CAMBIAL ACTIVITY OF *DIPTEROCARPUS COSTULATUS* IN RELATION TO DIFFERENT STEM DIAMETERS AND CLIMATE FACTORS

KH Wang[1, *], AA Abdul Azim[1] & MH Sahri[2]

[1]*Faculty of Forestry, Universiti Putra Malaysia, 43400 UPM Serdang, Selangor Darul Ehsan, Malaysia*
[2]*School of International Tropical Forestry, Universiti Malaysia Sabah, Jalan UMS, 88400 Kota Kinabalu, Sabah, Malaysia*

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WANG KH, ABDUL AZIM AA & SAHRI MH. 2014. Cambial activity of *Dipterocarpus costulatus* in relation to different stem diameters and climate factors. This study investigated the seasonal cambial activity in *Dipterocrpus costulatus* trees with different range of stem diameter at breast height (dbh). Samples from main stem of *D. costulatus* with dbh < 15 cm and > 25 cm growing in natural lowland dipterocarp rainforest of west Peninsular Malaysia were collected for this purpose. Collections of cambial samples were carried out in 2-month intervals from August 2010 till June 2011. Cambial activity was determined by counting the numbers of cambial and expansion zone cell layers towards the outer sapwood. A greater number of cell layers indicated greater cambial activity. Results showed that the cambium of trees with dbh < 15 cm were influenced by the amount of rainfall. However, cambium of trees with dbh > 25 cm showed relatively less sensitivity to rainfall. *Dipterocrpus costulatus* showed active and inactive phases during the observation period. Thus, this study has proven that this species did not grow continually at the same rate in natural forests. Instead it showed periods of alternate active and inactive growth.

Keywords: Rainfall, secondary xylem growth, growth variations

INTRODUCTION

Studies on seasonal cambial activity of tropical trees species are particularly important in predicting the climate–growth relationship of trees and their productivity (Marcati et al. 2008). Such studies are also important for silvicultural system and to understand the impacts of climate change on tropical forests (Worbes 1999). Majority of past studies on cambial activity are conducted using temperate trees as well as tropical trees growing in distinct dry and wet season. However, similar studies on the seasonal activity of vascular cambium are relatively few for trees growing in tropical rainforest with a lack of clear seasonality. Information on cambial activity and formation of secondary xylem in trees growing in Malaysia under natural conditions is thus very limited and only fragmentarily understood.

Relationship between tree diameter growth and climatic conditions have been extensively studied through dendrochronological researches which generally detect tree growth by minimising tree characteristics (e.g. size, age, microenvironment and species) and assuming that climate–growth relationship is independent of tree size (Carrer & Urbinati 2004, Briffa et al. 2008, St George et al. 2008). Nevertheless, recent studies have proven the sensitivity of tree growth rate to climatic conditions is dependent on both tree size and species (Nabeshima et al. 2010). Hence, it is important to consider variation in tree diameter growth within the same species in predicting its climate–growth relationship.

Therefore, the present study was aimed at investigating seasonal cambial activity in *Dipterocarpus costulatus* growing under natural conditions with various ranges of stem diameter. The species studied was selected based on its importance as a timber species, apart from the fact that it is easily available in the study site. The present study on cambial activity in relation to climatic factors will help improve our understanding of growth pattern in trees growing in tropical rainforest of west Peninsular Malaysia.

*wkanghan@gmail.com

Furthermore, information on radial growth of *D. costulatus* would be essential in managing forests to overcome timber shortage of this species.

MATERIALS AND METHODS

Study site

Ayer Hitam Forest Reserve, located in the state of Selangor, west of Peninsular Malaysia (2° 56'–3° 16' N and 101° 30–101° 46' E) was selected as the study site. The forest is a lowland dipterocarp secondary rainforest which has yet to reach fully rehabilitation (Faridah-Hanum 2004). Figure 1 shows the location of the study site.

Sampled trees

Four trees of *D. costulatus* were sampled in this study. Two diameter classes were selected, i.e. 10–12 cm and 24–27 cm. The two diameter classes were selected because they were easily available at the study site. All sampled trees were evergreen. The exact age of the sampled trees was not known.

Sample collection and preparation

Cambial samples comprising inner bark, cambial tissues and outer sapwood were collected from the main trunk at diameter breast height (dbh) of every sampled tree. Collections of samples were made every two months from August 2010 till June 2011. The size of the collected samples was 2 cm × 2 cm × 2 cm (radial × tangential × longitudinal). Samples were fixed in the field with 3% glutaraldehyde in distilled water directly after collection for preservation.

In the laboratory, the samples were trimmed to 2 mm × 2 mm × 10 mm before being dehydrated in a graded series of ethanol (i.e. 30, 50, 70 and 95%) and embedded in epoxy. Transverse sections with a thickness of 20–25 µm were cut from the epoxy-embedded blocks using a sliding

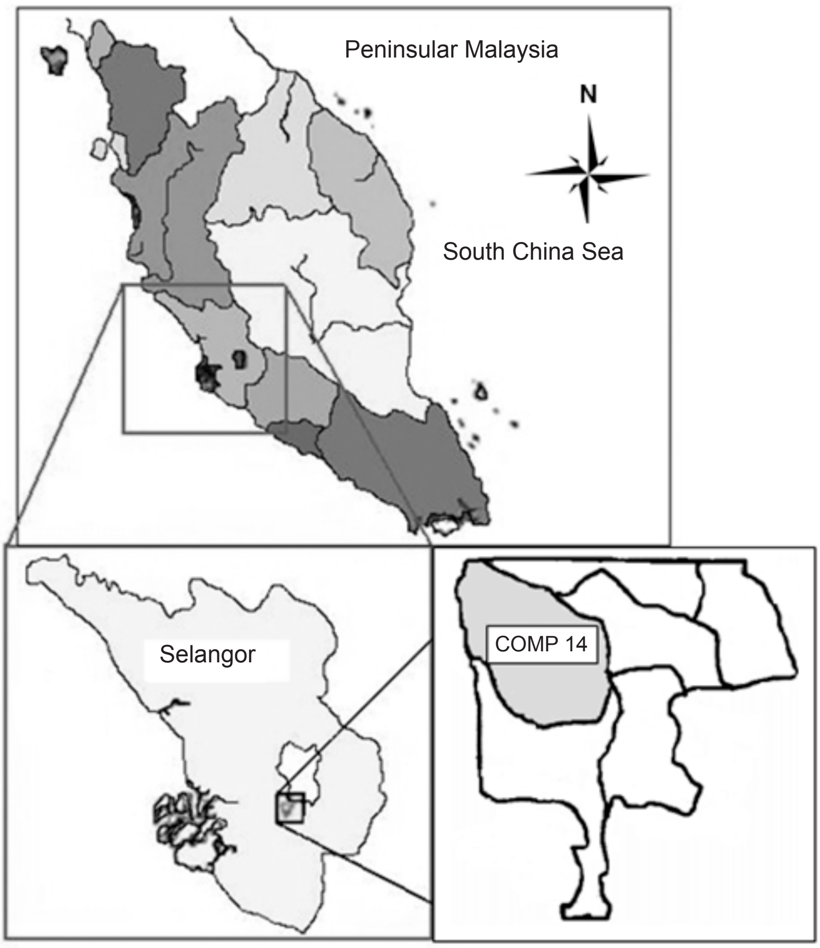

Figure 1 Study site in Ayer Hitam Forest Reserve, Puchong, Selangor; COMP = compartment; source: Paiman and Yaman (2007)

microtome (Nobuchi & Hori 2008) and stained with periodic acid-schiff reaction (McManus 1948) to distinguish the different stages of cell development (cambial reactivation, cell division and xylem differentiation stages, particularly in distinguishing secondary wall deposition as well as lignification). The changes from thin walled cambial cells to thick-walled secondary xylem were observed under light microscope. Sections were dried and mounted in dibutyl phthalate xylene mounting medium to prepare permanent microscope slides.

Analyses in laboratory

A light microscope with bright field and polarised light was used to observe the anatomical characteristics of the cambium and xylem. In order to evaluate anatomical characteristics of cambial zone and cells derived from it, the numbers of cell layers in both cambial and expansion zone were counted on the transverse sections (Nobuchi & Hori (2008). It is important to consider the formation of vessel element when counting the number of cells because formation of vessel element results in earlier enlargement of vessels in cell rows compared with those without vessels (Wakuta et al. 1973). Figure 2 shows the structure of cells that were used to distinguish between the cambial and expansion zone cells in transverse section. Figure 3 illustrates the transverse sections of the cambial and expansion zone cells under bright field and polarised light microscope.

Climatic data

Climatic data of the study site were collected from the meteorological station at Pusat Pertanian Serdang since there was no meteorological station at the study site. The distance between the meteorological station and the study site is about 15 km. Monthly total rainfall, monthly mean temperature and monthly mean relative humidity from August 2010 till June 2011 are shown in Figure 4. The highest rainfall (513.9 mm) recorded during the experimental period was in September 2010 whereas lowest (83.6 mm), in May 2011. Mean temperature ranged from 23.4 to 27.7 °C, with relative humidity ranging from 66.9 to 79.1%.

RESULTS

Figures 5 and 6 show the light micrographs of the cambial and expansion zones of the sampled trees in 2010 (August, October, December) and 2011 (February, April, June). Figures 7 and 8 exhibit the numbers of cambial and expansion zone cells in relation with total rainfall during the sampling dates. Trees with different stem diameter ranges showed variation in mean numbers of cells from August 2010 till June 2011. Cambial activity of all sampled trees was considered more active in August 2010 when the amount of rainfall recorded was high. Trees with dbh 10–12 cm showed a decrease in cambial activity with 9–11 layers of cells in October 2010 when total monthly rainfall dropped drastically. Although trees

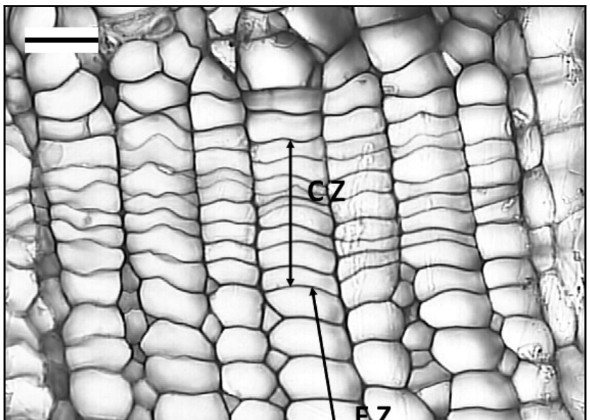

Figure 2 Transverse section showing cambial and enlarging zone cells; CZ = cambial zone cells; EZ = expansion zone cells; scale bar = 30 μm

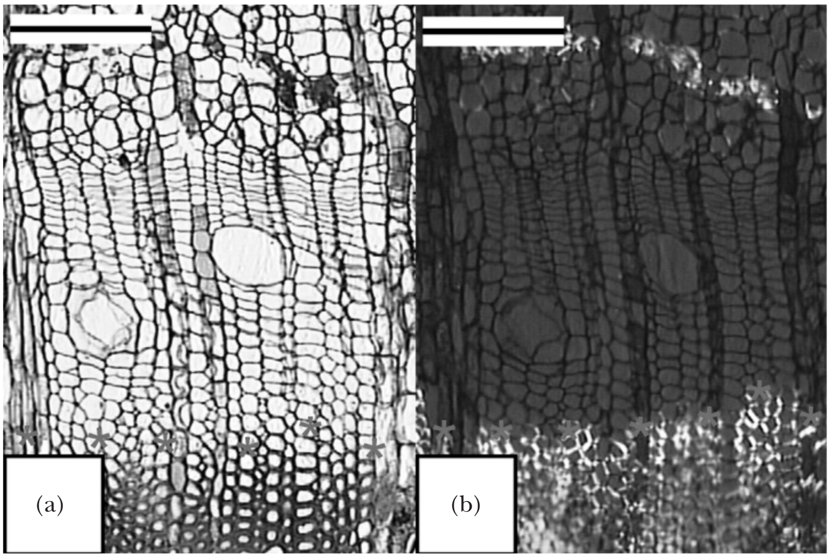

Figure 3 Transverse sections showing location of cambial and expansion zone cells; (a) conventional light micrograph and (b) polarised light micrograph; asterisks indicate the initiation of S_1 layer formation; scale bar = 200 μm

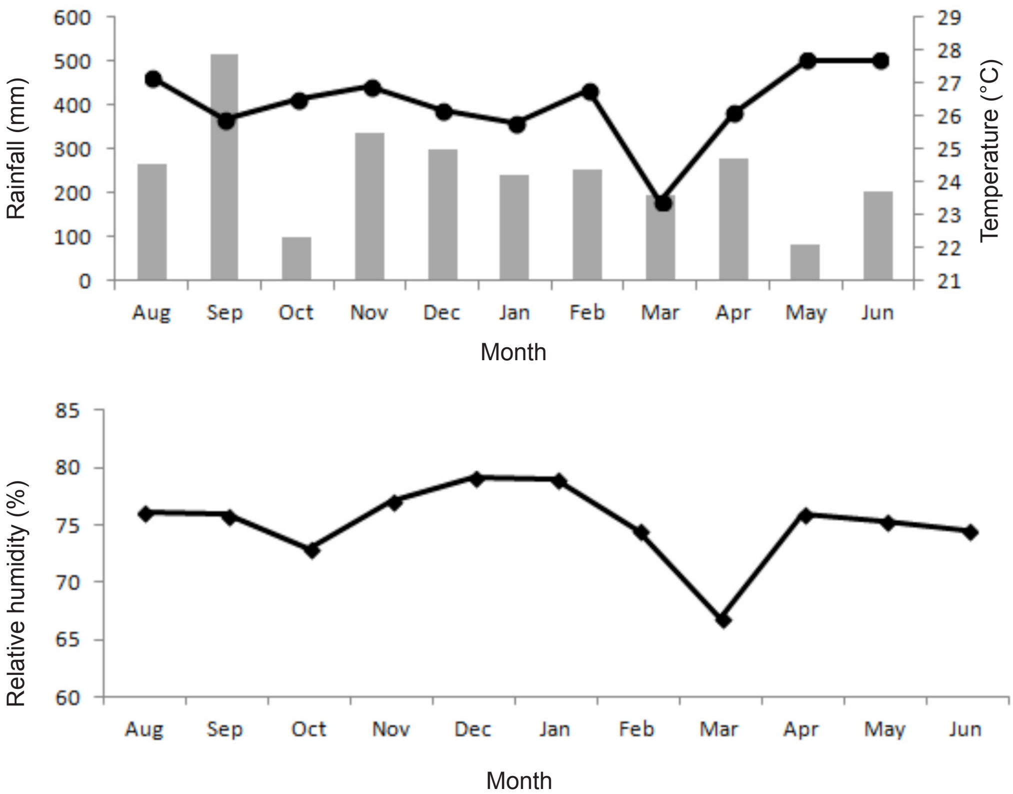

Figure 4 Climatic conditions of monthly mean rainfall, monthly mean temperature and monthly mean relative humidity from August 2010 till June 2011 at Pusat Pertanian Serdang Meteorological Station

with smaller diameter had decreased cambial activity, anticlinal divisions which increase the circumference of trees were observed during this dry month. However, decrease of rainfall in October did not reduce cambial activity of trees with dbh 24–27 cm. Trees with larger diameter showed almost the same number of cell layers in August 2010.

Trees with smaller dbh increased cambial activity in December when rainfall increased.

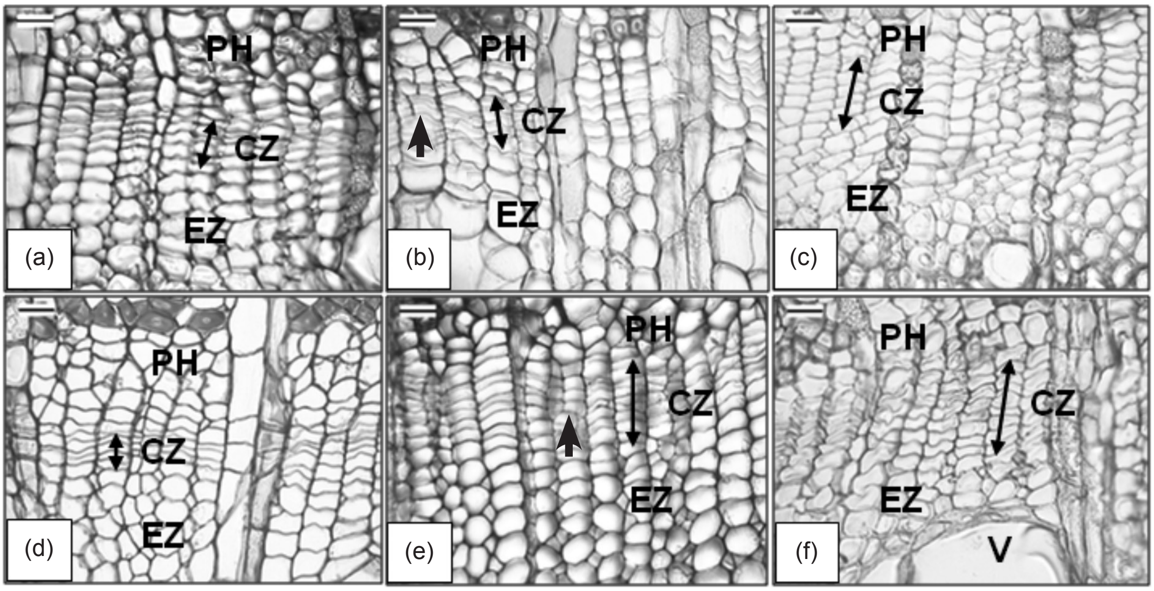

Figure 5 Transverse view of cambium with adjacent xylem and phloem in *D. costulatus* with dbh 10–12 cm in (a) August 2010, (b) October 2010, (c) December 2010, (d) February 2011, (e) April 2011 and (f) June 2011; arrow indicates anticlinal division; CZ = cambial zone cells, EZ = expansion zone cells, PH = phloem, V = vessel; scale bar = 30 µm

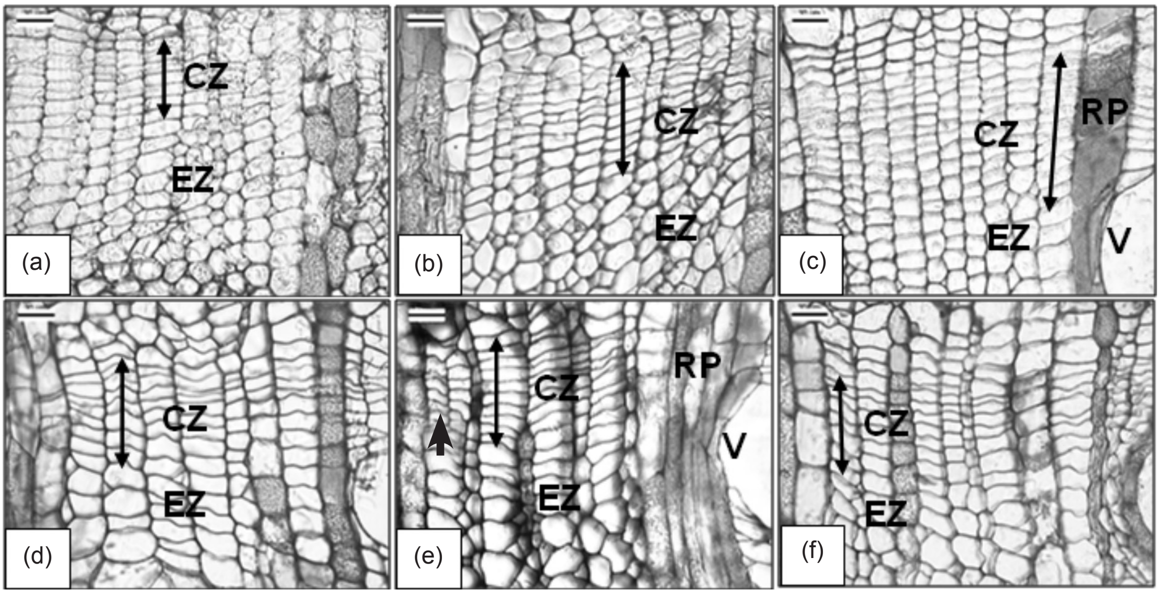

Figure 6 Transverse view of cambium with adjacent xylem and phloem in *D. costulatus* with dbh 24–27 cm in (a) August 2010, (b) October 2010, (c) December 2010, (d) February 2011, (e) April 2011 and (f) June 2011; arrow indicates anticlinal division; CZ = cambial zone cells, EZ = expansion zone cells, PH = phloem, V = vessel; scale bar = 30 µm

Cell divisions evident from cell plate formation increased the cambial and expansion zone cells. Cambial cell divisions were relatively higher and consequently widened gradually with 12 layers of cells. Trees with larger diameter showed increasing monthly cambial activity from August 2010 (from 17–18 layers of cells) till December 2010 (from 21–25 layers of cells). During these months, cell walls were thin and considerable number of cell plates was formed, forming wider cambial zone. The cambial activity started to reduce from February 2011 till June 2011.

Trees with smaller dbh (10–12 cm) had the highest layers of cells, i.e. 13–15 layers in April

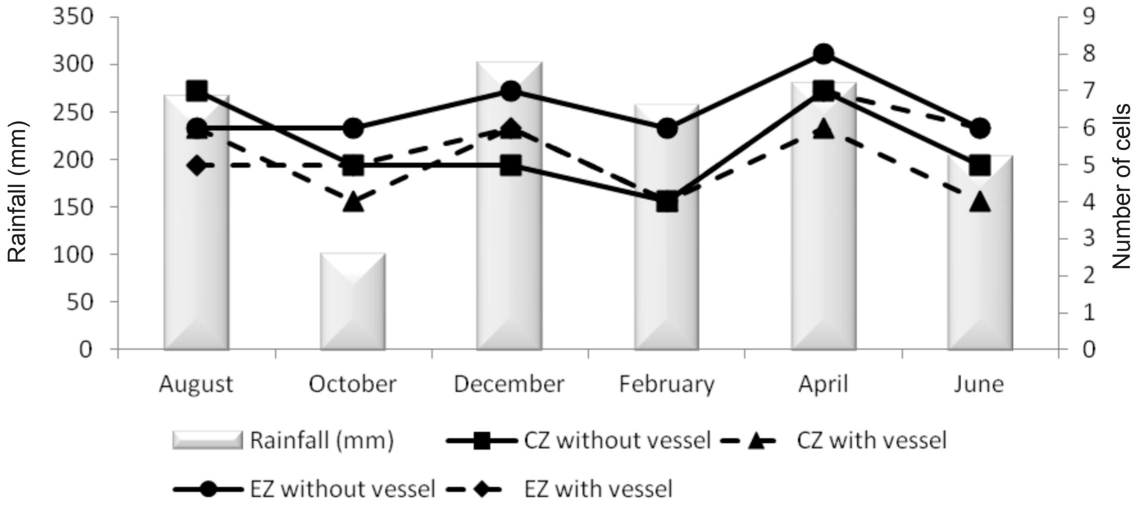

Figure 7 Relationship between monthly precipitation and mean number of cells for rows with and without vessel in *D. costulatus* with dbh10–12 cm; CZ = cambial zone cells, EZ = expansion zone cells

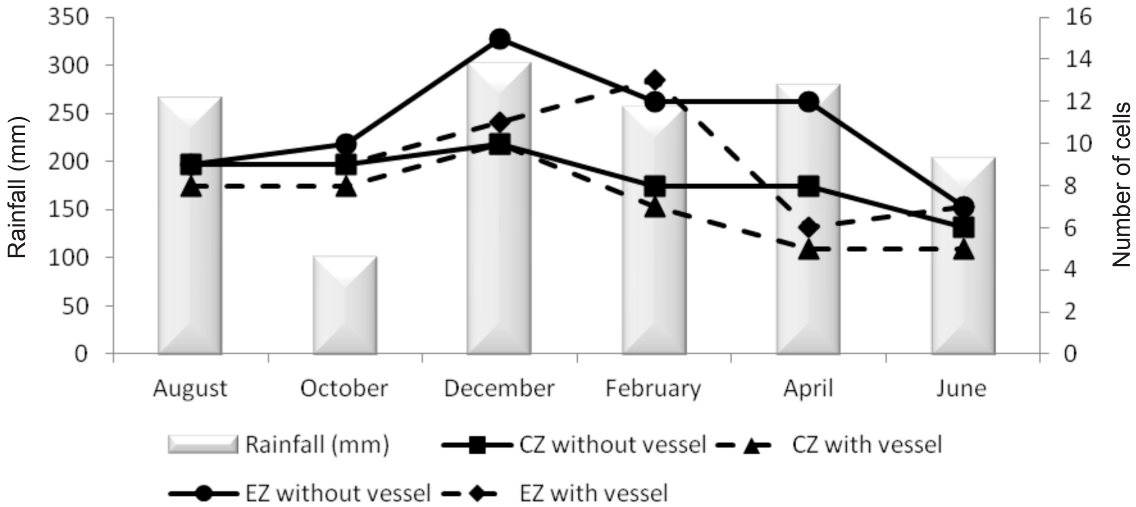

Figure 8 Relationship between monthly precipitation and mean number of cells for rows with and without vessel in *D. costulatus* with dbh 24–27 cm; CZ = cambial zone cells, EZ = expansion zone cells

2011 when the total rainfall was relatively high compared with that of trees with dbh 24–27 cm. During this month, cambial cells showed several anticlinal divisions, indicating active cambial activity in the sampled trees with smaller dbh. Trees with smaller dbh showed relatively less cambial activity (10–11 layers of cells) in June 2011 compared with April of the same year.

The changes in the number of cell layers of the trees with smaller diameter were similar with the changes in total monthly rainfall (Figures 7 and 8). Trees with larger dbh, however, showed relatively less similarity to changes in rainfall pattern. This was due to the fact that the dry October 2010 month did not influence cambial activity and, thus, did not decrease the total number of layers of cambial and expansion zone cells. Increase and decrease in rainfall in April and June 2011 respectively did not influence cambial activity of sample trees. Thus, it proved that the radial growth of sample trees can be influenced by stem size.

DISCUSSION

The growth patterns for trees with smaller dbh concur with findings by Rajput & Rao (1998), Rajput et al. (2005), Krepkowski et al. 2011, Diè et al. (2012) and Wang et al. (2013) whereby cambial activity of tropical trees is influenced by the amount of rainfall. However, *D.costulatus* with dbh 24–27 cm showed relatively active cambial activity during the dry month in October 2010. This phenomenon was also reported by Hazlett (1987) who observed significant *Pentaclethra macroloba* growth during the season with less rainfall and greater water loss via transpiration. The study showed that trees might have efficient water utilisation adaptation in lowland tropical forest. Trees with larger dbh are considered to have water adaptation that can facilitate growth during dry months. Results of this study demonstrated that climatic factor such as rainfall and relative humidity affected cambial activity difrerently depending on tree stem size.

Cambial growth of *D. costulatus* with smaller dbh was affected by water deficit as seen by the reduced cell layers in October 2010. Cambial activity gradually increased in December 2010 after the dry month, indicating that growth was limited by the amount of rainfall (Borchert 1998). Hence, rainfall is considered to be one of the important factors to reactivate cambial activity in *D.costulatus* with smaller diameter after a period of dry month. Pumijumnong and Buajan (2012) studied cambial growth dynamics of trees growing in central Thailand. The result showed that in Thailand, cambial activity of *Canarium euphyllum*, *Toona ciliate*, and *Spondias axillaris* increased with increased rainfall after a short dry season from November till January. *Dipterocarpus costulatus* with dbh 24–27 cm showed the highest number of cell layers in December 2010 and this was associated with the highest rainfall received. Climate–growth analysis of *Tabebuia chrysantha* in the tropical forest of southern Ecuador showed positive relationship between tree growth and rainfall (Volland-Voigt et al. 2011). Similar result was reported by Dave and Rao (1982), who observed that the division and differentiation rate of cambial cells in *Gmelina arborea* reached their peaks during the maximum rainfall. *Tetrameles nudiflora* and *Magnolia baillonii* growing in the seasonally wet but evergreen forest also have the highest cambial activity in June with maximum rainfall (Pumijumnong & Buajan 2012).

The role of rainfall on cambial activity has been documented in the tropics. Higher rainfall is an important factor in cambial reactivation and xylem production especially in regions where soil moisture is dependent on rainfall (Rao & Rajput 2000, 2001a, b). Nevertheless, this study showed that rainfall influenced cambial activity in sample trees with smaller stem size but not in sample trees with larger stem size. Cambial activities in trees with dbh 24–27 cm were lower in June than in October. Rainfall was thus unlikely an important factor in influencing cambial behaviour of the sample trees with larger stem size. Hence, this study suggested that the role of rainfall in influencing radial growth of trees is also dependent on tree stem size. Cambial activity in trees with larger stem size may be controlled by other physiological and other factors besides the selected climatic data (Larson 1994, Rao & Rajput 1999). Previous studies have reported correlations between growth and rainfall, since tropical areas are generally found to show little inter-annual variations in temperature throughout the year. Variation in temperature during this study had less effect on the cambial activity in the species examined. The study site exhibited almost a constant temperature and was unlikely to influence trees growth. This is opposite of the relationship between trees growth and temperature in temperate countries where temperature play a crucial role in influencing cambial activity.

Radial growth of tropical trees is either continuous throughout the year or for the major months of the year. During the observation period, no dormancy was observed, only inactive cambial activity. According to Rao and Rajput (2001a, b), trees receiving abundant amount of water over a long period of the year will show continuous cambial activity. Climatic factors such as rainfall, temperature and relative humidity affect cambial activity differently depending on tree species (Pumijumnong & Buajan 2012) as well as tree size. This study of *D. costulatus* growing in a tropical rainforest in west Peninsular Malaysia indicates that trees with different stem sizes demonstrated different growth pattern in response to the local climate.

CONCLUSIONS

Rainfall is an important climatic factor in influencing the cambial activity of the studied species, especially in trees with smaller dbh. This study revealed that *D. costulatus* with different stem diameter exhibited different growth behaviours under similar climatic conditions. In particular, cambial layer also showed active and relatively inactive periods and thus provided information regarding the cambial dynamic of this species.

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