Palaeobotanist 50 (2001) 83-87
0031-0174/2001/83-87 $2.00

A dendrometer band study of teak (*Tectona grandis* L.F.) in north Thailand

B.M. BUCKLEY[1], O. TONGJIT[2], R. POONSRI[3] AND N. PUMIJUMNONG[4]

[1]*Tree-Ring Laboratory, Lamont-Doherty Earth Observatory, USA.*
[2]*Lampang Agricultural Research and Training Centre, Lampang, Thailand.*
[3]*Mae Na Forest Protection Unit, Chiang Dao, Thailand.*
[4]*Dept. of Environment and Resource Studies, Mahidol University, Salaya, Thailand.*

(Received 19 June 2000; revised version accepted 10 December 2001)

ABSTRACT

Buckley BM, Tongjit O, Poonsri R & Pumijumnong N 2001 A dendrometer band study of teak (*Tectona grandis* L.F.) in north Thailand. Palaeobotanist 50(1) : 83-87.

We present results from a dendrometer band study of teak in north Thailand. We track daily circumferential changes for three trees over nearly sixteen months from November 3, 1998 to February 29, 2000. This period encompasses one complete cycle of dry and wet seasons, along with the very important transitions from wet to dry (November) and from dry to wet (April). Circumferential changes were observed for all three stems: decreasing in response to the onset of drought, and increasing following rain events, particularly after leafout and during the wet season. Dry-season rain events also resulted in stem swelling, when the trees were devoid of leaves and thought to be dormant. While these dormant-season fluctuations can be attributed to hydration/dessication of the stem tissue and not cambial cell division, there appears to be a net gain in circumference following a rain event in the middle of the first dry season. We therefore stress the importance of climate/physiology relationships even during periods of dormancy. We recognise the need for more detailed monitoring of environmental and growth factors, to maximise our understanding of the effects of climate on cambial activity and radial growth. This information is critical for understanding the complex relationships between climate and tree growth in these tropical forests, for which precious little data exist.

Key-words—Teak, Dendrometer, Dendroclimatology, Radial growth, Thailand.

उत्तरी थाईलैण्ड से प्राप्त टीक (*टेक्टोना ग्रैण्डिस* एल.एफ.) का डेन्ड्रोमीटर बैण्ड सम्बन्धी अध्ययन

ब्रेन्डन एम. बकले, ओ. टांग्जिट, आर. पूंसरी एवं नासुदा पूमिजुमनांग

सारांश

प्रस्तुत शोध पत्र में हमने उत्तरी थाईलैण्ड के टीक वृक्ष के डेन्ड्रोमीटर बैण्ड सम्बन्धी अध्ययन से प्राप्त परिणामों को प्रस्तुत किया है। इस हेतु हमने 3 नवम्बर, 1998 से 29 फरवरी 2000 तक की सोलह महीनों से अधिक अवधि के दौरान तीन वृक्षों के परिधीय परिवर्तनों का नित्य प्रेक्षण किया। इस कालावधि के दौरान आरम्भ में पूर्णतः शुष्क मौसम था, तत्पश्चात आर्द्र से उष्ण के मध्य का महत्त्वपूर्ण मौसम (नवम्बर माह) था तथा अन्त में शुष्क से आर्द्र (अप्रैल माह) मौसम के मध्य का काल था। हमने पाया कि जैसी सम्भावना थी, उसी के अनुरूप शुष्क मौसम के प्रारंभिक समय में अनावृष्टि के प्रारम्भ में सभी तीनों तनों की परिधि में ह्रास था तथा पतझड़ के पश्चात वर्षा के प्रारम्भ में परिधि में वृद्धि लक्षित होती है। बहरहाल, शुष्क मौसम के मध्य के दौरान, जब वृक्ष पत्तियों से रहित हो जाते हैं तथा प्रसुप्तावस्था में

होते हैं, हमने वर्षा की घटनाओं के परिणाम स्वरूप परिधि में वृद्धि पाई। शुष्क मौसम के मध्य में वर्षा के पश्चात परिधि में एक सकल वृद्धि प्रतीत होती है, जो प्रसुप्तावस्था के दौरान भी जलवायु/भूआकृतिक सम्बन्धों के महत्त्व को दर्शाती है। एधात्मक (कैम्बियमी) गतिविधियों तथा अरीय वृद्धि के प्रभावों को और अधिक समझने हेतु इस अध्ययन के अगले चरण में हमें पर्यावरण एवं वृद्धि के कारकों का और अधिक विस्तृत अनुश्रवण करना होगा। उदाहरण के लिए, सम्पूर्ण वर्ष के दौरान केम्बियमी ऊतकों के नियमित नमूने प्रेक्षित करने का कार्यक्रम एधा (कैम्बियम) के कोशिकीय अनुभागों के प्रारम्भ के काल मापन को अधिक शुद्धतापूर्वक निर्धारित कर सकेगा। हम इस दृष्टिकोण का उपयोग न सिर्फ टीक में कर रहे हैं, अपितु सम्पूर्ण उत्तरी थाईलैण्ड की अन्य अनेक अत्यधिक महत्त्वपूर्ण प्रजातियों हेतु भी कर रहे हैं। ये सूचनाएँ इन उष्णकटिबन्धीय वनों में जलवायु एवं वृक्ष वृद्धि के मध्य के जटिल सम्बन्धों को समझने हेतु अत्यन्त महत्त्वपूर्ण हैं, जिनके लिए इससे पहले बहुत कम आंकड़े ही उपलब्ध थे। इस अनुसन्धान को दीर्घावधि तक जारी रखना अत्यन्त महत्त्वपूर्ण है, क्योंकि यह अध्ययन भविष्य के अनुसन्धान कार्यों हेतु आधार तैयार करेगा।

संकेत शब्द—टीक, डेन्ड्रोमीटर, वृद्धि, उष्णकटिबन्धीय वन, थाईलैण्ड.

INTRODUCTION

THE experiment reported in this paper was implemented as part of FIELDWEEK 99, a training workshop on tropical dendrochronology held in Chiang Mai, Thailand in February, 1999. Teak (*Tectona grandis* L.F.) is one of only three tree species from Thailand (along with two species of *Pinus*) shown to have identifiable annual growth rings that are useful for dendrochronology (e.g., Buckley *et al.*, 1995; D'Arrigo *et al.*, 1997; Pumijumnong *et al.*, 1995a, b, c). Other studies on teak clearly demonstrate its usefulness as a proxy for Monsoon rainfall (e.g., De Boer, 1951; Murphy & Whetton, 1989; Pant & Borgaonkar, 1983; Jacoby & D'Arrigo, 1990; D'Arrigo *et al.*, 1994; Pumijumnong *et al.*, 1995c; Borgaonkar *et al.*, this volume) and as a proxy for the El Nino Southern Oscillation (ENSO) phenomenon (Stahle *et al.*, 1998). As such, teak is arguably the most important tropical tree species for dendroclimatic research, certainly with regards to Monsoon Asia. A more detailed understanding of the physiological response to climate for this important species, throughout its entire annual cycle, is therefore of great interest to dendroclimatologists.

Dendrometer studies have been demonstrated to provide useful information about annual radial tree growth, with particular relevance to the effects of precipitation on cambial activity (e.g., Fritts, 1962; Palmer & Ogden, 1983; Worbes, 1995). We have, accordingly, begun a programme to monitor the radial growth of teak and other proven or promising tropical species for successive seasons, as part of a broader baseline study for understanding tropical tree growth and the effects of climate.

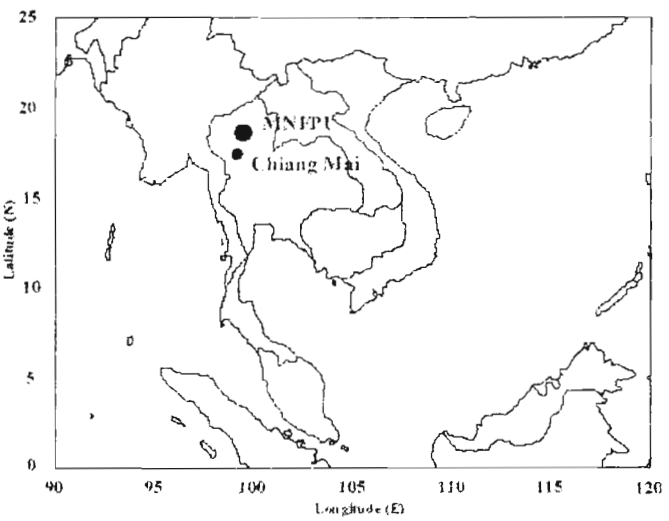

Fig. 1—Location of the Mae Na Forest Protection Unit (MNFPU) in north Thailand.

MATERIAL AND METHODS

We installed manual band dendrometers on three teak trees at the Mae Na Forest Protection Unit (MNFPU), about 80 km north of Chiang Mai, Thailand (Fig. 1). This remnant stand, consisting of approximately 100 stems, survived previous large-scale logging in the Chiang Dao area and is currently protected from further logging and other major disturbance. For purposes of this study these trees are considered to be growing in a largely natural environment, although on-site housing and groundskeeping activities certainly exert an effect on the groundcover. No artificial watering occurs at the site, however, so these trees are entirely dependent on natural rainfall.

The climate of the region can be compared to that of Chiang Mai, the general climate characteristics for which are illustrated in Fig. 2 of Borgaonkar *et al.* (this volume). The dry period north Thailand is from December to March

Fig. 2—A Gensler manual band dendrometer on a teak tree at MNFPU

with nearly 90% of the annual rain falling during the May to October Monsoon. Mean temperature remains above 20°C throughout the year, with April and May comprising the warmest months.

The manual band dendrometer used for this study (Fig. 2) was made by Agricultural Electronics Inc., USA, and are comprised of metal alloy bands that encircle the tree and are connected to a spring-loaded vernier scale. The band material is made of Hastalloy 276, with a coefficient of thermal expansion of 11·2 micrometers/meter/degree C. The vernier scale registers the daily circumferential change to 0·1 mm accuracy. Measurements must be taken manually by visually reading the vernier scale, increasing the possibility for measurement error. Therefore, measurements are checked by two recorders whenever possible. For consistency, we record band measurements at the same time each day, between 8:00 and 9:00 AM. As a further check we record stem circumference just below the band each day at the time of band reading, using a forester's tape measure. This proved to be a valuable calibration check during times when bands needed to be reset due to mechanical reasons.

Along with the dendrometer measurements, we record temperature at the time of measurement, and the occurrence or absence of rainfall during the 24 hours leading up to the time of measurement. (We recently began measuring absolute rainfall amount at the site on February 2, 2001, when we installed two manual rain gauges and a max/min thermometer). In addition to climate variables we also record phenological phenomena (e.g.; date of flowering, and "leaf out") and mechanical problems (e.g.; termite activity that results in band expansion, and stem shrinkage with drought that extends beyond the scale of the bands). In such instances corrections are made and the bands reset.

RESULTS AND DISCUSSION

The dendrometer band measurements for the period November 3, 1998 to February 29, 2000 are shown in Fig. 3. As expected, these data clearly indicate the importance of precipitation for radial growth activity in teak during the monsoon months. Following each rain event, even during the period of dormancy, we recorded circumferential increases that were followed by decreases in stem size as conditions dried out again. This demonstrates that active transport of water through the stem occurs even in the absence of photosynthetic processes, but does not imply that cambial cell division is taking place. There is a net gain in circumference following a three-days rain period from January 16-18, 1999, however, right in the middle of the dry season. After the first leaves appeared on February 27, 1999 additional rain events resulted in further increases in circumference. However, all three stems reached a 3 months low before May 5, 1999 when a heavy rain occurred and the trees swelled in size once again, attaining their largest sizes of the season.

During the 1999 wet season, all three stems swelled beyond the range of the bands on two occasions, thus the "plateau" effect as seen in Fig. 3 (corrections were made using daily tape measurements of circumference as noted earlier). In contrast, a period of reduced rainfall from late June to mid-July resulted in significant stem shrinkage in the midst of the wet season, between the two largest growth periods. By the end of the wet season all three trees decreased in circumference, until receiving rain in late February. By the end of the recorded period a net increase of approximately 10 mm can be seen from the prior year, and is consistent with tape measurements of circumference (Fig. 4) that show increases of 1·5, 1·4 and 2·2 cm for trees 36, 51 and 57,

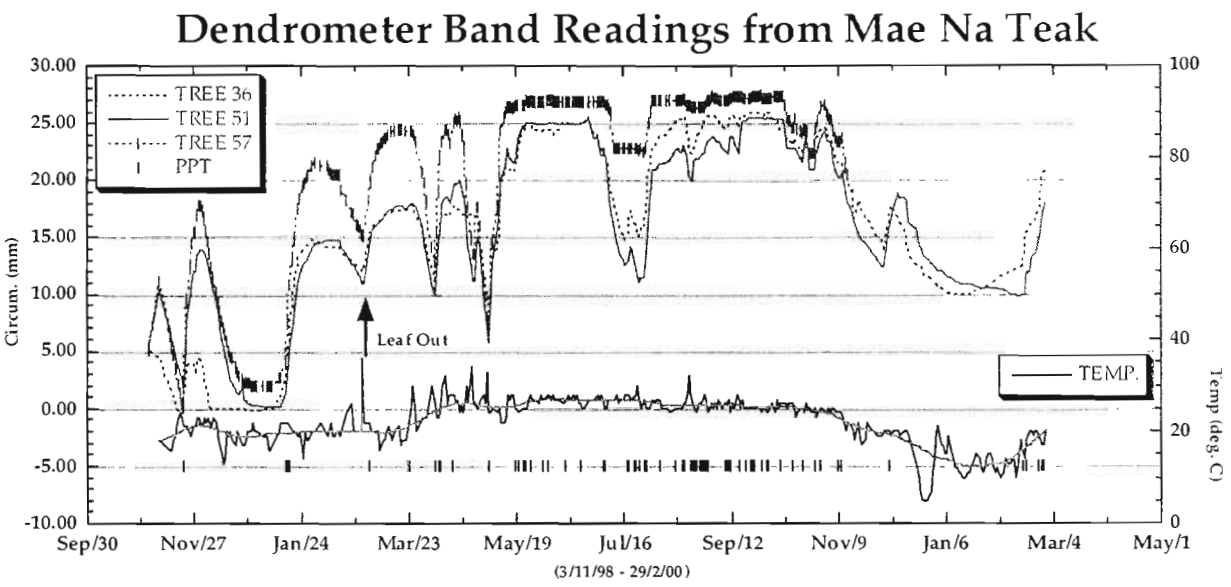

Fig. 3—Dendrometer band measurements from 3 teak trees at MNFPU from Nov. 3, 1998 to Feb. 29, 2000. The shaded area in the center of the graph denotes the "traditional" wet season period from May through October. The arrow marks the day when the first leaves appeared (Feb. 27). The line at the bottom shows daily temperature. The vertical black bars indicate the occurrence of rain events.

respectively. We also cored and measured the year 1999 growth ring for all three trees.

Borgaonkar *et al.* (this volume) demonstrate the importance of precipitation for the MNFPU teak stand through time. Their response function analyses show a significant ($p<0.05$) positive relationship with precipitation for November of the prior season (transitional season from wet to dry), and also during the wet season (May to October). Drought conditions at the stand coincide with below average radial growth, and wetter conditions coincide with increased radial growth over the past 87 years. The authors note that while there is an inverse response between ring width and temperature during the hottest month of April, this may in fact be related to the correlation between temperature and precipitation and not a direct response to temperature, *per se*. However, Pumijumnong and Park (this volume) note a relationship between temperature and earlywood vessel density that suggests that more research is required to address the possibility of temperature influencing some aspects of growth in teak. Prior research by Kaosa-Ard (1977; 1986) demonstrates that temperature does have an effect on teak seedlings. The author notes an optimum range for growth around 30°/25°C.for day/night temperature. Temperatures dipping below 18°C caused a cessation of growth in teak seedlings. It is interesting to note that in the Mae Na teak stand, the first leaves appeared on the first day following the hottest temperature recorded during the course of this study (36°C on February 26). Further exploration of the effects of temperature on teak growth therefore seems warranted.

Tree ID	CBH Jan. 4, 1999	CBH Jan. 20, 2000
Tree 36	149·5	151·0
Tree 51	134·0	135·4
Tree 57	147·8	150·0

Fig. 4—Circumference at band height, in centimeters, for the three teak trees. Measurements were taken just below the band dendrometers with a foresters tape measure, on Jan. 4, 1999 and Jan. 20, 2000, two periods of stem minima.

This preliminary study sheds some light on the annual growth cycle of teak in north Thailand. For example, the onset of shoot development and leaf out, and more importantly cambial activity, is largely considered to be sometime in April (e.g., Pumijumnong *et al.*, 1995a, b). Our results show that the first leaves can appear much earlier, in this instance late February, and that cambial activity may, under some circumstances, begin earlier than previously thought. We are now incorporating other techniques into this study, most notably cambial scarring or "pinning" methods, in order to absolutely determine the date of first cambial cell division. It is necessary to continue monitoring these factors over successive seasons and to incorporate more variables into our experimental design. We are applying this approach to several species in multiple locations in Thailand, an exercise we anticipate will be of immense value in future studies that aim to utilise tree-ring parameters for modelling past environmental changes in the tropics.

Acknowledgements—*The authors wish to thank the participants, and those who helped organise and host FIELDWEEK 99, as well as the funding agencies NSF and PAGES. We extend our heartfelt thanks to the chief of the Mae Na Forest Protection Unit, Khun Songsak Suriyawong, and staff member Khun Songkran for their hospitality, cooperation and assistance. We also thank Weerachai Nanakorn and Suyanee Vesabutr from the Queen Sirikit Botanic Garden in Mae Rim, for graciously hosting FIELDWEEK 99 participants during the laboratory and classroom components of our programme. In addition, we greatly appreciate the support of Apichart Kaosa-Ard and Soontorn Kamyong, from the Dept. of Forest Resources at Chiang Mai University. We wish to thank two anonymous reviewers for their helpful comments that improved the manuscript.*

REFERENCES

Borgaonkar HP, Pumijumnong N, Buckley BM, Taesumrith O & Chutiwat S 2001. Tree ring analysis of teak (*Tectona grandis*) ring width chronology from Mae Na, Thailand. Palaeobotanist 50 : 41-45.

Buckley BM, Barbetti M, Watanasak M, D'Arrigo R, Boonchirdchoo S & Sarutanon S 1995. Dendrochronological investigations in Thailand. IAWA Journal 16 : 393-409.

D'Arrigo RD, Jacoby GC & Krusic PJ 1994. Progress in dendroclimatic studies in Indonesia. Terrestrial, Atmospheric and Oceanographic Sciences 5 : 349-363.

D'Arrigo RD, Barbetti M, Watanasak M, Buckley BM, Krusic PJ, Boonchirdchoo S & Sarutanon S 1997. Progress in dendroclimatic studies of mountain pine in northern Thailand. IAWA Journal 18 : 433-444.

De Boer HJ 1951. Tree-ring measurements and weather fluctuations in Java from 1514 AD. Proceedings koninklijke nederlandse akademie van wetenschappen. Series B, 54 : 194-209.

Fritts HC 1962. The relevance of dendrographic studies to tree-ring research. Tree-Ring Bulletin 24 : 9-11.

Jacoby GC D'Arrigo RD 1990. Teak (*Tectona grandis* LF): A tropical species of large scale dendroclimatic potential. Dendrochronologia 8 : 83-98.

Kaosa-Ard A 1977. Physiological studies on sprouting of teak (*Tectona grandis* L.F.) planting stumps. Ph.D. Thesis, Australian National University, Canberra, Australia.

Kaosa-Ard A 1986. Teak, *Tectona grandis*, Linn. F. nursery techniques. Seed leaflet No. 4A. Danida Forest Seed Centre, Denmark, 42 pp.

Murphy JO & Whetton PH 1989. A re-analysis of tree-ring chronology from Java, Proceedings koninklijke nederlandse akademie van wetenschappen. Series B, 92 : 241-57.

Palmer J & Ogden J 1983. A dendrometer band study of the seasonal pattern of radial increment in kauri (*Agathis australis*). New Zealand Journal of Botany 21 : 121-126.

Pant GB & Borgaonkar HP 1983. Growth rings of teak trees and regional climatology (An ecological study of Thane region). *In*: Singh LR, Singh S, Tiwari RC & Srivastava RP (Editors)—Environmental Management : 153-158. Published by the Allahabad Geographical Society, Allahabad, India.

Pumijumnong N, Eckstein D & Sass U 1995a. A network of *Tectona grandis* tree-ring chronologies in northern Thailand. *In:* Tree-rings from the past to the future. Proc. Workshop on Asian and Pacific Dendrochronology, 4-9 March, 1995, Tsukuba, Japan : 35-41.

Pumijumnong N, Eckstein D & Sass U 1995b. Reconstruction of rainfall in northern Thailand from tree-ring series of teak. *In:* Palaeoclimate and Environmental Variability in Austral-Asian Transect During the past 2000 Years. Proc. IGBP-PAGES/PEP-II Symposium, Nagoya, Japan : 86-91.

Pumijumnong N, Eckstein D & Sass U 1995c. Tree-ring research on *Tectona grandis* in northern Thailand. IAWA Journal 16 . 385-392.

Pumijumnong N & Park WK 2001. Teak vessel chronologies as an indicator of Southeast Asia Monsoon temperature. Palaeobotanist 50 : 21-26.

Stahle DW, D'Arrigo RD, Krusic PJ, Cleaveland MK, Cook ER, Allan RJ, Cole JE, Dunbar RB, Therrell MD, Gay DA, Moore MD, Stokes MA, Burns BT, Villanueva-Diaz J & Thompson LG 1998. Experimental dendroclimatic reconstruction of the Southern Oscillation. Bulletin of the American Meteorological Sòciety 79 : 2137-2152.

Worbes M 1995. How to measure growth dynamics in tropical trees: A review. IAWA Journal 16 : 227-351.