IAWA Journal, Vol. 20 (3), 1999: 285–294

VESSEL CHRONOLOGIES FROM TEAK IN NORTHERN THAILAND AND THEIR CLIMATIC SIGNAL

by

Nathsuda Pumijumnong[1] **& Won-Kyu Park**[2]

SUMMARY

Five teak trees in northern Thailand were selected for the study of vessels in terms of dendroclimatology. The tree rings were divided into earlywood and latewood, and four parameters (average vessel area, average vessel diameter, average conductive area, and vessel density) were measured by automatic image analysis technique to obtain 50-year (1947–1996) time series. Two questions were addressed: 1) How strongly are the vessel characteristics related to climate and 2) are these relationships different from those of ring widths? All vessel parameters of the total ring and of the earlywood were negatively correlated with precipitation during the transitional period between the dry and the wet season. The latewood vessel parameters, however, are negatively correlated with June temperature. The climatic signals of the vessel parameters and of the tree-ring width are different from each other.

Key words: Teak, Thailand, vessels, climate.

INTRODUCTION

Tree-ring width is traditionally used to establish relationships between tree growth and climate (Fritts 1976). In the early 1970s, it has been shown that maximum latewood density of subalpine conifer species is more sensitive to temperature than tree-ring width (Schweingruber 1982). Later, image analysis technique provided a new approach to use the anatomical structure of the wood for dendroclimatology (Woodcock 1989; Park 1990; Sass 1993).

Anatomical variables have been exploited for dendroecology and dendroclimatology quite early (Eckstein et al. 1977). Eckstein and Frisse (1982) found that the vessel area of oak, a ring-porous species, has a stronger relationship with climate, particularly with rainfall, than tree-ring width. Sass and Eckstein (1992, 1995) showed the same for the diffuse-porous species *Fagus sylvatica* L. Woodcock (1989) studied the ring-porous species *Quercus macrocarpa* Michx., *Q. rubra* L. and *Fraxinus pennsylvanica* L. for various variables such as diameter of the largest vessels, total conductive area, and vessel density. She concluded that the vessel density in the latewood is appropriate for precipitation reconstruction. However, no studies have dealt with the vessels of tropical and subtropical trees.

---

1) Faculty of Environment and Resource Studies, Mahidol University, Nakhonpathom 73170, Thailand.

2) College of Agriculture, Department of Forest Products, Chungbuk National University, Cheongju 361-763, Republic of Korea.

Teak (*Tectona grandis* L.) is a dominant tree species in subtropical forests. Its anatomy varies from ring-porous to semi-ring-porous (Gottwald & Parameswaran 1980). Tree-ring width of teak has already been tested for its dendroclimatic potential: Thailand (Pumijumnong 1995), Indonesia (Murphy & Whetton 1989; Jacoby & D'Arrigo 1990; Palmer & Murphy 1993) and India (Pant & Borgaonkar 1983; Bhattacharyya et al. 1992; Wood 1996). In Thailand the precipitation from April to July and the temperature during May to July were reconstructed back to 1870 (Pumijumnong et al. 1995a,b).

OBJECTIVES

We investigated the vessels of teak in northern Thailand using image analysis. Two major questions are addressed: 1) How strongly are the vessel characteristics related with climatic variables? 2) Are these relationships different from those of ring widths?

STUDY AREA AND SAMPLE SITE

Teak is the best known, most universally used and most valuable tree species in Thailand since centuries. It flourishes in Mixed deciduous forests in alluvial flats and on moist slopes. Tree species associated with teak in the upper canopy are *Xylia kerrii*, *Lagerstroemia calyculata*, *Afzelia xylocarpa*, and *Pterocarpus macrocarpus* and in the lower layer *Gmelia arborea* and *Vitex peduncularis*; bamboo is very common as undergrowth.

The study area, Maehongson Province, is located in the northern mountainous region (Fig. 1) close to Myanmar and the southwestern part of China between 18°–20° N and 99°–100° E. The sampling site is in Pay Wildlife Sanctuary on a moderate slope (20%) at 600–700 m above sea level.

Instrumental records for rainfall are available from 1911 to 1996, for temperature only from 1951 to 1996. The latter period was used for the analysis. The data have been collected by a meteorological station in the Muang District, Maehongson Province, 30 km distant from the study site.

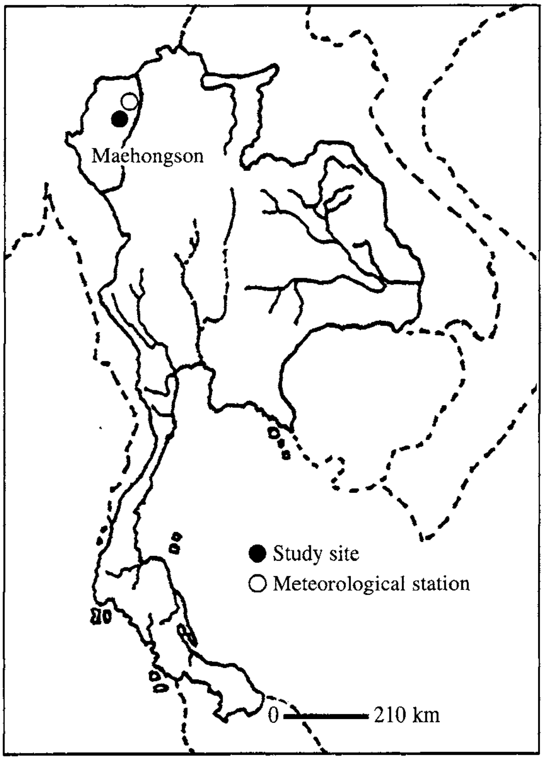

Fig. 1. Map of Thailand and study area.

MATERIAL AND METHODS

Two cores each from thirty teak trees of a cylindrical and straight bole without external damage were extracted for tree-ring width analysis, and out of them five trees, i.e. ten cores, were selected for vessel measurements.

Each core was mounted in a grooved wooden stick with waterproof glue. To reduce the difficulty in surfacing, the samples were boiled for 2 hours in water. Then the samples were cut with a sharp surgical blade to get a large and smooth surface. After drying, chalk was applied to fill the vessels and enhance the contrast between the pores and the background tissue.

The tree-ring widths were measured to the nearest 0.01 mm under a binocular microscope with a linear stage (Velmex) interfaced with a computer. The TSAP program (Rinn 1989) was used to plot the series for visual cross-dating. False and missing rings could be detected and corrected on a light table. The cross-dating was subsequently checked with the COFECHA program (Holmes 1983).

For the vessel measurements an image analysis system (Image-Pro Plus, Media Cybernetic L.P. 1994) of an IBM-compatible computer, a Video digitizer, and a high-resolution microscope was used.

The cores on the microscope stage were illuminated by ring light. The image of each tree ring was converted to a gray-scale with values from 0–255. An upper and a lower gray-level threshold were chosen to distinguish the vessels from the background tissue; they were 130 and 255, respectively. The video signals from the camera converted the image into digital signals by a digitizer. The graphic painting program Paintshop 4.1 removed unwanted objects such as ray cells and cracks and corrected the image until the vessels and the background showed sufficient contrast.

Four variables from each earlywood, latewood, and total tree ring were measured. These variables were average vessel area and diameter, average conductive area, and vessel density. The conductive area was calculated by the fourth power of the area. The vessel density represents the number of vessels per unit area. All measurements were done for 50 tree rings from 1947 to 1996. The chronologies of the vessel parameters were worked by the same methods of detrending and filtering as known from ring-width analysis.

RESULTS AND DISCUSSION

Climate signal of tree-ring width

A tree-ring width chronology from thirty teak trees has been produced. The autocorrelation and mean sensitivity were 0.72 and 0.31, respectively. A positive correlation was found with rainfall from May to July; however, there was no significant correlation between tree-ring width and temperature (Fig. 2E). This climate/growth relationship was basically the same as previously found for a wide range of sites throughout northern Thailand (Pumijumnong 1995).

Climate signal of vessel parameters

The various vessel parameters over the total tree ring showed some differences in their responses to climate. Altogether, most of them correlated positively with tem-

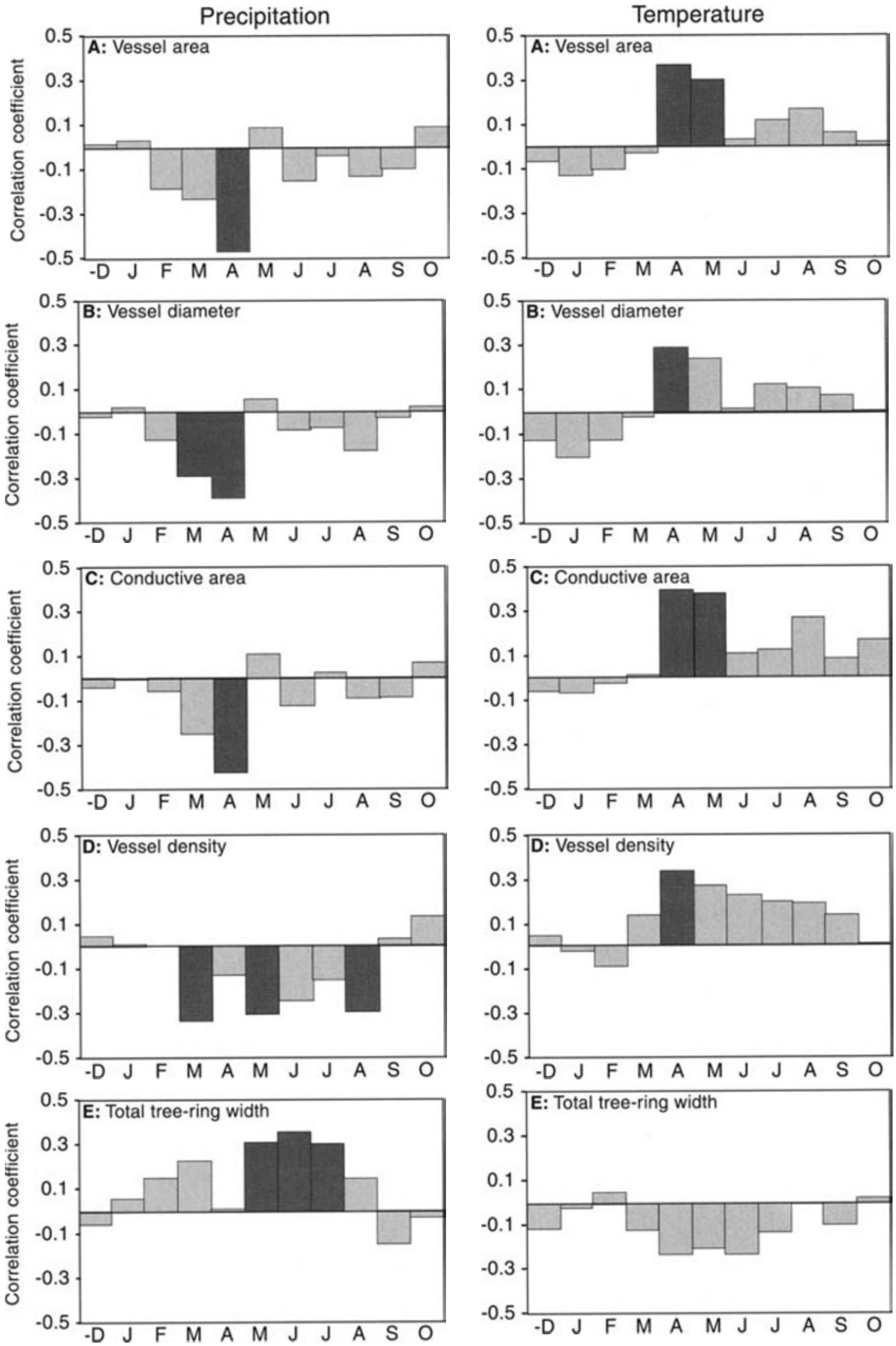

Fig. 2. Climate-growth relationships of anatomical variables over the total ring [A–D] and of the tree-ring width [E] for the period 1947–1996; bars represent correlation coefficients, with significant values in dark-grey.

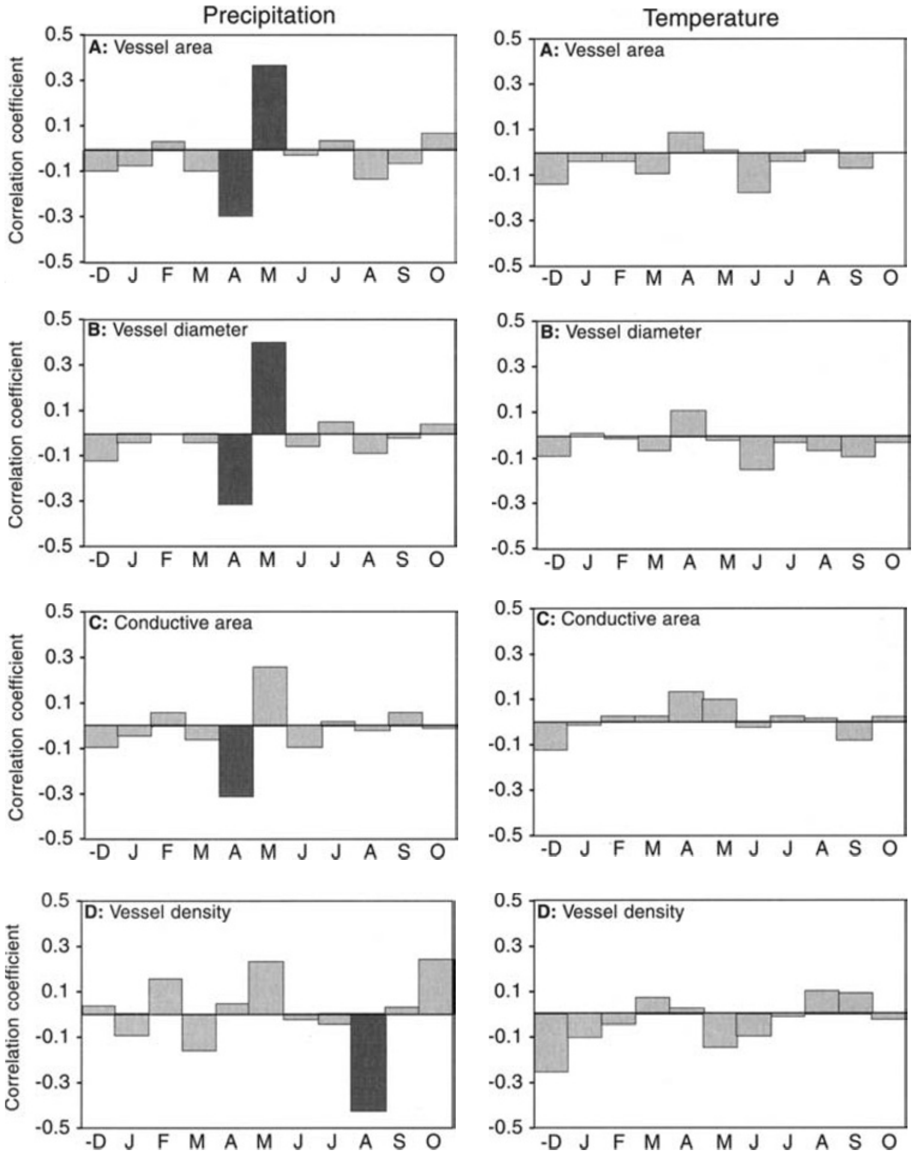

Fig. 3. Climate-growth relationships of earlywood vessel parameters for the period 1947–1996; bars represent simple correlation coefficients, with significant values in dark-grey.

perature in current April and May and negatively with current March and April rainfall (Fig. 2A–D).

All vessel parameters of the earlywood did not show any significant correlation with temperature (Fig. 3). But most of them were negatively correlated with current April rainfall and positively correlated with current May rainfall. The vessel density

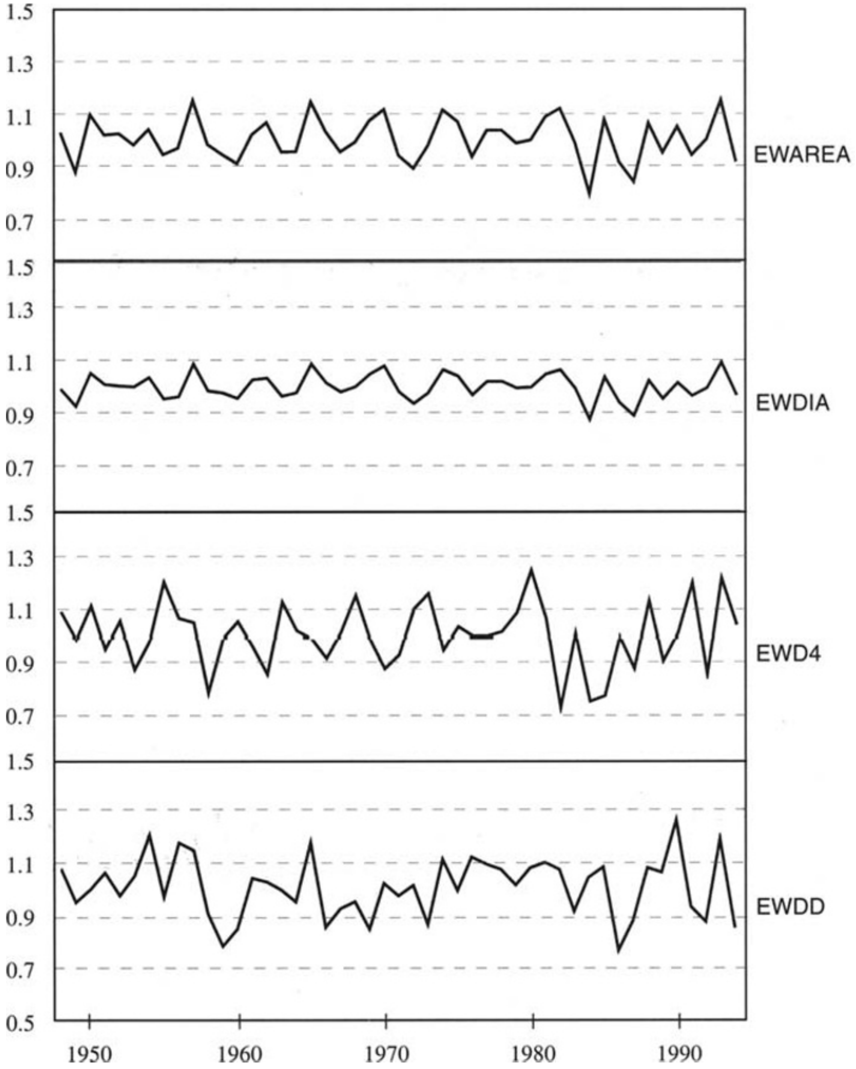

Fig. 4. Earlywood vessel chronologies; for the abbreviations see Table 1.

showed a negative correlation with current August rainfall. As an example, the time series of vessel area and diameter as well as of the conductive area and vessel density are given in Figure 4.

The latewood vessel parameters, except vessel density, were negatively correlated with temperature, particularly in current June (Fig. 5). However, a positive correlation with temperature was found for vessel density, particularly in current April and May. The relationship with rainfall was rather weak.

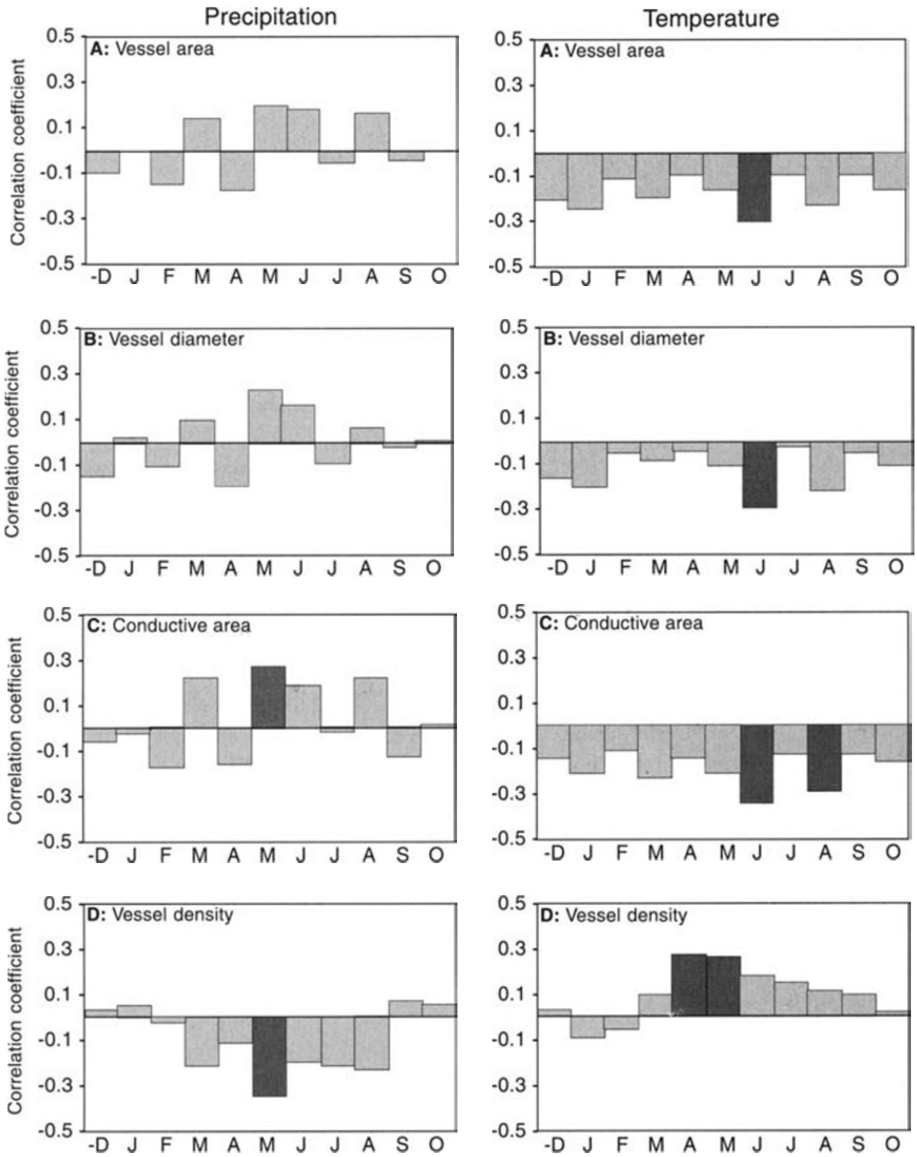

Fig. 5. Climate-growth relationships of latewood vessel parameters for the period 1947–1996; bars represent simple correlation coefficients, with significant values in dark-grey.

The autocorrelations and mean sensitivities of all vessel parameters and of the tree-ring width are given in Table 1. The autocorrelation of the tree-ring width is the highest whereas all other time series, except the vessel density time series, are nearly without any autocorrelation. As regards the mean sensitivities, the vessel diameter time series have the lowest values. The conductive areas show even higher values than tree-ring widths with a maximum of 0.54.

Table1. Autocorrelation and mean sensitivity of the chronologies (standard version) of vessels and of tree-ring width.

	Variables	Auto-correlation	Mean sensitivity	
Earlywood	EWAREA	0.10	0.21	EWAREA = Earlywood vessel area
	EWDIA	0.06	0.13	EWDIA = Earlywood vessel diameter
	EWD4	0.13	0.38	EWD4 = Earlywood conductive area
	EWDD	0.29	0.34	EWDD = Earlywood vessel density
Latewood	LWAREA	0.14	0.27	LWAREA = Latewood vessel density
	LWDIA	0.14	0.19	LWDIA = Latewood vessel diameter
	LWD4	0.14	0.54	LWD4 = Latewood conductive area
	LWDD	0.46	0.40	LWDD = Latewood vessel density
Total ring	TWAREA	0.18	0.18	TWAREA = Total ring vessel area
	TWDIA	0.20	0.13	TWDIA = Total ring vessel diameter
	TWD4	0.17	0.33	TWD4 = Total ring conductive area
	TWDD	0.55	0.39	TWDD = Total ring vessel density
Ring width	RW	0.72	0.31	RW = Ring width

Tree-ring width and vessel parameters

The correlation among the vessel parameters and between these parameters and tree-ring width is summarized in Table 2. Similar results and trends were found by Woodcock (1989) for other ring-porous tree species.

CONCLUSION

The climate signals of the vessel parameters, although statistically significant, are not easy to be physiologically explained. In any case they are different from those of tree-ring width. Warm and dry conditions from March to April (May) generally favour the formation of large vessels over the whole growing season. Whereas the earlywood vessels are more controlled by moisture availability, the size of the latewood vessels is more dependent on cool summer conditions. Altogether the results are promising to stimulate more such studies of tropical or subtropical tree species.

ACKNOWLEDGEMENTS

The project was funded by the Korean Science and Engineering Foundation (KOSEF) and the Thai's Research Council, in cooperation with Chungbuk National University and Mahidol University. We also thank all members of the Maehongson forest station for helping with sample collection.

Table 2. Correlation among anatomical variables (compare Table 1) and between these parameters and tree-ring width (RW); ** = significant at 0.001 level, * = significant at 0.05 level.

	TWAREA	TWDIA	TWD4	TWDD	EWAREA	EWDIA	EWD4	EWDD	LWAREA	LWDIA	LWD4	LWDD	RW
TWAREA		0.955**	0.934**	0.588**	0.454**	0.406**	0.416**		0.299*	0.318*		0.588**	
TWDIA	0.955**		0.839**	0.590**	0.367**	0.320*	0.337*		0.386**	0.448**	0.241*	0.632**	-0.250*
TWD4	0.934**	0.839**		0.491**	0.569**	0.514**	0.552**					0.455**	
TWDD	0.588**	0.590**	0.491**								-0.394**	0.931**	-0.694**
EWAREA	0.454**	0.367**	0.569**			0.978**	0.882**	0.500**	0.296*	0.322*	0.311*		0.328*
EWDIA	0.406**	0.320*	0.514**		0.978**		0.877**	0.463**	0.294*	0.321*	0.324*		0.346**
EWD4	0.416**	0.337*	0.552**		0.882**	0.877**		0.481**					
EWDD					0.500**	0.463**	0.481**						
LWAREA	0.299*	0.386**		-0.267*	0.296*	0.294*				0.948**	0.943**		0.257*
LWDIA	0.318*	0.448**			0.322**	0.321*			0.948**		0.865**		
LWD4		0.241*		-0.394**	0.311*	0.324*			0.943**	0.865**			0.350**
LWDD	0.588**	0.632**	0.455**	0.931**									-0.698**
RW		-0.250*		-0.694**	0.328*	0.346**			0.257*		-0.350**	-0.698**	

REFERENCES

Bhattacharyya, A., R.R. Yadav, H.P. Borgaonkar & G.B. Pant. 1992. Growth ring analysis of Indian tropical trees: dendroclimatic potential. Current Science 62: 736–741.

Cook, E.R. 1985. A time-series analysis approach to tree-ring standardization. Thesis, University of Arizona, Tucson. 175 pp.

Eckstein, D. & E. Frisse. 1982. The influence of temperature and precipitation on vessel area and ring width of oak and beech. In: M.K. Hughes, P.M. Kelly, J.R. Pilcher & V.C. LaMarche (eds.), Climate from tree rings: 12–13. Cambridge University Press, Cambridge.

Fritts, H.C. 1976. Tree rings and climate. Academic Press, London, New York.

Gottwald, H. & N. Parameswaran.1980. Anatomy of wood and bark of Tectona (Verbenaceae) in relation to taxonomy. Bot. Jahrb. Syst. 101: 363–384.

Holmes, R.L. 1983. Computer-assisted quality control in tree-ring dating and measurement. Tree-Ring Bull. 43: 69–78.

Jacoby, G.C. & R.D'Arrigo. 1990. Teak (Tectona grandis L.f.), a tropical tree species of large scale dendroclimatic potential. Dendrochronologia 8: 83–98.

Media Cybernetic L.P. 1994. Image-Pro Plus. Version 1.3 for Windows. Reference Guide. 8484 Georgia Avenue, Silver Spring, MD 209100, USA.

Murphy, O. & P.H. Whetton. 1989. Re-analysis of a tree ring chronology from Java. Proc. Kon. Ned. Akad. Wetensch. 92: 241–257.

Palmer, J.G. & J.O. Murphy. 1993. An extended tree ring chronology (teak) from Java. Proc. Kon. Ned. Akad. Wetensch. 96: 27–41.

Pant, G.B. & H.P. Borgaonkar. 1983. Growth rings of teak trees and regional climatology. In: L.R. Singh, S. Singh, R.C. Tiwari & R.P. Srivastava (eds.), Environmental management: 154–158. The Allahabad Geographical Society, Dept. Geography, Univ. Allahabad, India.

Park, W.-K. 1990. Development of anatomical tree-ring chronologies from southern Arizona conifers using image analysis. PhD Thesis, University of Arizona, Tucson. 234 pp.

Pumijumnong, N. 1995. Dendrochronologie mit Teak (Tectona grandis L.) in Nord-Thailand – Jahrringbildung-Chronologiennetz-Klimasignal. Diss., Fachbereich Biologie, Univ. Hamburg. 104 pp. + Annex.

Pumijumnong, N., D. Eckstein & U. Sass. 1995a. Tree-ring research on Tectona grandis in northern Thailand. IAWA J. 16: 385–392.

Pumijumnong, N., D. Eckstein & U. Sass. 1995b. A network of Tectona grandis chronologies in northern Thailand. In: Proc. International Workshop on Asia and Pacific Dendrochronology, 4–9 March 1995, Tsukuba, Japan: 35–41.

Rinn, F. 1989. TSAP-Time Series Analysis Program. Version 2.3, Reference Manual. Heidelberg, Germany.

Sass, U. 1993. Die Gefässe der Buche als ökologische Variable – Bildanalytische Erfassung, dendroklimatologische Prüfung, ökologische Bewertung. Diss., Fachbereich Biologie, Univ. Hamburg. 172 pp.

Sass, U. & D. Eckstein. 1992. The annual vessel area of beech as an ecological indicator. Proc. Tree Rings and Environment. Lundqua Report 34: 281–285.

Sass, U. & D. Eckstein. 1995. The variability of vessel size in beech (Fagus sylvatica L.) and its ecophysiological interpretation. Trees 9: 247–252.

Schweingruber, F.H. 1982. Measurement of densitometric properties of wood. In: M.K. Hughes, P.M. Kelly, J.R. Pilcher & V.C. LaMarche (eds.), Climate from tree rings: 38–45. Cambridge University Press, Cambridge.

Wood, M.L. 1996. Synoptic dendrochronology in the upper Narmada River Basin: An exploratory study in Central India. Master Thesis, University of Arizona, Tucson. 176 pp.

Woodcock, D.W. 1989. Climate sensitivity of wood-anatomical features in a ring-porous oak (Quercus macrocarpa). Can. J. For. Res. 19: 639–644.