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Determining the Climatic Sensitivity of *Wallaceodendron celebicum* Koord Tree Using Selected Physico–Structural Characteristics

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ABSTRACT

In order to determine the climate sensitivity of a 100-year-old Wallaceodendron celebicum Koord tree, selected physico–structural properties of its wood were used. Oven-dried specific gravity was unaffected by both increasing temperature and amount of rainfall. For fiber morphology, only lumen diameter was significantly affected by temperature while only cell wall thickness was significantly influenced by the amount of rainfall. Thus, the different physical and anatomical properties of the tree were not sensitive to changes in both temperature and amount of rainfall. Nonetheless, temperature tends to decrease the cell wall thickness while the amount of rainfall tends to improve it.

Keywords: *Carbon sequestration, climatic sensitivity, rainfall, temperature, Wallaceodendron celebicum Koord*

INTRODUCTION

Secondary growth in trees is a dynamic and continuous process that involves cell propagation, xylem enlargement and specialization, secondary wall biosynthesis, and cell death (Zhang *et al*. 2014). It is a rhythmic biological process determined by regular environmental oscillation within the annual growth cycle (Brienen 2005). This growth in trees is determined by the changes in temperature and precipitation (Dunwiddie 1979). Normally, the vascular cambium is active when water is readily available at high temperatures and inactive when water is scarce at low temperature (Waisel & Fahn 1965).

Temperature affects the cambial activity of the tree by influencing the amount of available water to the plant. In temperate countries, temperature increase initiates cambial reactivation and xylem differentiation (Begum *et al*. 2013) during spring time by melting the ice. While in tropical regions, temperature increase tends to lead to the seasonality of moisture availability (Rozendaal & Zuidema 2010) as it affects the water evaporation rate. This in turn causes drought resulting to the dormancy of the cambium (Marcati *et al*. 2016). This periodic cambial dormancy and reactivation plays an important role in determining the quality of wood and the environmental adaptability of the tree (Begum *et al*. 2013).

The width of the annual rings or growth rings is a reflection of the sensitivity of the tree to environmental changes. It also provides a picture of the lifetime growth rates and physiological responses of the plants (Zuidema *et al*. 2012). Through this, past environmental events (Norton *et al*. 1987) like prolonged drought and extreme heat (Mbow *et al*. 2013) could be observed.

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Another advantage of using annual rings as climate change indicator is that it could also be cross–referenced to the exact year when a particular climate irregularity occurred sometime in the past (Carrier & Urbinati 2004).

Besides its use to detect climate irregularities, annual ring is a direct estimate of tree age (Woodgate *et al*. 1994). By periodically removing the bark and wood samples, Chowdhury (1940), was able to determine the precise age count in pines and other species. Vigorous growth produces large diameter thin–walled earlywood cells while drought results to small diameter–thick walled latewood cells (Groover & Robischon 2006) resulting in the production of very distinct growth rings. However, irregular weather patterns could impede the activity of the cambium resulting in the formation of indistinct growth rings as well as the production of false rings and other structural irregularities. These irregularities could also result in changes in the structure of the material which would definitely alter its overall properties including its physical traits.

With this in mind, the present study attempted to use selected structural and physical traits of the wood to determine its climatic sensitivity.

METHODOLOGY

Sample Preparation

A 10–cm thick cross sectional disk was prepared from a *Wallaceodendron celebicum* Koord (Banuyo) trunk 0.5m above the ground. After determining the diameter, a straight line was drawn across the radius of the trunk. From the pith, the growth rings were counted along this straight line. From the core, the 10^{th} growth ring was carefully identified using a hand lens in order to eliminate the possibility of including false rings in the sample. And from there, every succeeding 10th growth ring was identified up to the peripheral portion of the stem. Sample blocks were then prepared from these rings.

Oven-Dried Specific Gravity

A set of 1 cm^3 sample blocks were prepared from every 10th growth ring. Ten blocks per growth ring were made. Samples were oven-dried in an oven set at 100 ± 3ºC until constant weight (Wo). Likewise, oven-dried volume (Vo) was determined using a vernier caliper. Specific gravity was computed using the formula:

$$\text{Sp. Grav} = \text{Wo/Vo} \times \text{Dw}$$

Where:
Sp. Grav = Specific Gravity
Wo = Oven-dried weight (g)
Vo = Oven-dried volume (cm^3)
Dw = Density of water (1g cm^{-3})

Fiber Biometrics

The matchstick samples were macerated in 50:50 solutions of glacial acetic acid and 20% hydrogen peroxide. Upon defibrillation, at least 30 whole fibers were randomly selected. Fiber length, fiber diameter, and lumen diameter were measured using a standard light microscope with a built–in vernier scale. Cell wall thickness was obtained using the formula:

$$CWT = \frac{FD - LD}{2}$$

Where:
CWT = Cell wall thickness (mm)
FD = Fiber diameter (mm)
LD = Lumen diameter (mm)

Average values coming from every portion were used in the evaluation.

Climatological Data

Rainfall and temperature data of the Philippines for the last 100 years were downloaded from the following website:
http://sdwebx.worldbank.org/climateportal/index.cfm?page=downscaled_data_download&menu=historical

RESULTS AND DISCUSSION

Sample Description

Banuyo (*Wallaceondendron celebicum* Koord) is a premium wood species (DAO 19 1995) belonging to the Family Fabaceae. It normally grows up to 25–30 m tall and its wood is excellent in cabinet making, carving, sculpture, and high grade interior panels.

A cross sectional sample of the trunk was collected (**Figure 1).** Its average diameter was about 1.07 m. The annual rings were carefully counted and cross–matched to the year when the tree was actually planted sometime in 1902. Results showed that the growth ring count of 107 was within ± 10% of the true age of the tree, which is an acceptable range similar to the findings of Alcorn *et al*. (2001) on Eucalyptus trees.

Considering the year the tree was planted and cross–matching it with the actual growth ring counts, a timeline beginning 1902 up

Figure 1. Cross section of the tree sample.

to 2009 was prepared. This was correlated to different properties of the wood observed at that particular growth ring of the tree.

Oven-Dried Specific Gravity

Oven-dried specific gravity is a reflection of the amount of cell wall substance that the wood possesses. It is one of the important wood traits because it is directly correlated to wood strength and flexibility (van Buijtenen 1969) and a good estimate of the amount of stored carbon (Baker *et al*. 2004).

Figure 2 shows the wood specific gravity pattern across the diameter of the trunk. Specific gravity tended to increase from 1902 to 1950 where it peaked at 0.70 followed by a decrease from 1960 to 2009. The year 1970 gave the lowest value with 0.55. Similar specific gravity trends were noticed in western hemlock species (DeBell *et al*. 2004). On the average, the overall wood specific gravity of the trunk was about 0.60.

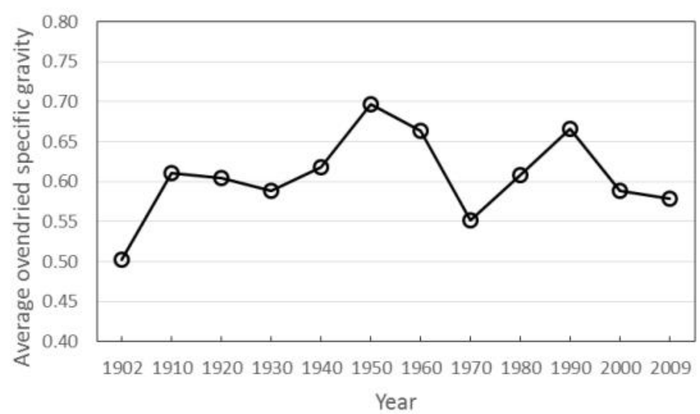

Figure 2. Oven-dried specific gravity pattern across the diameter of the trunk.

Fiber Biometrics

Wood formation depends on the activity of the vascular cambium of trees (Funada 2008). Such activities dictates the xylem cell characteristics including its fiber properties. **Figure 3** depicts the fiber length profile across the diameter of the trunk. Fiber length showed a steady increase from 1902 to 1980 except in1930 where a peculiar rise in fiber length was noticed. Without this point, it could be said that fiber length increased with age congruent to the findings of Hizal and Erdin (2016) on Alder wood.

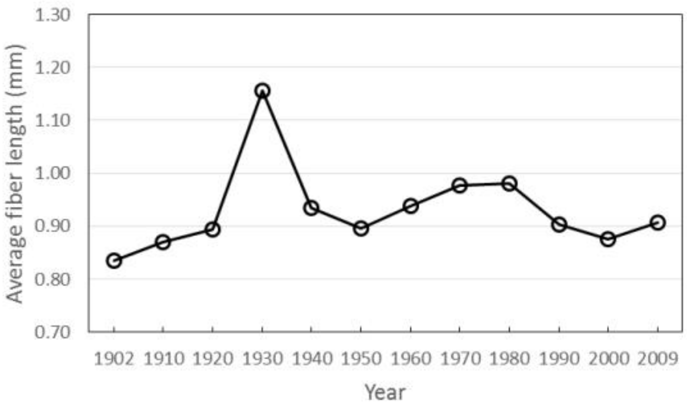

Figure 3. Fiber length profile across the diameter of the trunk.

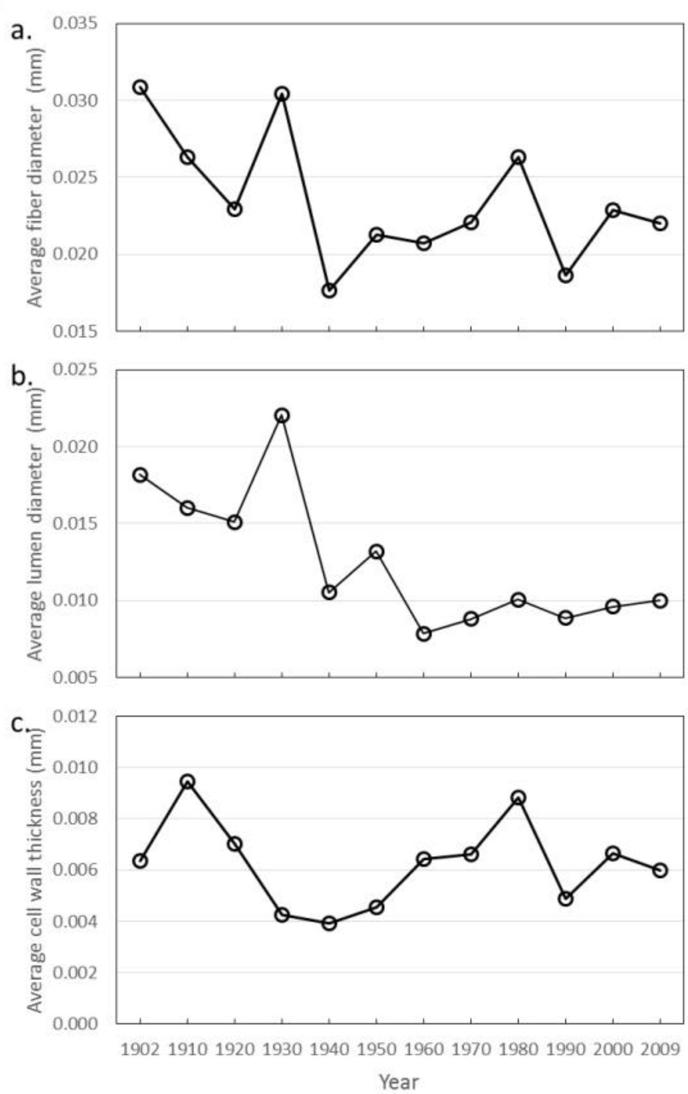

Figure 4. Fiber characteristics across the diameter of the trunk – a. Fiber diameter; b. Lumen diameter; c. Cell wall thickness.

Figure 4 shows the fiber diameter, lumen diameter of cell wall thickness distribution across the diameter of the trunk. Fiber diameter (4a) was a little unstable through the years. For the first 22 years it decreased from 0.031 mm to 0.023 mm followed by a sudden rise in 1930. Nonetheless, if the curve is smoothened, it could be said that fiber diameter decreased steadily through the years.

Fiber lumen diameter (4b) showed similar trend to fiber diameter. A steady decrease in diameter from 1902 to 2009 was observed except in 1930 where an unusual increase in lumen diameter was noticed. Finally, cell wall thickness (4c) peaked in 1910 at 0.0095mm and was lowest in 1940 at 0.004 mm. This was followed by a steady increase till 1980 followed by a decrease up to 2009.

Climatological Data

The Philippines is regularly visited by an average of 24 typhoons a year (Lapinig *et al*. 2015). Such visits could bring up to 1,000 mm of rain during its onset. Climatological data for the last 100 years for the Philippines are presented in **Figure 5**. A steady increase in temperature (5a) was observed for the last 100 years. Taking the average change per 10 years, approximately 0.25 ºC increase was noticed. For every degree Celsius increase in global mean temperature, it was observed that there was a reduction in yield by 6.0% for wheat, 3.2% for rice, 7.4% for maize, and 3.1% for soybean (Zhao *et al*. 2017). It would be interesting to see the effect of this constant temperature rise on the properties of wood samples.

Amount of rainfall (5b) was highest in 1910 at 2937 mm followed by a drop from 1920–1930 to 2136 mm. This was followed by a

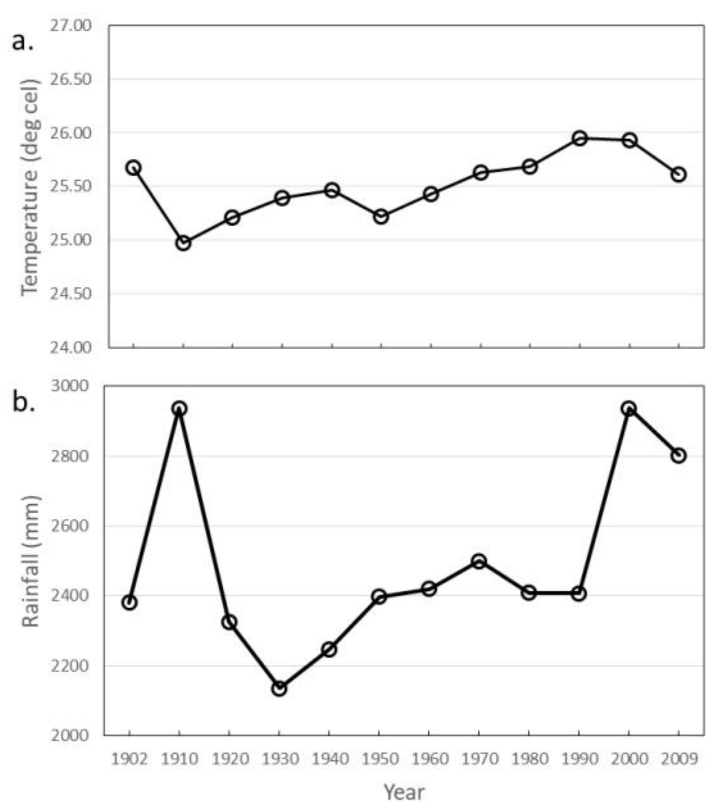

Figure 5. Climatological data of the Philippines for the last 100 years (*http:// sdwebx.worldbank.org/climate portal*).

steady increase from 1940–1950. Interestingly from 1950– 1990, rainfall was a bit stable at 2400 mm. In 2000, a sharp rise was again noticed to the 2937 mm mark.

Influence of Temperature on:

Oven-Dried Specific Gravity

Figure 6 shows the influence of temperature on the specific gravity of the tree. The relationship was weak with a correlation coefficient of r = –0.22 ns. Nonetheless, temperature tended to negatively impact the specific gravity of the wood. Apparently as the tree was exposed to increasing temperature over its life span, it produced low density wood. Considering that wood specific gravity with stem size determines the amount of carbon sequestered in the wood (Chave *et al*. 2009; Osawa–Peters et al. 2014), it could also be deduced that temperature negatively influenced the carbon sequestration potential of the tree. This result was aligned with the global trend (Briffa *et al*. 2008) but contrary to the findings of Thomas *et al*. (2007) who observed a 20% increase in wood density of *Eucalyptus grandis* seedlings at higher temperatures. This discrepancy could be attributed to the difference in the samples used.

Fiber Morphology

Figure 7 depicts the relationship between temperature and fiber length. Similar to oven-dried specific gravity, fiber length did not show any significant relationship with temperature. However, a decreasing trend in fiber length decreased with increasing temperature. Nonetheless, the relationship was not significant (r = – 0.048).

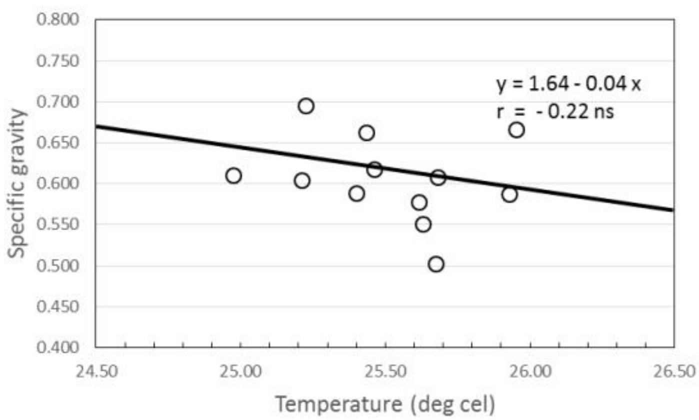

Figure 6. Influence of temperature on the specific gravity of the tree.

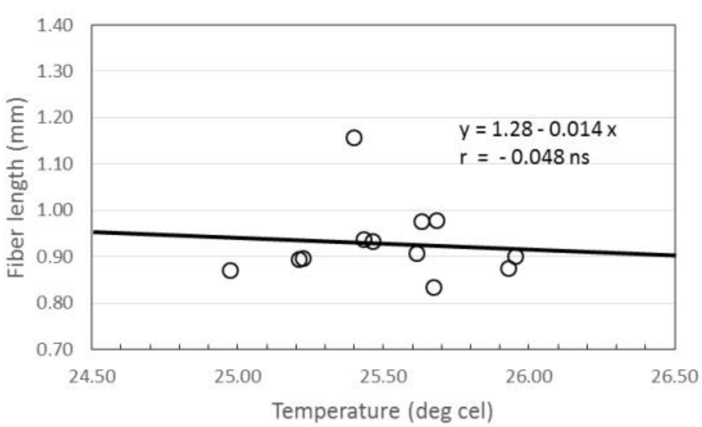

Figure 7. Influence of temperature on fiber length.

Figure 8 shows the influence of temperature on fiber diameter (8a), lumen diameter (8b) and cellwall thickness (8c). All the fiber traits were negatively influenced by temperature although, only lumen diameter gave a significant correlation with r = –0.46 at α = 95%. Similar findings were observed in maple wood (Bakhshi *et al*. 2011) and in black spruce saplings (Balducci *et al*. 2013). Increase in temperatures normally results to drought that reduces cell wall thickness while increasing lumen diameters (Martin–Benito *et al*. 2017).

Influence of Amount of Rainfall on:

Seasonal rainfall is directly linked to phenological events and wood properties (Worbes 2002). This is attributed to the control of available water on many physiological processes in trees (Taiz and Zeiger 2002) including cell expansion (Wei and Lintilhac 2007) and cell wall synthesis (Hsiao 1973).

Oven-Dried Specific Gravity

The relationship between specific gravity and amount of rainfall is depicted in **Figure 9**. Rainfall did not significantly affect the oven-dried specific gravity of the material. Precipitation normally activates the cambium influencing radial tree growth and wood density (Olivar *et al*. 2015). However, considering the

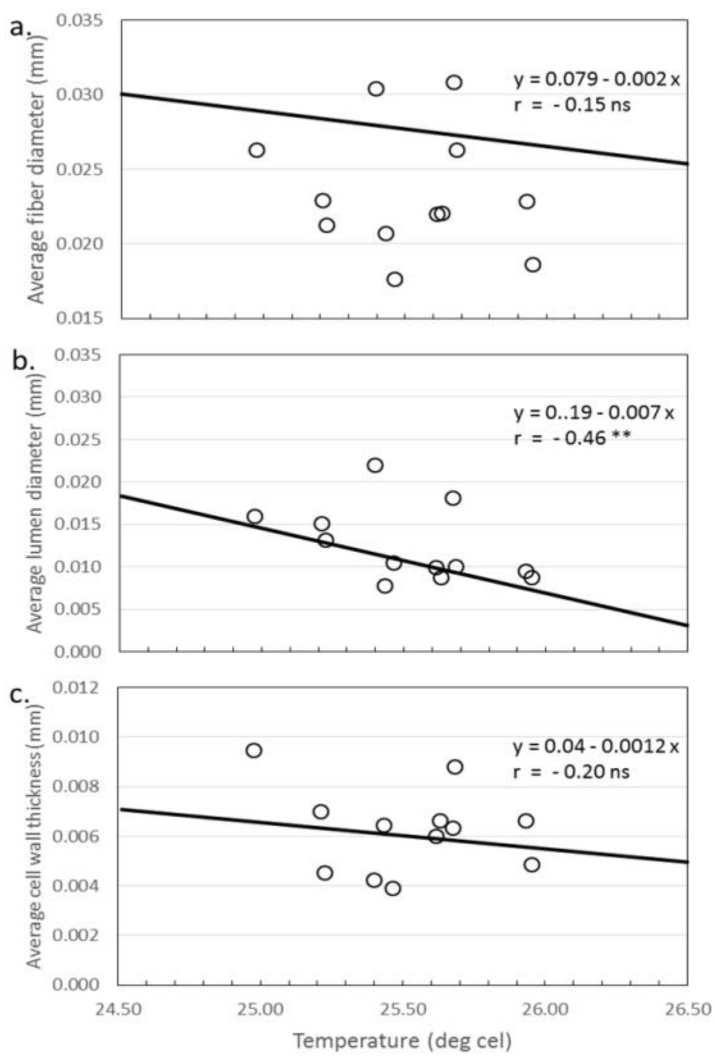

Figure 8. Influence of temperature on the different fiber traits. a. Fiber diameter; b. Lumen diameter; c. Cell wall thickness.

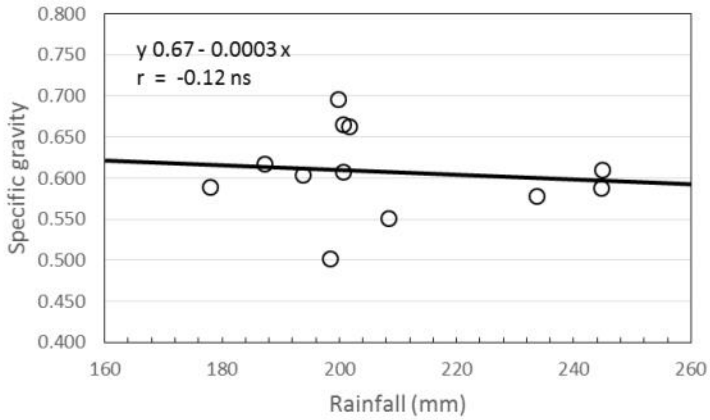

Figure 9. Influence of amount of rainfall on the specific gravity of wood.

rainfall pattern for the last 100 years, taking away year 1910 and 2000 where a drastic increase in rainfall were observed, it could be said that generally the rainfall patterns were more or less stable with ranges of about 2200–2400 mm.

Fiber morphology

Figure 10 shows the interaction between fiber length and amount of rainfall. It was evident that fiber length was significantly affected by the amount of rainfall ($r = -0.51$) at $\alpha = 95\%$. Apparently, an increase in the amount of rainfall corresponded to a decrease in fiber length. Water affects cambial activities, cell expansion rate, and cell division (de Luis *et al.* 2011). In times of drought, the cambium reduces its activities to save energy (Mc Dowell 2011).

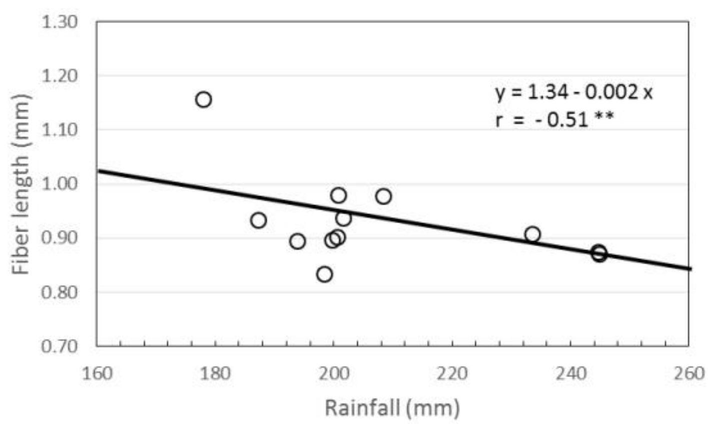

Figure 10. Influence of amount of rainfall on fiber length.

Figure 11 shows the influence of rainfall on fiber diameter (11a), lumen diameter (11b), and cellwall thickness (11c). Among the three fiber characteristics, only cell wall thickness gave a statistically significant result at $\alpha = 95\%$. Cell wall thickness reflects the amount of carbon because it is indicative of the cellulose content of the walls. Thus, rainfall positively influenced the carbon sequestration potential of the tree. This is contrary to the result of Jyske *et al.* (2009) wherein cell wall thickness increased in water–stressed Norway spruce. One reason for this discrepancy could be attributed to their differences in plant subdivision. Spruce belongs to the

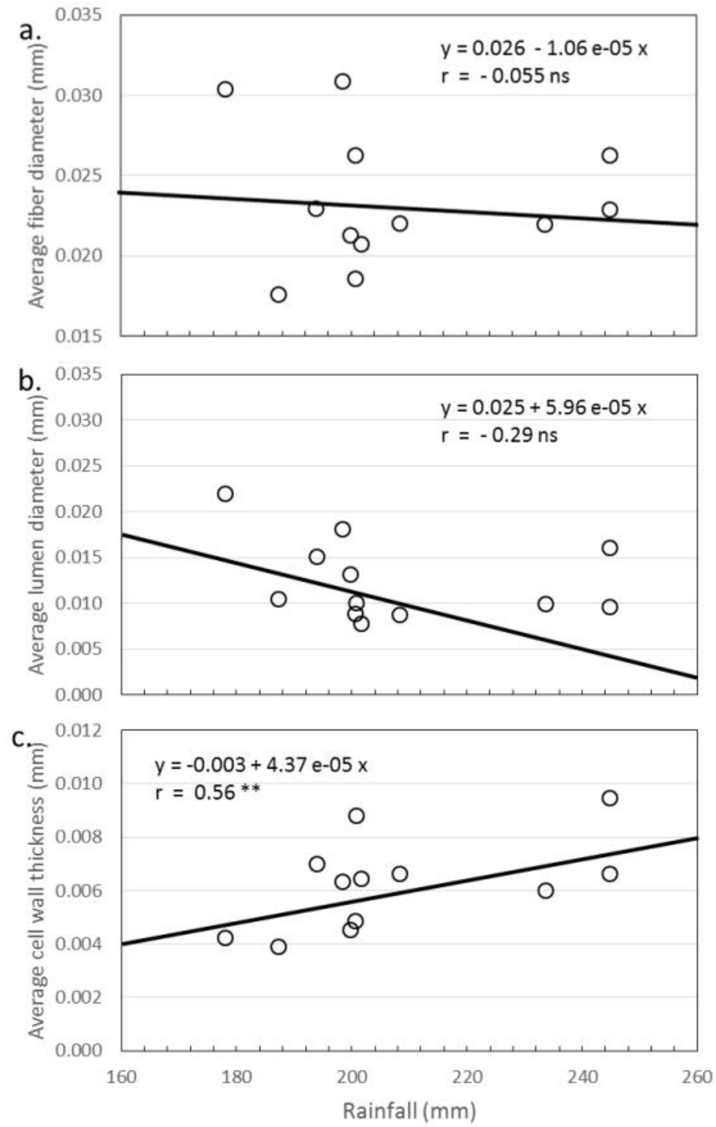

Figure 11. Influence of amount of rainfall on the different fiber traits. a. fiber diameter, b. lumen diameter, c. cell wall thickness.

Gymnosperms, which develops more thick–walled latewood when there is a reduction in available water while *Wallaceodendron celebicum* is an angiosperm where latewood development is not that prominent (Panshin & de Zeeuw 1978).

CONCLUSION

Wood formation depends on the cambial activities of a tree. These cambial activities are regulated by both internal and complex environmental factors as well as the sensitivity of the plant to such climatological variations. Normally, annual ring width is used to determine sensitivity of the plant to climate change. However it could lead to erroneous results especially when false and indistinct rings are present in the sample. The present study used selected basic physical and anatomical properties of the tree to determine its sensitivity to varying climate patterns. The different physical and anatomical properties of *Wallaceodendron celebicum* were not sensitive to both temperature and amount of rainfall, hence could not be used to detect varying climatological patterns.

Nonetheless, considering the direct relationship between specific gravity and carbon sequestration, it was deduced that temperature tends to decrease the carbon sequestration potential of the tree while rainfall tends to improve it.

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