the anatomical characters observed in *P. septatum* sp. nov. support the idea that the fossil wood studied here possibly lived under warm and humid to seasonally dry environmental conditions. The Vulnerability Index (V) and Mesomorphy ratios (M) in the fossil wood show values of 8.43 and 1458 respectively. These values indicate that *P. septatum* sp. nov. shows mesomorphic features (Carlquist, 1977).

Using TIA method, anatomical features of the fossil wood indicates that the presence of few small vessels, with simple and scalariform (with low bar numbers) perforation plates is common in tropical lowland habitats (Wheeler and Baas, 1991). Distinct growth rings are considered indicators for seasonal climates (Creber and Chaloner, 1984; Wheeler and Baas, 1991, 1993). However, concerning the evolution in wood character, scalariform plates and heterogeneous rays are usually considered primitive characters. P. septatum sp. nov. has both primitive and advanced characters, as simple perforation plates and alternate intervessel pits. Most genera of Lauraceae have both scalariform and simple perforation plates, which are considered a transitional position in the Lauraceae. This suggests that Lauraceae are more transitional rather than primitive among the allied families of the Laurales (Heo, 1998). The climate inferred from the wood anatomy of *P. septatum* sp. nov. agrees with sedimentological data (Tofalo, 1986) and suggests a humid to semiarid seasonal climate during this geologic period.

Lauraceae was widespread and diverse by the Early Cretaceous (Renner, 2005). This family radiated when trans-Tethyean migration was relatively easy, and basal lineages were clearly established on the Gondwana or Laurasian terrains by the Late Cretaceous (Renner, 2005). Biogeographic studies suggested that the basal lineages of Lauraceae were sorted into two main geographic groups of Gondwanan or Laurasian origins (Chanderbali et al., 2001; Nie et al., 2007; Li et al., 2011).

Scora and Bergh (1992) proposed the western African Gondwanaland flora, probably by Paleocene time, as the place of origin of *Persea*. For these authors, its ancestral species migrated to Asia, where around 80 species exist today. Other species migrated to southwestern Europe and from there to North America when Eurasia and North America were in direct contact during the Late Cretaceous and islands were scattered along the mid-Atlantic ridge in the Paleogene times. Other species migrated from Africa via Antarctica, which at that time and with its geographic location close to Africa, was covered with tropical rainforests common to

Table 1

Comparison between the selected wood anatomical characters of *Paraperseoxylon septatum* sp. nov. and most related extant genera of Lauraceae. References: Record y Hess 1942; Hwang, 1962; Nazma et al., 1981; Rancusi et al., 1987; Hoadley, 1990; Heo, 1998; Silva Guzmán et al., 1999; León, 2002; InsideWood 2004–onwards.

| | Growth rings | Vessels | Perforation plates | Intervessel pits | Fibers | Parénquima | Rays | Idioblast |
|---|--------------------|--|--|--|--------------------------------------|---|---|--|
| Paraperseoxylon septatum sp. nov. | Distinct | Small to medium sized (<100 μm). Mostly solitary and radial multiples of 2 -4 pores and rarely in clusters. | Simple and scalariform | Small, bordered, rounded, alternate and sub-opposite | Non-septate and sometimes septate | Paratracheal, vasicentric, lozenge-aliform to confluent, and in strands | 1—2 seriate, homogeneous | Present in axial and radial parenchyma and among de fibers |
| Actinodaphne Nees. | Distinct | Moderately small (90—100 μm), | Simple and scalariform | Moderately small (7—10 µm), oppositely | Thick-walled | Apotracheeal diffuse | 1—2 seriate, rarely triseriate, heterogeneous | Present in axial and radial parenchyma and among de fibers |
| Chlorocardium rodiei (Schomb.) Rohwer, H.G.Richt. & van der Werff | Absent | 115–160 μm of diameter Solitary, radial multiples (2 —3) and in clusters | Simple | 3.75–5 μm | Non septate, thick walled | Paratracheal, vasicentric, lozenge-aliform, confluent, in strand (3–10 cells) | 1–2 seriate, homogeneous, occasionally heterogeneous | Absent |
| Laurus L. | Distinct | Small (<70 μm). Mostly solitary and radial multiples of 2 -4 pores. | Simple and scalariform | Alternate, circular, 7—8 μm | Sometime septate present | Paratracheal and scarse | Predominantly multiseriate with uniseriate tails, heterogeneous and homogeneous | Rarely observed in parenchyma strand |
| <i>Lindera</i> Thunb. | Distinct | Small (50–65 µm) of diameter. Solitary and in small radial multiples. | In part scalariform with a few coarse bars | Small (5 μm), not crowded | With medium thick gelatinous wall | Sparingly paratracheal | 1–3 seriate. Weakly heterogeneous | With much reduced borders to apparently simple |
| Litsea chinensis Lam. | Distinct or absent | Medium to small, mostly in radial multiples of 2 or 3, rarely 6 and occasionally solitary | Simple and scalariform | Alternate, small to large | Septate and non septate | Paratracheal, vasicentric, scarse | Moderately broad to fine | Present in axial and radial parenchyma and among the fibers |
| Neolitsea (Benth.) Merr. | Distinct | Medium to small. Solitary vessel outline angular | Simple and scalariform | Alternate, small to medium | Septate and non septate | Paratracheal, vasicentric, in strand | 1—3 seriate or multiseriate, heterogeneous, | Present in axial and radial parenchyma |
| Persea Mill. | Distinct or absent | Mostly medium- sized, occasionally only 70 μm Solitary and radial multiples (2–5), rare in clusters. | Simple and scalariform | Alternate, 9–15 μm | Septate or septate a non septate | Vasicentric, lozenge-aliform, confluent, in strand (2–7 cells) | 1–5 seriate, mostly 2–3 seriate; heterogeneous or homogeneous | Present in axial and radial parenchyma and among de fibers |
| Sassafras J. Presl | Distinct | Circular porosity. Solitary or in small multiples | Simple and scalariform | Medium to large (7 —14 μm) | Thin-walled | Fairly abundant, paratracheal and confluent | 1—4 seriate, heterogeneous | Present in axial and radial parenchyma and among de fibers |
| Umbellularia (Nees) Nutt. | Distinct | Small-medium (100–200 µm). Solitary and in multiples of 2 to several | Simple | Alternate, with medium-sized, rounded to angular pits. Small to medium (4—10 μm) | Non septate or septate. | Vasicentric parenchyma | 1–4 (mostly 2) seriate, heterogeneous | Present in radial parenchyma |

Table 2

Comparison of anatomical characteristics between Lauraceae fossil genera and Paraperseoxylon septatum sp. nov. References: Leisman 1986; Richter, 1987; Wheeler and Manchester 2002; Dupéron-Laudoueneix and Dupéron, 2005; Castañeda-Posadas et al., 2009; Wheeler and Dillhoff, 2009; Franco 2012.

| | Growth rings | Porosity | Vessels | Perforation plates | Intervessel pits | Fibers | Parénquima | Rays | Vessel ray pits | Idioblast |
|--|---------------------------|----------|--|-------------------------------------|--|--|---|--|---|--|
| Paraperseoxylon septatum sp. nov. | Distinct | Diffuse | Solitary, in radial multiples and rarely in clusters | Simple and scalariform | Rounded, alternate and sub-opposite | Non-septate and septate | Paratracheal, vasicentric, lozenge-aliform to confluent, and in strands (7–11 cells) | 1—2 seriate, homocellular, and few partially heterocellular | With distinct borders, are similar to intervessel pits in size and shape | In ray parenchyma and among fibers |
| Argapaloxylon Castañeda-Posadas, Calvillo-Canadell and Cevallos-Ferriz, 2009 | Distinct | Diffuse | Solitary, in radial multiples, and few clusters | Simple | Oval and alternate | Septate and non septate | Vasicentric and diffuse | Biseriated mainly homogeneous | Opposite | Present |
| Beilschmiedioxylon Dupéron-Laudoueneix and Dupéron, 2005 | Distinct to indistinct | Diffuse | Solitary and in clusters | Simple | Alternate and large (10 −12 μm) | | Paratracheal, vasicentric, sometimes in bands | 1—6 seriate, heterocellular | Very large and enlongated | Present, among fibers |
| Caryodaphnopsoxylon Gottwald, 1992 | | | | Simple | 8–13 μm | Septate | Vasicéntric | 7–8 (12) cells wide and 1.5–2 (4) mm de long, heterocellular | | In parenchyma |
| Cinnamomoxylon Gottwald, 1997 Cryptocaryoxylon Leisman, 1986 | Distinct | | Solitary and in radial multiples of up to four | Simple and scalariform Simple | Circular, bordered or scalariform pits | Elongate and with pointed ends, pits simple | Vasicentric, aliform and confluent Sparse, in tangential bands up to 15 cells wide, probably paratracheal | Weakly heterocellular Usually multiseriate, up to 5 cells wide, homocelullar | | In rays and parenchyma In ray parenchyma and among de fibers |
| Curtiembrexylon Franco, 2012 | | Diffuse | Solitary, in radial and tangential series and in clusters | Simple | Very small | Arranged in radial row | Scarce vasicentric | 2—3 cells width, homocellular | | In ray parenchyma and among the fibers. |
| Laurinoxylon (Felix) emend Duperón, Duperón-Laudoueneix, Sakala and Franceschi, 2008 | | | Solitary and in radial multiples | Simple and scalariform | Alternate and large | | Paratracheal | 1—5 seriate, weakly heterocellular | Very large and enlongated | Present |
| Mezilaurinoxylon Wheeler and Manchester, 2002 | | Diffuse | Solitary and in short radial multiples | Simple | Alternate, >10 μm | All septate | Scanty paratracheal to vasicentric | 1–5 seriate, heterocellular, usually with one row of marginal square to upright cells | Enlarged and with reduced borders | Occasional in ray margin |
| Olmosoxylon Estrada-Ruiz, Martinez-Cabrera and Cevallos-Ferriz 2010 | Indistinct | | Solitary and in radial multiples of 2–4, | Simple | Alternate | Septate and non septate | Scanty paratracheal | Grouped, homocellular and heterocellular | Very large of variable form, class B and C of Richter (1987) | Irregularly distributed in the rays |
| Paraperseoxylon Wheeler and Manchester, 2002 | | Diffuse | Solitary and in short radial multiples | Simple and scalariform | Crowded alternate, approximately 5 μm across | Non septate, thin to thick wall | Scanty paratracheal to vasicentric to confluent | 1—4 seriate, weakly heterocellular | Richter class a (1987) | Common in ray margins, and scattered among fibers |
| Richteroxylon Wheeler and Dillhoff, 2009 | Distinct to indistinct | Diffuse | Solitary and in short radial multiples | Predominantly simple | Crowded alternate, small to medium | Predominantly non-septate | Scanty paratracheal to vasicentric | 1—3 seriate | Similar to intervessel pits in size and shape | Present, associate with rays |
| Sassafrasoxylon Brezinová and Süss, 1988 | | Ring | | Simple and scalariform | Alternate and bordered | | Sparsely paratracheal | Homogeneous to weakly Heterogeneous, 1 —4 seriate | Enlarged, rounded to horizontally elongated and unilaterally bordered | Present |

396

South America (Scora and Bergh, 1992). When North and South America joined in the late Neogene, the genus was united again. Mountain building in Central America created new habitats in which speciation could take place (Scora and Bergh, 1992).

Later, Rohwer et al. (2009) considered two possible hypotheses to explain the American–Macaronesian disjunction pattern of the *Persea* group. One is the relict hypothesis: Macaronesian species of Lauraceae may well be interpreted as relicts from the European-Mediterranean Cenozoic laurel forest. An alternative explanation is the long-distance dispersal hypothesis. Rohwer et al. (2009) considered this less likely: the Macaronesian Islands are far too young for a Cretaceous disjunction and a long dispersal in the opposite direction, from America to Macaronesia, seems unlikely too for the present authors because *Persea indica appears* nested among the American species in their analysis. However, this last hypothesis appears to be a possible explanation for the American–Macaronesian disjunction between neotropical *Persea species* and the Macaronesian species for Li et al. (2011).

Li et al. (2011) suggested that the *Persea* group originated from the Perseeae-Laureae radiation in early Eocene Laurasia. The tropical and subtropical Amphi-Pacific disjunction pattern of the *Persea* group probably resulted from the disruption of the boreotropical flora by climatic cooling during the mid-to late Eocene. However, the American–Macaronesian disjunction pattern in the *Persea* group is also most likely explained by long-distance dispersal.

The presence of a Cretaceous fossil wood with affinity to *Persea* from the Puerto Yeruá Formation, Eastern Argentina, provides information relevant to understanding the biogeographic history of this genus and its phylogenetic context.

6. Conclusions

A new Cretaceous Lauraceae species, *P. septatum* sp. nov, has been studied from the Puerto Yeruá Formation in Entre Ríos Province, Eastern Argentina. This material, with anatomical characters similar to the extant genus *Persea*, is the first record known from the Cretaceous of Northeastern Argentina.

This is the earliest occurrence in the Southern Hemisphere of a fossil taxon with features closest to *Persea*, now with a tropical and subtropical disjunct distribution in the Americas, Asia, and on the Canary Islands. The modern distribution of *Persea* may represent a relict of a more geographically widespread taxon in the past.

The Vulnerability Index, Mesomorphy ratios and the Taxon Independent Approach indicate that this new fossil wood grew under warm and humid to seasonally dry environmental conditions.

P. septatum sp. nov clearly establishes the presence of Lauraceae in Northeastern Argentina during the Cretaceous. This material is very important because of the critical role of fossils and because of the morphological considerations of fossils in phylogenetic contexts. The present study provides information pertinent to understanding the phylogenetic context and the biogeographic history of the Persea-like group.

Acknowledgments

The authors thank Cristina Vassallo de Cettour (Director of the Museo de Antropología y Ciencias Naturales de Concordia, Entre Ríos, Argentina), Fabián Cevey (Municipalidad de Puerto Yeruá, Entre Ríos, Argentina), Gabriela Girau (Casa de la Cultura y Museo, Puerto Yerúa, Entre Ríos, Argentina), members of Dirección de Flora y Fauna and Jorge Vassallo for their cooperation and continuous support in the fieldwork. We thank Ofelia Tofalo, Eduardo Bellosi and Sebastián Apesteguía for useful discussions about the geology of the fossiliferous locality.

The authors would like to express their thanks to the two anonymous reviewers and the Editor for their valuable help in providing critical and constructive comments.

References

- Aceñolaza, P.G., Aceñolaza, G.F., 1996. Improntas foliares de una Lauraceae en la Formación Paraná (Mioceno superior), en Villa Urquiza, Entre Ríos. Ameghiniana 33, 155–159.
- Anzótegui, L.M., 1980. Cutículas del Terciario superior de la provincia de Corrientes, República Argentina. 2do Congreso Argentino de Paleontología y Bioestratigrafía y 1er Congreso Latinoamericano de Paleontología (Buenos Aires, 1978). Actas 3, 141–167.
- Anzótegui, L.M., Aceñolaza, P.G., 2008. Macrofloristic assemblage of the Paraná Formation Middle - Upper Miocene) in Entre Ríos (Argentina). Neues Jahrb. fur Geol. Paläontol. 248, 159–170.
- APG III, 2009. An update of the Angiosperm Phylogeny Group classification for the orders and families of flowering plants: APG III. Bot. J. Linn. Soc. 161, 105–121.
- Bossi, J., 1966. Geología del Uruguay, 2. Departamento de publicaciones de la Universidad de la República, Colección Ciencias, Montevideo, Uruguay, 469 pp.
- Brea, M., 1995. Ulminium chubutense n. sp. (Lauraceae), leño permineralizado del Terciario inferior de Bahia Solano, Chubut, Argentina. Ameghiniana 32, 19–30.
- Brea, M., 1998. Ulminium mucilaginosum n. sp. y Ulminium artabeae n. sp., dos leños fósiles de Lauraceae en la Formación El Palmar, provincia de Entre Ríos, Argentina. Ameghiniana 35, 193–204.
- Brea, M., Artabe, A.E., Franzese, J.R., Zucol, A.F., Spalletti, L.A., Morel, E.M., Veiga, G.D., Ganuza, D.G., 2015. Reconstruction of a fossil forest reveals details of the palaeoecology, palaeoenvironments and climatic conditions in the late Oligocene of South America. Palaeogeogr. Palaeoclimatol. Palaeoecol. 418, 19–42.
- Carlquist, S., 1977. Ecological factors in wood evolution: a floristic approach. Am. J. Bot. 64, 887–896.
- Carlquist, S., Hoekman, D.A., 1985. Ecological wood anatomy of the woody southern Californian flora. IAWA Bull. 6, 319–347.
- Casadío, S., Manera, T., Parras, A., Montalvo, C.I., 2002. Huevos de dinosaurios (Faveoloolithidae) del Cretácico Superior de la Cuenca del Colorado, provincial de La Pampa, Argentina. Ameghiniana 39, 285–293.
- Castañeda-Posadas, C., Calvillo-Canadell, L., Cevallos-Ferriz, S.R.S., 2009. Woods from miocene sediments in Panotla, Tlaxcala, Mexico. Rev. Palaeobot. Palynol. 156, 494–506.
- Chanderbali, A.S., van der Werff, H., Renner, S.S., 2001. Phylogeny and historical biogeography of Lauraceae: evidence from chloroplast and nuclear genomes. Ann. Mo. Bot. Gard. 88, 104–134.
- Creber, G.T., Chaloner, W.G., 1984. Climatic indications from growth rings in fossil woods. In: Brenchley, P. (Ed.), Fossils and Climate. John Wiley and Sons Ltd, Londres, pp. 49–73.
- Cronquist, A., 1981. An Integrated System of Classification of Flowering Plants. Columbia University Press, New York.
- De Alba, E., Serra, N., 1959. Aprovechamiento del río Uruguay en la zona de Salto Grande. Informe sobre las condiciones y características geológicas. Dirección Nacional de Geología. Anales XI, Buenos Aires, Argentina, 35 pp.
- De Valais, S., Apesteguía, S., Udrizar Sauthier, D., 2003. Nuevas evidencias de dinosaurios de la Formación Puerto Yeruá (Cretácico), Provincia de Entre Ríos, Argentina. Ameghiniana 40 (3), 507–511.
- Dupéron, J., Dupéron-Laudoueneix, M., Sakala, J., De Franceschi, D., 2008. Ulminium diluviale Unger: historique de la découverte et nouvelle étude. Ann. Paléontol. 94, 1–12.
- Dupéron-Laudoueneix, M., Dupéron, J., 2005. Bois fossiles de Lauraceae: nouvelle découverte au Cameroun, inventaire et discussion. Ann. Paléontologie 91, 127–151.
- Franco, M.J., 2012. Maderas fósiles de Lauraceae de la Formación Ituzaingó (Plioceno-Pleistoceno), Cuenca del río Paraná. Argent. Rev. del Mus. Argent. Ciencias Nat. N. S. 14, 307–324.
- Guzmán, Silva, Fuentes Talavera, J.A., Richter, F.J., Alvarez, H.G., Sanjuan, G.A., Dueñas, R., 1999. Estructura de la madera de Persea americana var. guatemalensis Mill (Hass). Madera Bosques 5, 53–59.
- Heo, K., 1998. Wood anatomy and phylogeny of *Laurus* (Lauraceae). J. Plant Res. 1, 121–125.
- Herendeen, P.S., Crepet, W.L., Nixon, K.C., 1994. Fossil flowers and pollen of Lauraceae from the upper Cretaceous of New Jersey. Plant Syst. Evol. 189, 29–40.
- Hoadley, R.B., 1990. Identifying Wood: Accurate Results with Simple Tools. Taunton, Newton, CT.
- Huene, F.von, 1929. Los Saurisquios y Ornitisquios del Cretáceo Argentino. An. del Mus. La Plata 3 (2), 1–196.
- Hwang, S.-K., 1962. The Anatomy of Some Important Taiwan Woods. University of British Columbia, Department of Forestry.
- InsideWood, 2004-onwards, Published on the Internet. http://insidewood.lib.ncsu. edu/search [November 2012].
- Leisman, G.A., 1986. Cryptocaryoxylon gippslandicum gen. et sp. nov., from the Tertiary of Eastern Victoria. Alcheringa 10, 225–234.

M.J. Franco et al. / Cretaceous Research 56 (2015) 388-398

- León, H.W.J., 2002. Anatomía xilemática caulinar de 14 especies de la familia Lauraceae. Rev. For. Venez. 46, 15–25.
- Li, Li, Li, J., Rohwer, J.G., van der Werff, H., Wang, Z.H., Li, H.W., 2011. Molecular phylogenetic analysis of the Persea group (Lauraceae) and its biogeographic implications on the evolution of tropical and subtropical amphi-Pacific disjunctions. Am. J. Bot. 98, 1520–1536.
- Lindorft, H., 1994. Eco-anatomical wood features of species from a very dry tropical forest. IAWA J. 15, 361–376.
- Martínez-Cabrera, H.I., Ramírez-Garduño, J.L., Estrada-Ruiz, E., 2014. Plantas fósiles e inferencia paleoclimática: aproximaciones metodológicas y algunos ejemplos para México. Boletín la Soc. Geol. Mex. 66 (1), 41–52.
- Metcalfe, C.R., Chalk, L., 1950. Anatomy of the Dicotyledons, 2 Vol. Claredon Press, Oxford.
- Nazma, Ganapathy, P.M., Sasidharan, N., Bhat, K.M., Gnanaharan, R., 1981. A Handbook of Kerala Timbers. Division of Wood Science, Kerala Forest Research Institute.
- Nie, Z.L., Wen, J., Sun, H., 2007. Phylogeny and biogeography of Sassafras (Lauraceae) disjunct between eastern Asia and eastern North America. Plant Syst. Evol. 267, 191–203.
- Poole, I., Richter, H.G., Francis, J.E., 2000. Evidence for gondwanan origins for Sassafras (Lauraceae)? late cretaceous fossil wood of Antarctica. IAWA Bull. 21, 463–475.
- Powell, J.E., 2003. Revision of South American titanosaurid dinosaurs: palaeobiological, palaeobiogeographical and phylogenetic aspects. Rec. Queen Vic. Mus. 111, 1–173.
- Ramos, R.S., Brea, M., Krholing, D., 2012. Leños Fósiles de la Formación El Palmar (Pleistoceno tardío) en el Parque Nacional El Palmar, Entre Ríos, Argentina. Ameghiniana 4, 606–622.
- Rancusi, M.H., Nishida, M., Nishida, H., 1987. Xilotomy of important chilean woods. In: Nishida, M. (Ed.), Contributions to the Botany in the Andes II. Academy Scientific Book Inc., Tokyo, pp. 68–158.
- Raven, P.H., Axelrod, D.I., 1974. Angiosperm biogeography and past continental movements. Ann. Mo. Bot. Gard. 61, 539–673.
- Record, S.J., Hess, R.W., 1942. American timbers of the family Lauraceae. Trop. Woods 69, 7–33.
- Renner, S.S., 2005. Variation in diversity among Laurales, early Cretaceous to Present. Biol. Skr. 55, 441–458.
- Richter, H., 1981. Wood and Bark anatomy of Lauraceae. I: Aniba Aublet. IAWA Bull. 2, 79–87.
- Richter, H., 1987. Lauraceae. Mature secondary xylem. In: Metcalfe, C. (Ed.), Anatomy of the Dicotyledons, second ed., III. Oxford Science Publications, Oxford, pp. 167–171.
- Richter, H.G., Dallwitz, M.J., 2000. Commercial Timbers: Descriptions, Illustrations, Identification and Information Retrieval. onwards. www:http://biodiversity.uno. edu/delta/(2007-2011).

- Rohwer, J.G., 1993. Lauraceae. In: Kubitzki, K., Rohwer, J.G., Bittrich, V. (Eds.), The families and genera of vascular plants, vol. 2. Springer, Berlin, pp. 366–390.
- Rohwer, J.G., Li, J., Rudolph, B., Schmidt, S.A., van der Werff, H., Li, H.W., 2009. Is Persea (Lauraceae) monophyletic?—Evidence from nuclear ribosomal ITS sequences. Taxon 58, 1153–1167.
- Romero, E.J., 1970. *Ulminium atlanticum* n. sp. tronco petrificado de Lauraceae del Eoceno de Bahia Solano, Chubut, Argentina. Ameghiniana 7, 205–223.
- Schroeder, C.A., 1968. Prehistoric Avocados in California, 52. California Avocado Society 1968 Yearbook, pp. 29–34.
 Scora, R.V., Bergh, B.O., 1992. Origin of and taxonomic relationships within the
- Scora, R.V., Bergh, B.O., 1992. Origin of and taxonomic relationships within the genus Persea. In: Proceedings of Second World Avocado Congress, pp. 505–514.
- Scott, R.A., Wheeler, E.A., 1982. Fossil woods from the eocene clarno formation of Oregon. IAWA Bull. N. S. 3, 135–154 (3–4).
- Soto, M., Perea, D., Veroslavsky, G., Rinderknecht, A., Ubilla, M., Lecuona, G., 2009. Nuevos hallazgos de restos de dinosaurios y consideraciones sobre la edad de la Formación Guichón. Rev. Soc. Urug. Geol. 15, 11–23.
- Takahashi, M., Herendeen, P.S., Xiao, X., Crane, P.R., 2014. Lauraceous Fossil flowers from the Kamikitaba assemblage (Coniacian, Late Cretaceous) of northeastern Japan (Lauraceae). Syst. Bot. 39, 715–724.
- Taylor, T.N., Taylor, E.L., Krings, M., 2009. Paleobotany, the Biology and Evolution of Fossil Plants, second ed. Academic Press, Amsterdam.
- Tofalo, O.R., 1986. Depósitos clásticos y carbonáticos del Cretácico superior, Formación PuertoYeruá, Entre Ríos. 1º Reunión Argentina de Sedimentología. Actas 201–204. La Plata, Argentina.
- Tofalo, O.R., Pazos, P.J., 1999. Microestructuras de calcretes de la Formación Puerto Yeruá (Cretácico), Argentina. 5° Simposio sobre o Cretáceo do Brasil – 1er Simpósio sobre el Cretácico de América del Sur. Actas 71–77. Serra Negra. Brasil.
- Tofalo, O.R., Pazos, P.J., 2002. Caracterización de calcretes de la Formación Puerto Yeruá (Cretácico), en base a su micromorfología (Entre Ríos, Argentina). Lat. Am. Asoc. Argent. Sedimentol. Rev. 9, 127–134.
- Tortorelli, L.A., 1956. In: . Maderas y Bosques Argentinos. ACME, S.A.C.I, Buenos Aires.
- Werff, H., Richter, van der H.G., 1996. Toward an improved classification of Lauraceae. Ann. Mo. Bot. Gard. 83, 409–418.
- Wheeler, E.A., Baas, P., 1991. A survey of the fossil record for dicotyledonous wood and its significance for evolutionary and ecological wood anatomy. IAWA Bull. 12, 275–332.
- Wheeler, E.A., Baas, P., 1993. The potentials and limitations of Dicotyledonous wood anatomy for climatic reconstructions. Paleobiology 19 (4), 487–498.
- Wheeler, E.A., Dillhoff, T.A., 2009. The middle Miocene wood flora of Vantage, Washington, USA. IAWA J. Supplement 7, 101pp.
- Wheeler, E.A., Manchester, S.R., 2002. Woods of the eocene nut beds Flora, Clarno Formation, Oregon, USA. IAWA J. 3, 1–188.