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# Comparing Growth Ring Characteristics in *Calophyllum Inophyllum*: A Case Study of Two Distinct Sites in Taiwan

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## 1. Abstract

This study compares the tree-ring characteristics of *Calophyllum inophyllum* in two distinct growth locations, investigating differences in growth rate and wood density. Overall, tree-ring width characteristics in the Taichung region surpassed those in Tainan, indicating a superior growth trend. Radial variation analysis revealed varying performance between the regions in individual tree rings. In terms of tree-ring density, C. *inophyllum* in Taichung exhibited higher values, particularly in earlywood density, latewood density, and maximum density within each tree ring. Variations occurred inconsistently in the five tree-ring density characteristics, especially at positions from the pith to the 2nd and from the 5th to 7th tree rings. At specific positions, Taichung's C. *inophyllum* displayed higher density, except at the 10th tree-ring position. The correlation between tree-ring width and density was low and insignificant, suggesting a lack of a clear relationship. These findings provide valuable insights for forest management and product utilization.

## 2. Keywords

*Calophyllum inophyllum*; Ring width; Ring density; Ring features

## 3. Introduction

*Calophyllum Inophyllum*, commonly known as Kalofilum Kathing, is a coastal windbreak tree species widely distributed in Southeast Asia, India, the Ryukyu Islands, Australia, and the Pacific Islands, with rich economic value and ecological functions (Xu et al., 2014; 2015). The oil extracted from its seeds has diverse applications in cosmetics, medicine, and biofuels, while its finely textured wood finds uses in furniture, construction, and shipbuilding. Additionally, various parts of *C. inophyllum* exhibit pharmacological properties, including anti-inflammatory, anticancer, antioxidant, wound healing, antibacterial, lipid-lowering, and antidiabetic effects (Nguyen et al., 2017; Oo, 2018; Raharivelomanana et al., 2018). Despite its increasing cultivation in Taiwan, reports on its growth characteristics and wood density are relatively scarce.

*C. Inophyllum* shows significant genetic differences across different regions and habitats (Deng et al., 2017), and our observations suggest variations in the growth performance of trees in different locations. Therefore, the motivation for this study is to further understand the tree-ring characteristics of *C. Inophyllum* in different growth locations in Taiwan, providing a scientific basis for future tree management and utilization. Through the exploration of real data, we aim to support the improvement of planting techniques, promote sustainable development, and enhance the effective utilization of its economic value.

Tree-ring analysis, widely applied in dendrochronology, utilizes X-ray density scanning techniques to study the growth and density components of tree rings. Variations in tree-ring width and density are crucial indicators of environmental climate, tree growth, and wood density, holding significant importance for forest management and forestry applications. Through an in-depth study of *C. inophyllum* tree rings, we not only gain insights into differences in growth rates and wood density but also contribute to the formulation of effective conservation strategies, fostering its sustainable development in Taiwan.

In summary, this study will provide comprehensive ecological information about *C. Inophyllum*, offering a deeper reference for forest management and product utilization. It contributes to a better understanding of the adaptability of this unique species in different environments. By delving into the ecological information of this unique species, we can provide concrete scientific evidence for ecological conservation and sustainable development, furthering our understanding and appreciation of this valuable natural resource.

## 4. Material and Methods

### 4.1. Study site

The afforestation experiment was conducted in two locations in Taiwan: Qingshui District, Taichung City, and Jianguan District, Tainan City. Both sites are situated near the coastal zone. Based on the statistical data from the Central Weather Bureau of the Ministry of Transportation and Communications for the years 1991-2020, Taichung City has an average annual temperature of approximately 23.7°C, an average annual precipitation of 1,763 millimeters, and a relative humidity of 74.5%. In contrast, Tainan City has an average annual temperature of about 24.7°C, an average annual precipitation of 1,742 millimeters, and a relative humidity of 75.2%. Precipitation is concentrated mainly from April to September each year (Central Weather Bureau, 2021).

### 4.2. Sample collection and preparation

Samples were collected from 10-year-old *C. Inophyllum* broadleaf trees in Qingshui, near Qinghai Junior High School (35 trees), and in Jianguan, near Beipu (7 trees). The on-site planting density was 1,500 trees per hectare (3.3 m × 2 m). As the tree crowns have not fully closed, intact trees were selected as samples. At a height of 30 centimeters above the ground, one tree core was extracted in an east-to-west direction using a growth increment borer, forming X-ray scanning specimens for the analysis of tree-ring characteristics. The specimens used were tree cores obtained by drilling through the pith with a 5.15 mm diameter growth increment borer. After processing and adjustments, specimens with a thickness of 2.0 mm were prepared for X-ray scanning (Figure 1).

(a) *Calophyllum Inophyllum* plantation trees

(b) Core slices

(c) Quintek Measurement Systems X ray machine

**Figure 1:** Photographs of *Calophyllum Inophyllum* plantation, core specimens, and the x ray machine.

**4.3. Tree-Ring characteristic analysis**

The steps and methods of tree-ring analysis in this experiment were as reported previously by the authors (Lin et al. 2023). The density values were acquired using the QMS system, and optical density was resolved through microdensity measurement. By comparing the intensity changes before and after Soft X-ray scanning penetration of the specimens, the relationship of density variations within the specimens was determined, leading to the calculation of tree-ring density curves. The analysis of tree-ring characteristics combined Soft X-ray and microdensity measurement techniques, utilizing the Soft X-ray Microdensity System (QMS Tree Ring Analyzer). The output from these techniques was transformed into tree-ring density curves, and both internal and external software were used to correct the calculated data, resulting in nine tree-ring characteristic values.

The calculation method for analyzing tree-ring characteristic values is based on actual wood tree-ring density curves, determining the positions of earlywood and latewood boundaries within the specimens. Initially, image analysis determined relative positions, and boundary position data were input into tree-ring analysis software. Using the floating threshold method based on the boundary positions of each tree core specimen, the earlywood and latewood boundaries of the tree-ring density curves were established. Subsequently, with three consecutive earlywood and latewood boundary positions, one tree ring was determined, and the highest density, lowest density, and latewood percentage within one tree ring were found. Finally, nine tree-ring characteristic values, including tree-ring width components (earlywood width, latewood width, tree-ring width) and tree-ring density components (earlywood density, latewood density, tree-ring density), were sequentially calculated.

### 4.4. Statistical analysis

A total of 42 trees were selected, yielding 42 tree core samples for further analysis of the nine tree-ring characteristics. In total, 42 trees, 10 tree rings per tree, and 9 tree-ring characteristics were measured, resulting in approximately 3,780 tree-ring characteristic values. Statistical analysis, including descriptive statistics, correlation analysis, and t-tests, was performed using SPSS software. Through these analytical methods, a comprehensive understanding of the tree-ring characteristics of *C. Inophyllum* in different growth locations in Taiwan could be obtained, providing scientifically supported information.

## 5. Results

### 5.1. Tree-ring width characteristics

Comparison of tree-ring width, earlywood width, and latewood width in Taichung and Tainan regions is detailed in Table 1. The measurements for tree-ring width, earlywood width, and latewood width are 6.08, 2.36, 3.72 mm (Taichung) and 3.25, 1.64, 1.61 mm (Tainan), respectively. Statistical analysis using t-tests revealed significant differences in all three tree-ring width characteristics, indicating that *C. Inophyllum* trees in the Taichung region exhibited larger tree-ring width, earlywood width, and latewood width compared to those in the Tainan region. The investigation results suggest a faster growth rate of *C. Inophyllum* trees in the Taichung region.

| Variables | Trees growing in Taichung (N = 35) | Trees growing in Tainan (N = 7) | Significant (p value by t test) |
|---|---|---|---|
| Width (mm) | | | |
| Ring | 6.08 (0.15) | 3.25 (0.23) | < 0.01 |
| Earlywood | 2.36 (0.08) | 1.64 (0.14) | 0.04 |
| Latewood | 3.72 (0.12) | 1.61 (0.14) | < 0.01 |
| Density ($kg/m^3$) | | | |
| Ring | 596.4 (1.21) | 557.8 (4.30) | < 0.01 |
| Earlywood | 579.9 (1.48) | 560.3 (4.74) | < 0.01 |
| Latewood | 607.5 (1.34) | 595.8 (4.80) | < 0.01 |
| Highest | 663.7 (1.50) | 648.9 (5.45) | < 0.01 |
| Lowest | 521.5 (1.82) | 508.7 (4.54) | 0.06 |
| LWP (%) | 59.2 (1.09) | 49.4 (2.21) | 0.25 |

LWP, Latewood percentage; Number in parentheses is standard error

**Table 1:** Average ring characteristics of all sampled rings (10 ring numbers from the pith) obtained on *Calophyllum Inophyllum* trees growing in Taichung and Tainan.

For trees grown in both regions, radial variations of tree-ring width, earlywood width, and latewood width from the pith to the bark direction across the first to tenth tree rings are illustrated in Figures 2 to 4. The findings indicate that the annual growth of trees, represented by tree-ring width, earlywood width, and latewood width, showed a larger trend for *C. Inophyllum* in Taichung compared to Tainan. The radial variation from the pith to the bark direction is still developing due to the absence of canopy closure among trees. Additionally, a significant sudden increase is observed in the fifth tree ring, attributed to fertilization operations conducted in the fourth year.

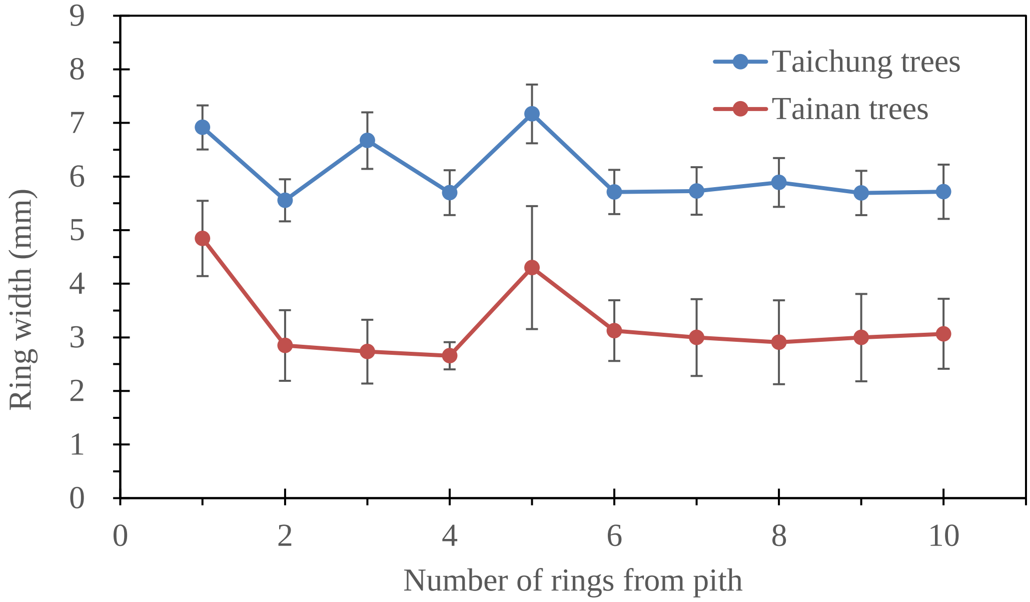


**Figure 2:** Radial variations in ring width based on all rings from the pith outward to the bark obtained from *Calophyllum inophyllum* trees growing in Taichung and Tainan (I, standard error) (The p values of ring width based on the 1st to 10th ring numbers from pith were 0.37, 0.16, 0.10, 0.01, 0.92, 0.41, 0.13, 0.32, 0.64, and 0.21, respectively (t test)).

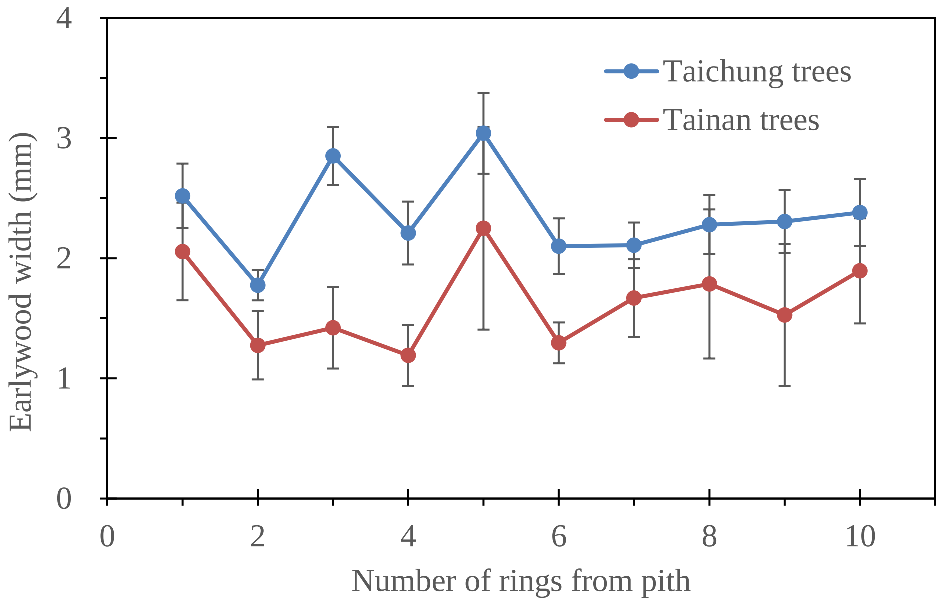


**Figure 3:** Radial variations in earlywood width based on all rings from the pith outward to the bark obtained from *Calophyllum inophyllum* trees growing in Taichung and Tainan (I, standard error) (The p values of earlywood width based on the 1st to 10th ring numbers from pith were 0.44, 0.64, 0.10, 0.01, 0.58, 0.02, 0.16, 0.69, 0.83, and 0.22, respectively (t test)).

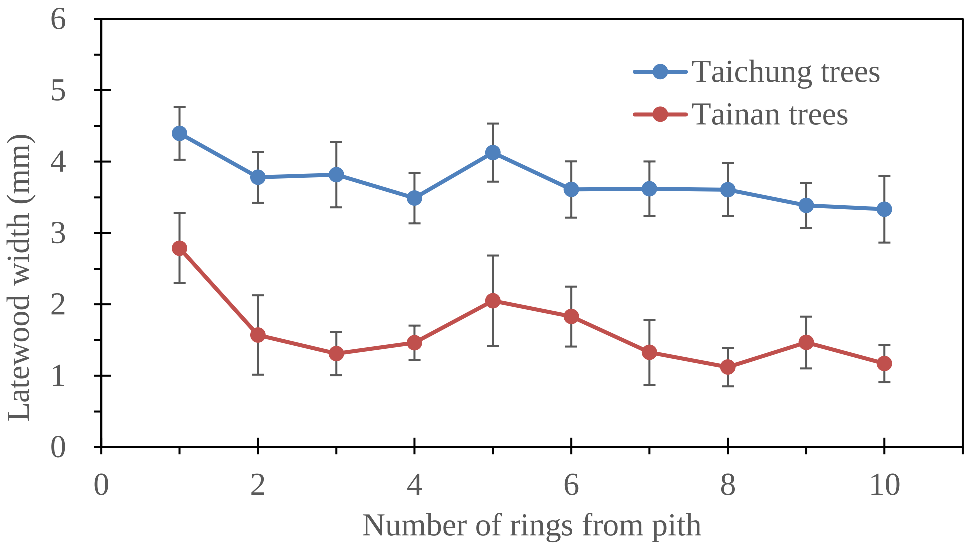


**Figure 4:** Radial variations in latewood width based on all rings from the pith outward to the bark obtained from *Calophyllum inophyllum* trees growing in Taichung and Tainan (I, standard error) (The p values of latewood width based on the 1$^{st}$ to 10$^{th}$ ring numbers from pith were 0.12, 0.04, 0.03, 0.01, 0.13, 0.10, 0.04, 0.07, 0.14, and 0.02, respectively (t test)).

When comparing the three tree-ring width characteristics for each tree ring from the pith to the bark direction in both regions, t-test results for tree-ring width showed significant differences only at the fourth tree ring, with p-values of 0.01. No significant differences were observed in other tree rings. For earlywood width, significant differences were found at the fourth and sixth tree rings, with p-values of 0.01 and 0.02, respectively. Latewood width exhibited significant differences at the second to fourth, seventh, and tenth tree rings, with p-values ranging from 0.01 to 0.14.

The standard errors are lower when significant differences are present, indicating varied responses or relatively lower relationships between earlywood and latewood growth within each annual tree ring.

In summary, among the three tree-ring width characteristics, *C. inophyllum* trees in Taichung exhibited a larger trend compared to those in Tainan. However, individual tree-ring analyses revealed different results for each tree ring.

**5.2. Tree-Ring density characteristics**

Comparison of tree-ring density, earlywood density, latewood density, maximum density within a tree ring, and minimum density within a tree ring in Taichung and Tainan regions is detailed in Table 1. The measurements for tree-ring density, earlywood density, latewood density, maximum density within a tree ring, and minimum density within a tree ring are 596.4, 579.9, 607.5, 663.7, and 521.5 kg/m³ (Taichung) and 557.8, 560.3, 595.8, 648.9, and 508.7 kg/m³ (Tainan), respectively. Statistical analysis using t-tests revealed significant differences in tree-ring density, earlywood density, latewood density, and maximum density within a tree ring, indicating that *C. inophyllum* trees in the Taichung region exhibited higher density characteristics compared to those in the

Tainan region. However, there was no significant difference in minimum density within a tree ring, suggesting comparable values for this particular characteristic between the two regions.

For trees grown in both regions, radial variations of tree-ring density, earlywood density, latewood density, maximum density within a tree ring, and minimum density within a tree ring across the first to tenth tree rings from the pith to the bark direction are illustrated in Figures 5 to 9. The findings indicate that, regarding the annual growth of tree-ring density, *C. inophyllum* trees in Taichung showed larger values for tree-ring density, earlywood density, latewood density, maximum density within a tree ring, and minimum density within a tree ring from the first to the sixth tree ring compared to those in Tainan. However, from the seventh to the tenth tree ring, the difference is less pronounced. The radial variation from the pith to the bark direction shows a gradual increase with increasing distance from the pith, more prominently observed for *C. inophyllum* in Tainan. Additionally, *C. inophyllum* trees in Tainan exhibited higher standard errors for the five density characteristics, indicating greater variability compared to those in Taichung.

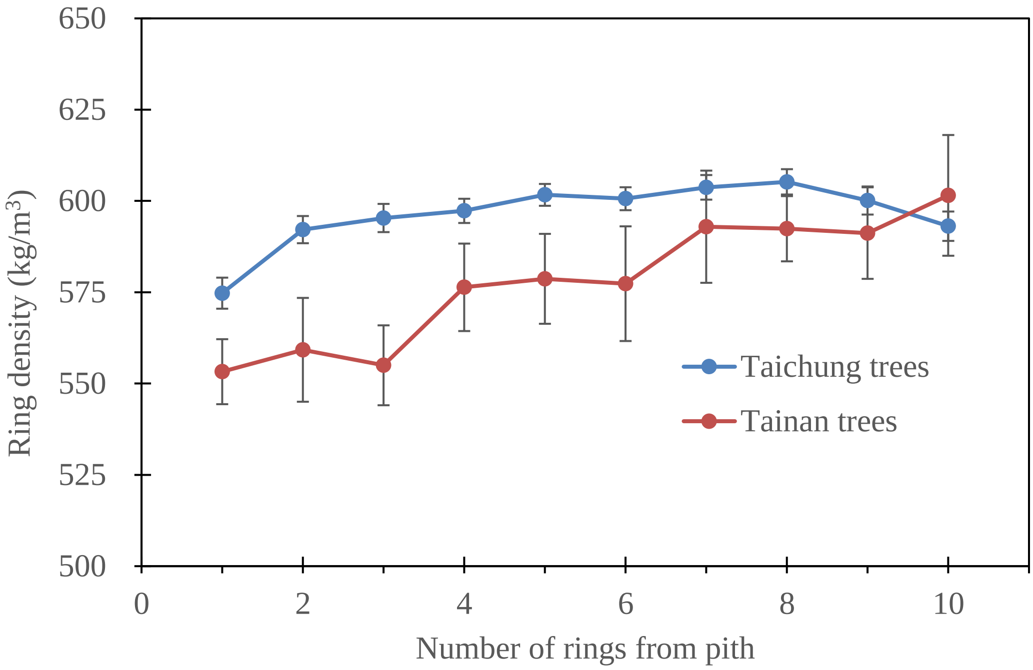


**Figure 5:** Radial variations in ring density based on all rings from the pith outward to the bark obtained from *Calophyllum inophyllum* trees growing in Taichung and Tainan (I, standard error) (The p values of ring density based on the $1^{st}$ to $10^{th}$ ring numbers from pith were 0.89, 0.02, 0.35, 0.27, 0.02, < 0.01, < 0.01, 0.55, 0.28, and < 0.01, respectively (t test)).

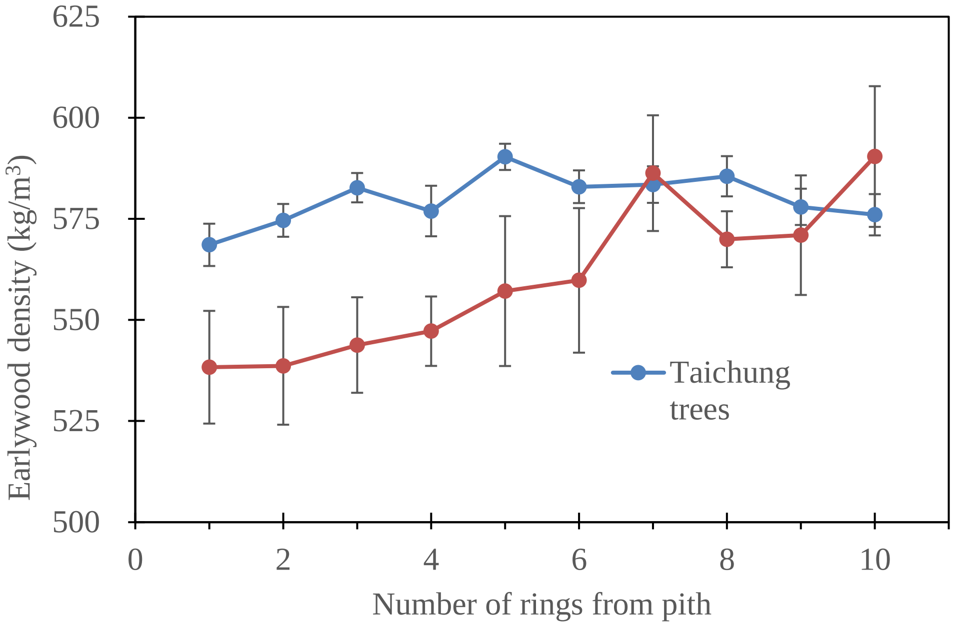


**Figure 6:** Radial variations in earlywood density based on all rings from the pith outward to the bark obtained from *Calophyllum inophyllum* trees growing in Taichung and Tainan (I, standard error) (The p values of earlywood density based on the 1$^{st}$ to 10$^{th}$ ring numbers from pith were 0.33, 0.01, 0.14, 0.37, < 0.01, < 0.01, 0.11, 0.44, 0.17, and 0.02, respectively (t test)).

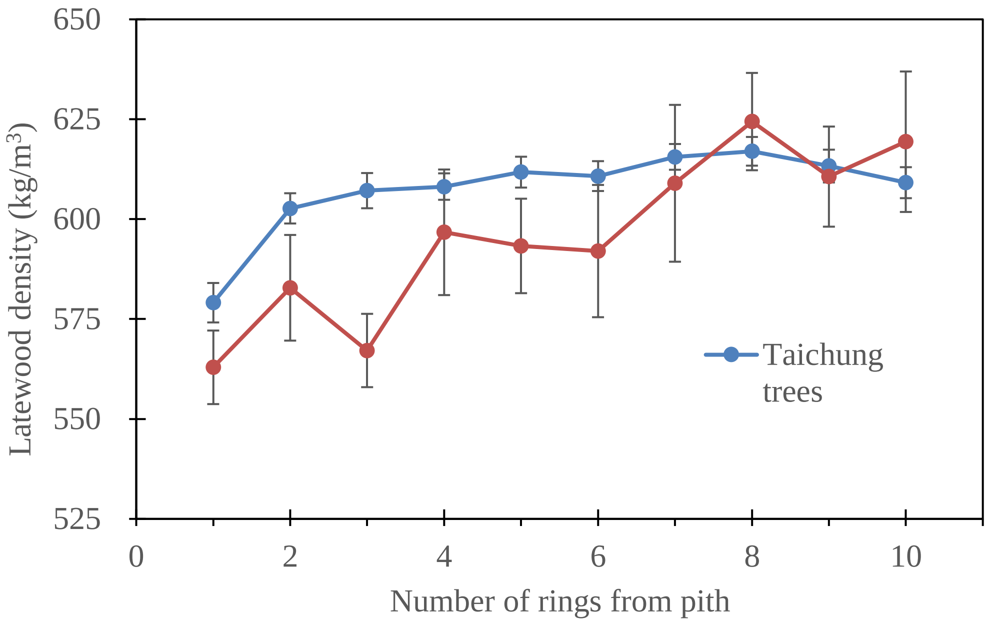


**Figure 7:** Radial variations in latewood density based on all rings from the pith outward to the bark obtained from *Calophyllum inophyllum* trees growing in Taichung and Tainan (I, standard error) (The p values of latewood density based on the 1$^{st}$ to 10$^{th}$ ring numbers from pith were 0.51, 0.20, 0.67, 0.02, 0.17, 0.01, < 0.01, 0.11, 0.40, and < 0.01, respectively (t test)).

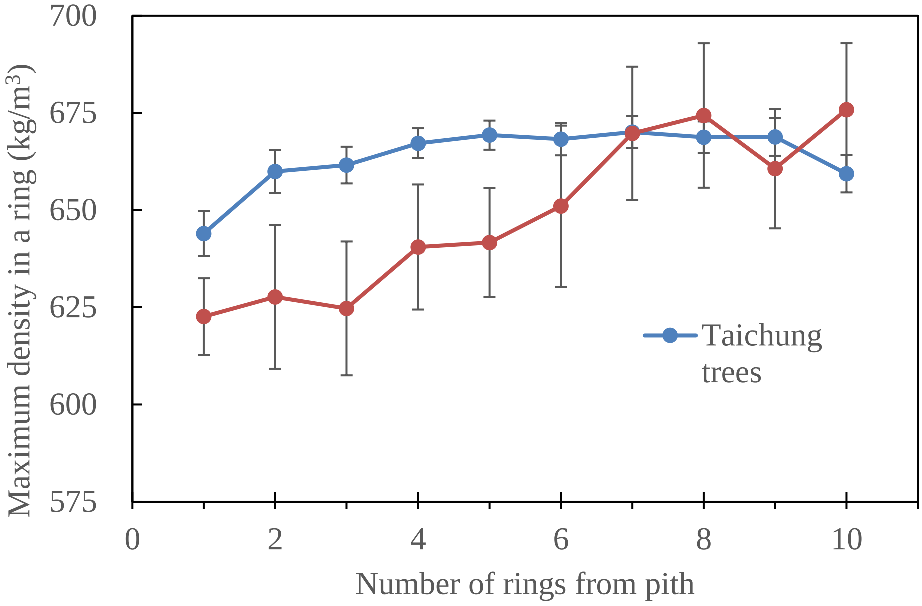


**Figure 8:** Radial variations in maximum density in a ring based on all rings from the pith outward to the bark obtained from *Calophyllum inophyllum* trees growing in Taichung and Tainan (I, standard error) (The p values of maximum density in a ring based on the 1st to 10th ring numbers from pith were 0.35, 0.30, 0.08, 0.01, 0.04, < 0.01, < 0.01, 0.01, 0.28, and 0.02, respectively (t test)).

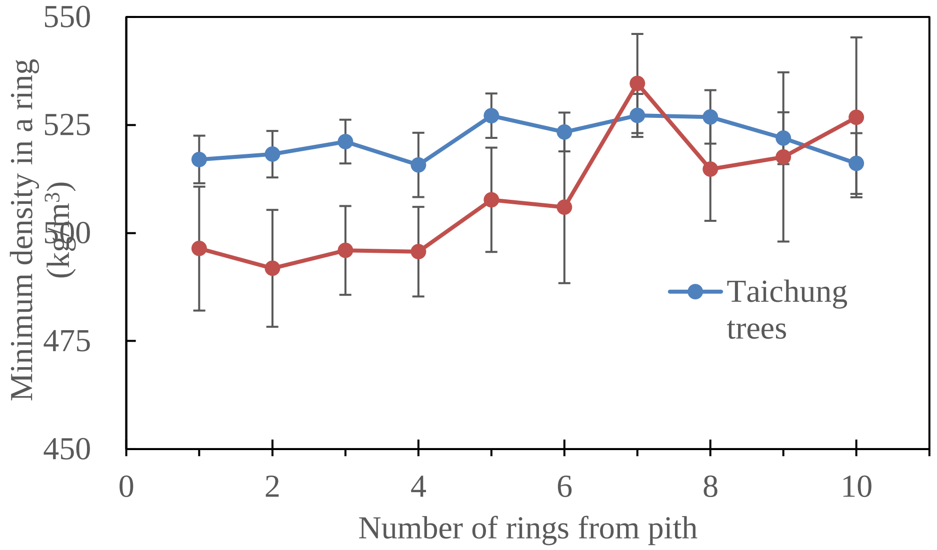


**Figure 9:** Radial variations in minimum density in a ring based on all rings from the pith outward to the bark obtained from *Calophyllum inophyllum* trees growing in Taichung and Tainan (I, standard error) (The p values of minimum density in a ring based on the 1st to 10th ring numbers from pith were 0.46, 0.81, 0.77, 0.51, 0.96, 0.02, 0.88, 0.59, 0.07, and 0.42, respectively (t test)).

When comparing the five tree-ring density characteristics for each tree ring from the pith to the bark direction in both regions, t-test results for tree-ring density showed significant differences at the second, fifth to seventh, and tenth tree rings, with p-values of < 0.01, 0.02, 0.02, 0.01, and < 0.01, respectively. For earlywood density, significant differences were found at the second, fifth to sixth, and tenth tree rings, with p-values of 0.01, < 0.01, < 0.01, and 0.02, respectively. Latewood density exhibited significant differences at the fourth, sixth to seventh, and tenth tree rings, with p-values ranging from < 0.01 to 0.02. Maximum density within a tree ring showed significant differences at the fourth to eighth and tenth tree rings, with p-values ranging from < 0.01 to 0.04. Minimum density within a tree ring showed significant differences at the sixth tree ring, with a p-value of 0.02.

In summary, the performance of the five tree-ring density characteristics varies each year. Specifically, tree-ring density, earlywood density, and latewood density showed significant differences in the second, fifth to seventh, and tenth tree rings, indicating that *C. inophyllum* in Taichung had higher density values in the second, fifth to seventh tree rings, while in the tenth tree ring, the density was higher in Tainan. Additionally, except for minimum density within a tree ring, there were significant differences at the tenth tree ring, suggesting that *C. inophyllum* in Tainan had higher values for the other four density characteristics compared to those in Taichung.

**5.3. Latewood percentage**

Comparison of latewood percentage between Taichung and Tainan is detailed in Table 1, with latewood percentages of 59.2% (Taichung) and 49.4% (Tainan). Although *C. inophyllum* trees in Taichung tend to have a higher latewood percentage than those in Tainan, statistical analysis using t-tests revealed no significant difference, indicating that there is no variation in latewood percentage between the two regions.

For trees grown in both regions, radial variations in latewood percentage from the first to the tenth tree ring, measured from the pith to the bark direction, are illustrated in Figure 10. The findings suggest that, regarding the annual growth, the latewood percentage of *C. Inophyllum* trees in Taichung is larger than those in Tainan. The radial variation from the pith to the bark direction indicates a gradual decrease in latewood percentage with increasing distance from the pith.

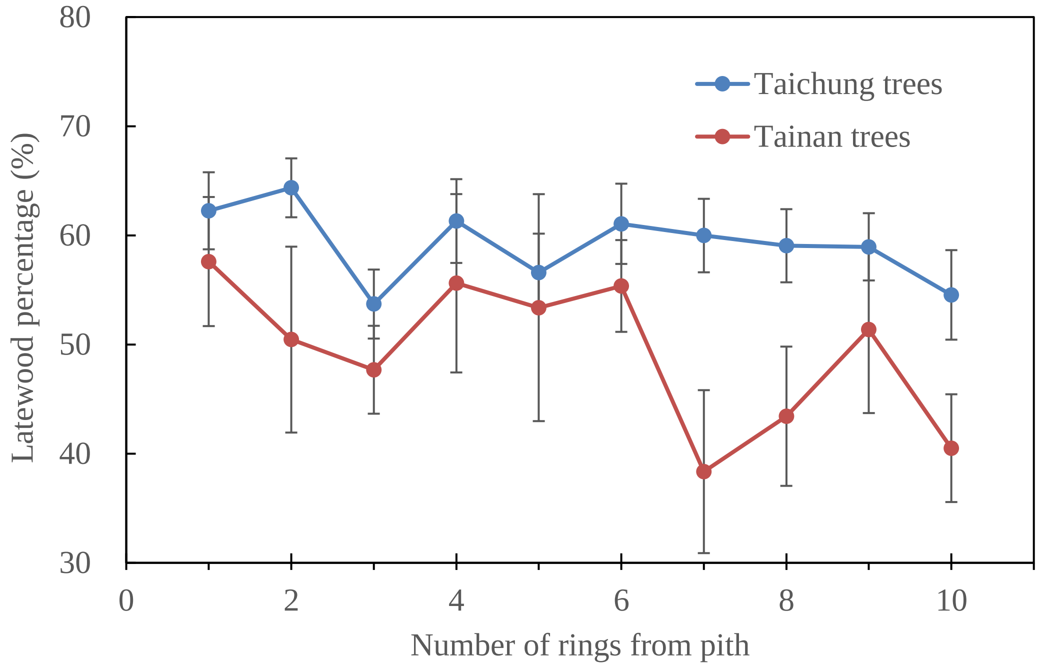

**Figure 10:** Radial variations in latewood percentage based on all rings from the pith outward to the bark obtained from *Calophyllum inophyllum* trees growing in Taichung and Tainan (I, standard error) (The p values of latewood percentage based on the 1st to 10th ring numbers from pith were 0.20, 0.26, 0.10, 0.92, 0.41, 0.04, 0.91, 0.67, 0.66, and 0.04, respectively (t test)).

When comparing latewood percentage for each tree ring from the pith to the bark direction in both regions, t-test results showed no significant differences at any of the ten tree rings, with p-values ranging from 0.04 to 0.92. This indicates that the latewood percentage for *C. inophyllum* trees does not vary significantly between the first and tenth tree rings in both Taichung and Tainan.

**5.4. Correlation analysis**

Tables 2 (Taichung) and 3 (Tainan) present the correlation coefficients between all sampled tree and tree-ring characteristics. Earlywood width and latewood width are identified as the most significant factors determining tree-ring width, with correlation coefficients of 0.54 and 0.83 (Taichung), and 0.83 and 0.80 (Tainan) ($p < 0.01$). Additionally, earlywood density, latewood density, maximum density within a tree ring, and minimum density within a tree ring are identified as the most critical factors determining tree-ring density. The correlation coefficients for these factors are 0.69, 0.87, 0.76, and 0.55 (Taichung), and 0.92, 0.93, 0.89, and 0.75 (Tainan) ($p < 0.01$).

| | RW | EW | LW | RD | ED | LD | Dmax | Dmin | LWP |
|---|---|---|---|---|---|---|---|---|---|
| RW | 1 | 0.54** | 0.83** | 0.09 | 0.12* | -0.07 | 0.11* | -0.02 | 0.22** |
| EW | | 1 | -0.02 | -0.08 | 0.21** | 0.02 | 0.02 | -0.05 | -0.64** |
| LW | | | 1 | 0.16** | 0.01 | -0.09 | 0.12* | 0.01 | 0.68** |
| RD | | | | 1 | 0.69** | 0.87** | 0.76** | 0.55** | 0.17** |
| ED | | | | | 1 | 0.51** | 0.53** | 0.78** | -0.15** |
| LD | | | | | | 1 | 0.75** | 0.36** | -0.12* |
| Dmax | | | | | | | 1 | 0.26** | 0.05 |
| Dmin | | | | | | | | 1 | 0.02 |
| LWP | | | | | | | | | 1 |

EW, earlywood width; LW, latewood width; RW, ring width; ED, earlywood density; LD, latewood density; RD, ring density; Dmin, minimum density in a ring; Dmax, maximum density in a ring; LWP, latewood percentage

* and ** indicate significance at 5 and 1% level by F-test.

**Table 2:** Coefficients of relationships (Pearson correlation coefficient) between the ring characteristics of *Calophyllum inophyllum* plantation trees growing in Taichung (N=35).

| | RW | EW | LW | RD | ED | LD | Dmax | Dmin | LWP |
|---|---|---|---|---|---|---|---|---|---|
| RW | 1 | 0.83** | 0.80** | 0.06 | 0.15 | -0.08 | 0.08 | 0.02 | 0.02 |
| EW | | 1 | -0.32** | 0.18 | 0.35** | 0.13 | 0.18 | 0.15 | -0.49** |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| LW | | | 1 | -0.09 | -0.11 | -0.27* | -0.06 | -0.13 | 0.55** |
| RD | | | | 1 | 0.92** | 0.93** | 0.89** | 0.75** | -0.24 |
| ED | | | | | 1 | 0.81** | 0.79** | 0.86** | -0.41** |
| LD | | | | | | 1 | 0.90** | 0.62** | -0.41** |
| Dmax | | | | | | | 1 | 0.53** | -0.28* |
| Dmin | | | | | | | | 1 | -0.28* |
| LWP | | | | | | | | | 1 |

EW, earlywood width; LW, latewood width; RW, ring width; ED, earlywood density; LD, latewood density; RD, ring density; Dmin, minimum density in a ring; Dmax, maximum density in a ring; LWP, latewood percentage

* and ** indicate significance at 5 and 1% level by F-test.

**Table 3:** Coefficients of relationships (Pearson correlation coefficient) between the ring characteristics of *Calophyllum inophyllum* plantation trees growing in Tainan (N=7).

In contrast, the correlation coefficients between tree-ring width and tree-ring density are relatively low (0.09 and 0.06) and not significant. This suggests that there is no significant correlation between the growth of tree-ring width and tree-ring density.

These findings contribute to understanding the key factors influencing tree-ring characteristics and provide valuable insights into the growth patterns of *C. Inophyllum* in Taichung and Tainan.

## 6. Discussion

Due to the isolation effect caused by the growth of *C. Inophyllum* trees in different islands and habitats, gene flow is hindered, leading to differentiation among different populations (Deng et al., 2017). In Taiwan, the *C. Inophyllum* trees in different habitats may exhibit distinct genetic populations, resulting in varied growth responses to environmental climatic conditions. This variability may extend to wood characteristics, seed oil composition, and secondary metabolite components in different parts of the tree.

In an investigation of biomass estimation in Indonesia, the tree-ring analysis of *C. Inophyllum* revealed varying growth characteristics in different regions. For instance, in the Gunung Kidul region, the average annual ring width ranged from 3.76 to 5.67 mm (30-46 years old), while in the Purworejo region, it ranged from 4.29 to 7.70 mm (24-58 years old). In the Wonogiri region, the average annual ring width varied from 2.8 to 15.2 mm (6-10 years old), indicating diverse growth patterns across different habitats (Basuki et al., 2022). This study focused on *C. Inophyllum* trees in Taichung (6.08 mm) and Tainan (3.25 mm) in Taiwan, revealing significant differences in tree-ring width growth between the two regions. However, this investigation is limited to these two regions and 10-year-old trees. Future research could expand the study to compare different habitats and investigate trees of larger ages to understand variations in tree-ring growth, density, and other characteristics across diverse regions.

*C. Inophyllum*, native to Donghai Island in Guangdong Province, China, is known for its resilience against typhoons. Its wood properties include an absolute dry density of 572.6 kg/m³ and a bending strength of 94.5 MPa (Xu et al., 2014; 2015). In Malaysia, the basic wood density is reported as 530 kg/m³, and the air-dry density is 660 kg/m³, while in the Philippines, the basic wood density is 560 kg/m³, and the air-dry density is 590 kg/m³ (Liu et al., 1996). In this study, *C. Inophyllum* trees in Taichung (596.4 kg/m³) and Tainan (557.8 kg/m³) in Taiwan exhibited significant differences in tree-ring density under air-dry conditions.

The width and density of tree rings respond differently to their respective environmental climates. The formation of Intra-Annual Density Fluctuations (IADF) within tree rings can be triggered by environmental changes, especially precipitation and temperature, influencing cambial activity and cell differentiation. IADF is considered a valuable tool for establishing yearly climate factors. Density profiles record intra-annual climate variations, capturing conditions related to short-term atmospheric events and resulting in fluctuations within the tree rings. IADF can be seen as anomalies in the density profile curves, with different types having various triggering factors and mechanisms (De Mico et al., 2016; Mayer et al., 2020; Gao et al., 2021).

In conclusion, *C. inophyllum* trees in Taichung exhibit larger trends in tree-ring width and density compared to those in Tainan. However, when examining individual tree rings, different results emerge, likely associated with environmental conditions. Trees in coastal areas face challenges such as sea winds, drought, salt spray, and high temperatures, contributing to varied responses in tree-ring width and density growth. Lastly, the correlation coefficients between tree-ring width and density are low and not significant, suggesting that the impact of environmental conditions on the growth of tree-ring width and density may differ.

In summary, the research findings suggest that *C. inophyllum* trees in the Taichung region exhibit superior growth performance in various aspects compared to those in the Tainan region. However, the relationship between tree-ring width and tree-ring density is not evident. Further investigations and analyses are warranted to understand the complex interactions between growth factors and wood properties in *C. inophyllum* trees in different regions.

## 7. Conclusions

1. Overall, *Calophyllum Inophyllum* trees in the Taichung region exhibited superior growth performance in tree-ring width, earlywood width, and latewood width compared to those in the Tainan region. The investigation results indicate that *C. Inophyllum* trees in the Taichung region grow at a faster rate than those in the Tainan region.
2. Radial variation analysis from pith to bark for trees grown in both regions revealed that, in terms of annual tree-ring width, earlywood width, and latewood width, *C. Inophyllum* trees in Taichung outperformed those in Tainan. However, further statistical analysis at the individual tree-ring level presented different results.
3. In general, *C. Inophyllum* trees in the Taichung region exhibited superior performance in tree-ring density, earlywood density, latewood density, and maximum density within each tree ring compared to those in the Tainan region. This indicates higher tree-ring density in *C. Inophyllum* trees in the Taichung region.
4. When examining the tree-ring density on an annual basis, the performance of the five density characteristics varies. Specifically, concerning tree-ring density, significant differences are observed at the 2nd, 5th to 7th, and 10th tree rings from the pith. This indicates that *C. Inophyllum* trees in Taichung, exhibit higher tree-ring density in the 2nd, 5th to 7th tree rings compared to those in Tainan. However, in the 10th tree ring, the tree-ring density is lower in Taichung, compared to Tainan.
5. The correlation coefficient between tree-ring width and tree-ring density was low and not significant, indicating a lack of clear correlation between the growth of tree-ring width and tree-ring density.

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