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The genus *Toona* (Meliaceae): dendrology, ecology and wood anatomy with reference to its applicability for tropical dendrochronology

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ABSTRACT

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The potentiality of *Toona* sp. trees, Meliaceae native in Asia and Australia continents, for dendrochronological studies is described, including its silviculture, ecology and wood anatomy. Emphasis is given to the presence of distinct annual growth rings sensitive to climatic variations and detectable by wood cross section analysis and X-ray densitometry technique.

Key-words—*Toona* sp., Meliaceae, Dendrochronology, X-ray densitometry, Growth rings.

टूना वंश (मीलिएसी) : उष्णकटिबन्धीय वृक्षवलयकालानुक्रमिकी हेतु इसकी अनुप्रयोगात्मकता के सन्दर्भ में वृक्षविज्ञान, पारिस्थितिकीविज्ञान तथा काष्ठ शारीरविज्ञान

मारियो टोमाज़ेलो एफ़, पी.सी. बोतोसो, सी.एस. लिसी

सारांश

प्रस्तुत शोध पत्र में एशिया तथा आस्ट्रेलिया महाद्वीप के मीलिएसी मूल के *टूना* प्रजाति के वृक्षों की वृक्षवलयकालानुक्रमिकीय अध्ययन में उपयोगिता का वर्णन अभिप्रेत है। इस अध्ययन में इसके वनवर्धन, पारिस्थितिकीविज्ञान तथा काष्ठ शारीरविज्ञान को समाहित किया गया है। अध्ययन में काष्ठ अनुप्रस्थ परिच्छेद विश्लेषण एवं एक्स-रे घनत्वमिति प्रविधि द्वारा पहचाने जा सकने वाले जलवायुविक परिवर्तनों के प्रति संवेदनशील सुस्पष्ट वृद्धि वलयों की उपस्थिति पर विशेष ध्यान दिया गया है।

संकेत शब्द—*टूना* प्रजाति, मीलिएसी, वृक्षवलयकालानुक्रमिकी, एक्स-रे घनत्वमिति विज्ञान, वृद्धि वलय.

INTRODUCTION

TAXA under Meliaceae occurs in tropical and pantropical regions throughout Africa, America and Asia, grouped in 51 genera and 1400 species with approximately 500 species of economic importance (Lawrence, 1951; Styles, 1972; Girardi, 1975; Holdridge, 1976a; Styles & Khosla, 1976; Barroso, 1984). This family is represented by 8 genera in South America—*Cedrela, Swietenia, Cabralea, Trichilia, Guarea, Carapa, Schmardaea* and *Ruegea* - with the first 6 genera naturally occurring in Brazil. In addition exotic genera introduced from other regions are—*Melia, Azadirachta, Toona* and *Khaya*, etc. (Holdridge, 1976a; Rizzini,1978; Pennington, 1981; Barroso, 1984). The

Meliaceae family was studied by several researchers, like De Candolle (1878), Kribs (1930), Smith (1960, 1965), Pennington and Styles (1975), Holdridge (1976a, b). In addition there are several reprots from Brazil itself—Pirani (1984), Pastore and Berzaghi (1989) in São Paulo, Amaral (1981) in Goiás, Klein (1984) in Santa Catarina, Girardi (1975) in Rio Grande do Sul and Pinheiro (1986) in Minas Gerais States.

Among the representative species of Meliaceae, in this paper emphasis is given to the genus *Toona*, considering its silvicultural and ecological importance, wood quality and dendrochronological applications in tropical regions of the world.

THE GENUS *TOONA*: DENDROLOGY, ECOLOGY AND WOOD ANATOMY

The systematic classification of the genus *Toona* has been discussed since long time by many authors, because of its similarity to the genus *Cedrela*. According to Smith (1960), 2 genera were initially established by Roemer in 1846: *Cedrela* including the American cedars and *Toona*, the Asiatic cedars. Later, in 1878, De Candolle grouped them as *Cedrela*, because its close similarities and Harms, in 1896, classified 2 different genera, regrouped again by De Candolle in 1908 (Pinheiro *et al.*, 1994).

However classification of Harms was accepted by Smith (1960), pointing of the differences between *Cedrela* and *Toona*. Chevalier and Begemann, cited by Grijpma and Ramalho (1969) relates 11 species, *Toona ciliata* (with 20 varieties), *T. calantas*, *T. fargesii*, *T. microcarpa*, *T. mollis*, *T. multijuga*, *T. paucijuga*, *T. serrata*, *T. serrulata*, *T. sinensis* and *T. sureni*. The most important species for the ecological conditions in Latin America are *T. ciliata* var. *australis*, *T. calantas* e *T. sureni*. Actually, the better revision referring to the genus *Toona* was done by Bahadhur (1988), in India, representing an analysis of the taxonomic knowledge, including descriptions, occurrence, economic uses, habitats, vernacular names, etc.

Toona ciliata Roem. var. *australis* (F. v M.) C. DC.

Toona ciliata has a natural widespread distribution, throughout India, Pakistan, Myanmar, Thailand, southern China, New Guinea, Malaysia, Philippines, Himalayan valleys (up to 1300 m height), Molucas Island, etc. The trees can be found across the river banks and in inclined lands, also in swampy and wet tropical forests, including all the western Pacific region (Grijpma & Ramalho, 1969).

Toona ciliata var. *australis* trees naturally occurs in eastern Australia in New South Wales (Ulladula, southern Sidney) and Queensland States (northern Atherton) and has the synonyms *T. australis*, *Cedrela australis* and *C. toona* var. *australis*. It's denominated "cedro australiano" or toona in Brazil, toona and cedar in Mexico, red cedar, Australian toona, Australian red cedar in all speaking English countries. The trees show monopodial growth and a superficial root system, reaching 30-46 m in height and 1·50-2·00 m trunk diameter and are light tolerant in the juvenile period,

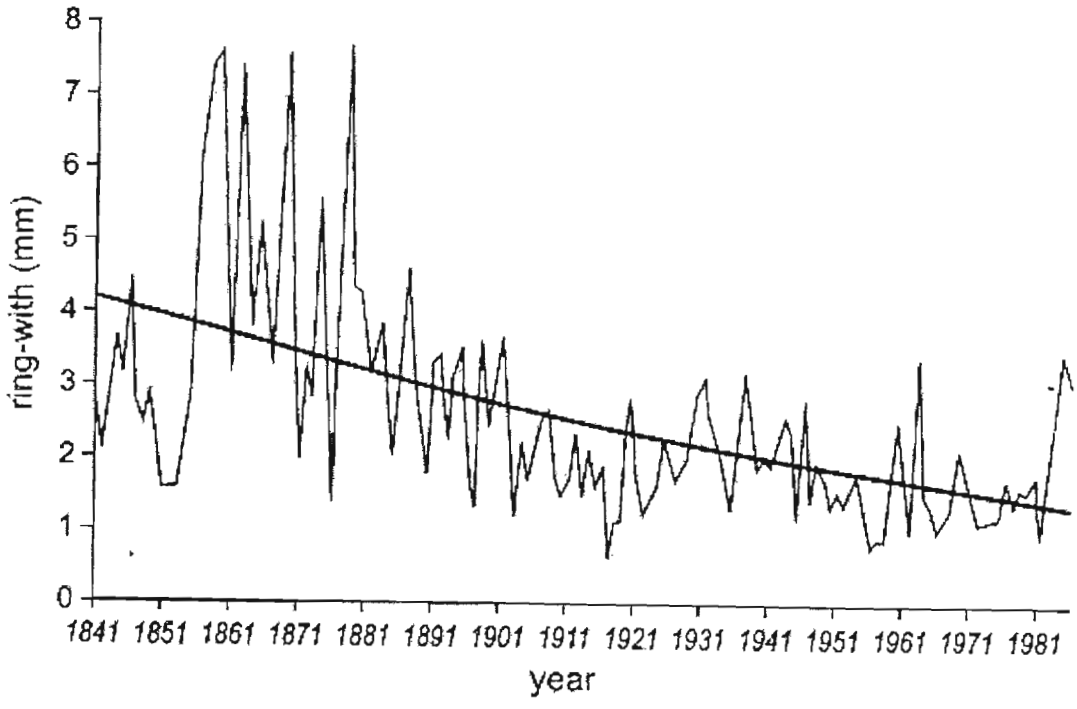

Fig. 1—Curve of growth ring width of *Toona ciliata* tress (after Bhattacharyya *et al.*, 1992).

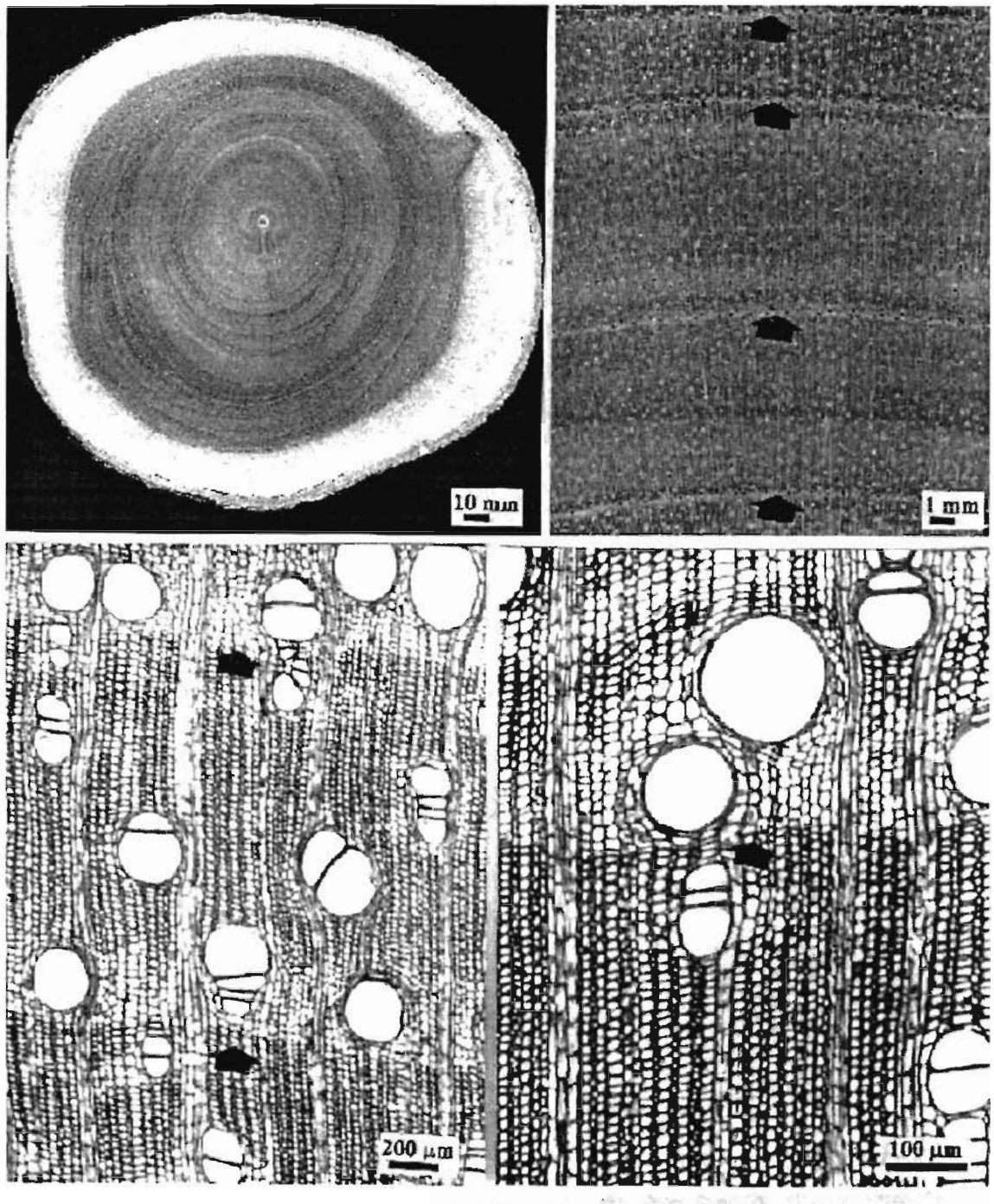

PLATE 1

Wood anatomy and growth rings of *Toona ciliata* var. *australis* tree. Cross section of a trunk (a) and wood (b) showing growth rings, delimited by initial parenchyma bands and semi-porous ring. Cross section (c, d) showing the features of the parenchyma cells, vessel and fiber wall thickness in early and latewood.

demanding sunlight in adult phase. In Australia it occurs in low to median lands, wet to very wet climates, with 1100-4000 mm annual precipitation and a dry period of 3-4 months. Despite their preference to wet soils, the trees can also develop in driest regions, with 800 mm annual precipitation, where the ground water table is accessible to the roots in the dry period. The temperatures can vary from -1 to 43°C, supporting light frosts; in Atherton region the temperature varies from -2 to 28°C. Rich and well-drained soils are ideal for toona, which prefers chalky soils and does not support dense clayish and

poor sandy soils (Grijpma & Ramalho, 1969; Walters, 1974; Rocas, 1986; Namikawa, 1988; Pinheiro *et al.*, 1994).

In Central America countries, like Mexico the *T. ciliata* trees were introduced from India and Myanmar and reach 15-17 m height in tropical area plantations (Rocas, 1986). In Costa Rica the trees grow excellent in well-drained and nutrient-rich soils with positive response to mineral fertilization. The pruning of branches is recommended in 15-20 years old trees for higher wood quality (Otarola *et al.*, 1976; Sanchez *et al.*, 1976).

Introduced in Hawaii in 1914, this tree species has been cultivated for its high increment rates, reaching 30-36 m in height and 0·25-0·65 m diameter in 22 years, producing wood with excellent properties. Their phenology is characterized by the flowering in April-June, fruit ripening and seed dispersal in July-October and leaves shading in dry sites with hydric deficit (Walters, 1974).

In South America, *Toona ciliata* var. *australis* trees were introduced in 1969, in Argentina, by Cozzo and Mangieri, with aim to replace the cedar species in a reforestation program, however in Missiones Province, 10 year-old toona plantations suffered from photosynthetic problems (Mangieri, 1972; Sanchez *et al.*, 1992). In 1988, toona was introduced in the Alto Parana region, Paraguay, where the tree plantations show high growth increment rates compared to other species (Serafina *et al.*, 1994).

In Brazil, toona shows good adaptation to several ecological conditions, also presenting resistance behaviour against Meliaceae shoot borer, *Hypsipyla grandella*, while it is attacked in its country of origin by *H. robusta* (Grijpma, 1976). In Minas Gerais State, toona trees reveal good growth increments and well-marked phenological events, flowering in September-November, fructification in January-March and leaves fall in June-July (Pinheiro, 1986). Plantations cited by Ledoux and Lobato (1976) in the Amazonian region prove the potential of toona, despite the great variability between trees. In the same way, plantations in São Paulo and Espírito Santo States demonstrate its potential concerning the wood volumetric increments (IPEF, 1975). The *T. ciliata* var. *australis* descriptions, including taxonomy, botany, ecological aspects, silvicultural features, phenology, etc., are presented by Gripjma and Ramalho (1969) and Pinheiro (1986).

The wood characteristics of *T. ciliata* trees and its variety *australis* are similar, with specific gravity of 0·45-0·64 g/cm^3, presenting the same characteristics as *Cedrela* (Record & Hess, 1947). Toona is considered as one of the best quality woods in India, Australia, etc., widely applied in furniture, carpentry, cabinet, etc. The bark can be used in medicine and trees as ornamental in parks and gardens (Grijpama & Ramalho, 1969; Walters, 1974; Rocas, 1986; Namikawa, 1988).

The wood of *T. ciliata* presents sapwood rose-light brown and in the var. *australis* the color is yellowish-white, and the heartwood darkened-brown to reddish. The wood anatomy and properties were studied by many authors (Francis, 1951; Bhat, 1985; Espinoza de Pernia, 1987; Cardoso & Tomazello Filho, 1988; Sudo, 1989; Haslett *et al.*, 1991), including fibers and early and latewood measurements (Bisset *et al.*, 1950). Additionally, dendrochronological studies were developed by Chowdhury (1939), Bhattacharyya *et al.* (1992) and Cardoso and Tomazello (1988), due to the presence of distinct annual growth rings, delimitated by some typical anatomical wood features like initial parenchyma bands, vessel arrangement and fiber wall thickness (PLATE 1).

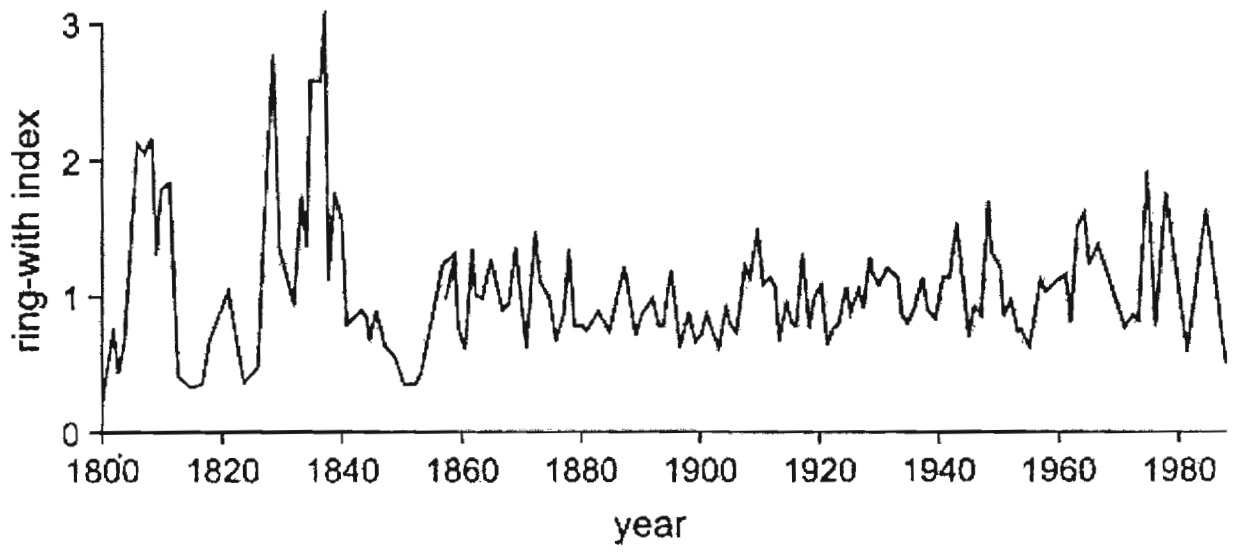

Fig. 2—Chronology of growth ring width index of *Toona ciliata* trees (after Bhattacharyya *et al.*, 1992).

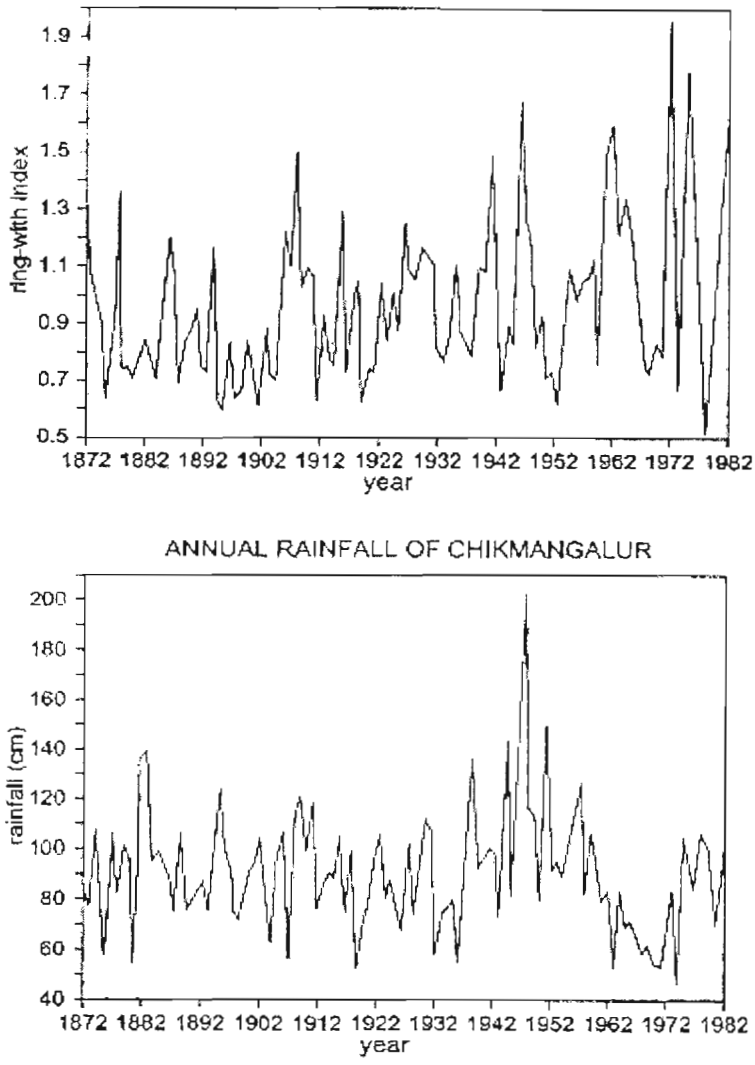

Fig. 3—Chronology of growth ring width index and annual rainfall showing the correlation between *Toona ciliata* tree growth and annual rainfall (aft er Bhattacharyya *et al.*, 1992).

Toona sureni (Bl.) Merril.

This species naturally occurs in low lands up to 1000 m altitude in the dense pluvial equatorial forests of Vietnam, Cambodia, Indonesia, Myanmar and Malaysia. The tree shows high growth increments, reaching 20-40 m height and 0·60-2·00 m diameter, producing high quality wood. The heartwood color is dark-brown, with characteristic odour, 0·39-0·45 g/cm^3 specific gravity, usually used in furniture, carpentry, etc. The trees are strongly attacked by *Hypsipyla robusta* in Asia, when growing in plantations. However, the toona trees in Puerto Rico plantations are resistant against *H. gnarled*, reaching 4·3 (2·30-8·30) m height and 7·0 (2·5-13·5) cm diameter in 5·5 years (Gripjma & Ramalho, 1969).

Toona calantas Merril et Rolfe

The species occurs in several provinces of the Philippines, near to the riverbanks and areas periodically inundated. The trees reach 40-50 m height and up to 1·50 m diameter. The straight and cylindrical trunk is free of branches until 50% trunk height. Heartwood light to dark reddish, specific gravity 0·41-0·44 g/cm^3. The wood can be easily worked and is applied in furniture, general carpentry, musical instruments, etc. (Gripjma & Ramalho, 1969).

TOONA CILIATA: A POTENTIAL SPECIES IN TROPICAL DENDROCHRONOLOGY

Toona ciliata var. *australis* presents distinct annual growth rings constituted by fibers with length variations

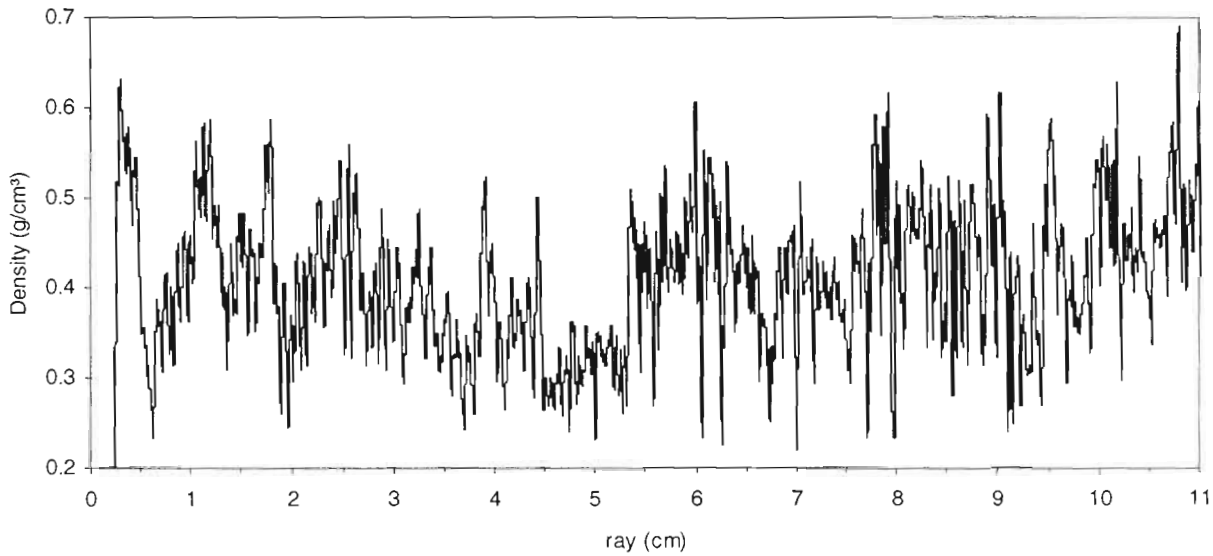

Fig. 4—Wood density profile by X-ray densitometry and demarcation of annual growth ring and boundaries of early (EW) and latewood (LW) of *Toona ciliata* tree (ref., Text-Figure 1).

related to the diameter increment rates. The shorter fibers, at the first earlywood layers, are formed in the beginning of spring, during the period of maximum cambium activity, while the latewood fibers of last layers produced in winter, during the minimum cambium activity are 83% longer (Bisset *et al.*, 1950).

In India, *T. ciliata* is a deciduous tree, starting radial growth only after the renovation of 50% of the canopy with new leaves. In response, the cambium produces distinct annual growth rings, the boundaries of which are delimited by initial parenchyma bands and large diameter vessels forming semi-porous rings, resulting in a period of fast growth followed by a period of lower growth rates (Chowdhury, 1940; Chowdhury & Rao, 1948).

Also in India, *T. ciliata* trees are found potential for dendrochronological studies. They exhibit annual growth-rings sensitive to climatic variations. The growth rings were dated and measured and a reference-chronology of growth ring width from 1800-1987 compared with growth ring width index chronology and annual rainfall. They recorded that the narrow growth rings width was correlated with hydric deficit in the soil, caused by a low photosynthetic activity during the less rainfall years during the peak of monsoon rainy season (June-August), when growth is supposed to be fast. *Toona* trees produce a superficial root system when growing in flat sticky red soils with low water infiltration and deficient drainage, when the water saturation may reduce soil oxygen supply and, consequently, inhibit the root growth (Bhattacharya *et al.*, 1992) (Figs. 1, 2, 3).

In Brazil, *Toona ciliata* trees produce distinct annual growth rings characterized by initial parenchyma bands and semi-porous ring, making possible the determination of tree age and annual increment rates (Cardoso & Tomazello Filho, 1988). Besides direct growth ring measurements on the polished cross section, the X-ray densitometry method can be applied for the delimitation of annual growth rings of toona wood samples. Significant values of maximum wood density between and within growth rings also can be obtained, like 5° and 16° annual rings, with a specific gravity of 0·35 and 0·60 g/cm^3, respectively. These results show the potentiality of both methodologies in the dendrochronological studies of tropical species, i.e., *Toona ciliata*, including tree age determination, stand dynamics and relationship to climate, etc. (Fig. 4).

CONCLUSIONS

Toona ciliata has a great potential for dendroclimatology studies and forest dynamics in natural forests and plantations in its area of natural occurrence and in Asia as well as in tropical areas of Central and South America. In American countries, including Brazil, the phenological characteristics of introduced toona trees are similar to other native Meliaceae species, mainly *Cedrela* and *Swietenia*. In these areas, however, resistant behaviour presented by toona trees against the Meliaceae shoot borer, *Hypsipyla grandella* constitutes the main advantage. In addition these species produces distinct annual tree rings delimitated by a typical initial parenchyma and semi-porous ring, essential for dendrochronological studies. The wood anatomy and X-ray densitometry methodologies can also be applied to the annual growth rings delimitation and to the intra- and inter-tree-ring density determination. However, a limited amount of

dendrochronological work has been carried out on toona trees, despite of the confirmed sensitivity of the annual growth rings to climatic variation.

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