Relationship Between Wood Specific Gravity and Average Annual Ring Width of 15 Korean Wood Species

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The correlation between specific gravity and average annual ring width was studied for 15 major Korean tree species. In coniferous trees, species with narrower rings exhibited higher specific gravity, with strong correlations observed in *Pinus densiflora* (Gangwon), *Larix kaempferi*, and *Pinus rigida*. In deciduous trees, the correlation between specific gravity and annual ring width did not exhibit a consistent pattern based on the distinction between diffuse-porous and ring-porous species. The correlation of *Liriodendron tulipifera* (diffuse-porous species) and *Quercus mongolica* (ring-porous species) showed higher specific gravity with wider rings, whereas other species, such as *Betula platyphylla* (diffuse-porous species) and *Robinia pseudoacacia* (ring-porous species) exhibited the opposite trend. Therefore, the correlation in deciduous trees appears to be an inherent characteristic of each species rather than a result of porous type.

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INTRODUCTION

The specific gravity of wood is the density of wood expressed relative to the density of water at 4 °C (Gao *et al.* 2017). The specific gravity of wood is an important indicator of wood quality. It is influenced by various factors such as tree species and growth environment. Within the same species, specific gravity can vary significantly depending on growth region and climate conditions (Jordan *et al.* 2008). Furthermore, within a single tree, specific gravity fluctuates in the radial direction from the pith to the bark (Pande and Dhiman 2012).

The microstructure of wood also affects its specific gravity. Specific gravity can be influenced by growth ring width, which reflects the growth rate of a tree. Growth rings consist of earlywood and latewood, which form due to seasonal variations in cell growth (Kwon *et al.* 2020). Earlywood has large lumen areas and thin cell walls, whereas latewood has smaller lumen areas and thicker cell walls (Cartenì *et al.* 2018). Air-dry density is negatively correlated with cell diameter but positively correlated with cell wall thickness (Chowdhury *et al.* 2012). Density tends to show a higher correlation with latewood than with earlywood (Pritzkow *et al.* 2014). The mechanical properties of wood are superior in latewood compared to those in earlywood (Büyüksarı *et al.* 2017). Additionally, narrower growth rings generally correspond to higher specific gravity and strength (Dahleh *et al.* 2018). However, in oak species, wider growth rings are associated with a higher proportion of latewood and increased density (Vavrčík and Gryc 2012). These findings suggest that the relationship between growth rings and specific gravity varies depending on the tree species.

Specific gravity is a key factor in evaluating the mechanical properties of wood. Both the modulus of elasticity (MOE) and the modulus of rupture (MOR) exhibit a strong correlation with specific gravity (Cramer *et al.* 2005; Missanjo and Matsumura 2016). Similarly, compressive strength and specific gravity show a positive correlation (Horáček *et al.* 2017). Furthermore, specific gravity is proportional to ultrasonic wave velocity (Duong *et al.* 2019), making it a useful indicator for determining the appropriate applications of a given wood type.

The correlation between average annual ring width and air-dry specific gravity has been investigated in various studies. However, no comprehensive research has been conducted on a wide range of tree species grown in South Korean forests. Therefore, this study aimed to analyze the correlation between average annual ring width and specific gravity in 15 representative coniferous and deciduous tree species with high forest accumulation in South Korea.

EXPERIMENTAL

Tested Wood Species

Among the tree species growing in South Korean forests, 16 species were selected based on their high forest biomass accumulation or potential for wood utilization. These included seven coniferous species (Korean red pine, Korean pine, Japanese larch, pitch pine, Rigitaeda pine, Japanese false cypress, Japanese cedar) and eight deciduous species (tulip tree, East Asian white birch, mossy locust, Sawleaf zelkova, East Asian ash, Oriental cork oak, sawtooth oak, Mongolian oak). The habitat and average age of the selected species are shown in Table 1.

Measurement of Air-dry Specific Gravity and Average Annual Ring Width

A total of 173 to 415 cubic specimens per species, each with a side length of 20 mm, were prepared without visible defects such as knots or cracks, ensuring clearly visible radial and tangential surfaces (Fig. 1). The specimens were collected at 2.4 meters from the ground level along the tree height. Measurement reference lines were drawn to ensure that length measurements were taken at the same positions regardless of changes in the moisture condition of the specimens. These lines were marked in the radial and tangential directions at the center of the transverse surface and in the fiber direction at the center of the tangential surface. For specific gravity measurements, the specimens were oven-dried at 103±2 °C until they reached a constant mass under air-dry conditions.

The condition for achieving constant mass was defined as a mass change rate of less than or equal to 0.2% over a minimum interval of 8 hours. The three-dimensional lengths (l_{la}, l_{ra}, l_{ta}) and mass (w_o) of the specimens were measured under air-dry conditions. The number of growth rings intersecting the radial measurement reference line on the transverse surface of the specimen was counted. The average ring width was calculated by dividing this number by the specimen width. The air-dry specific gravity was calculated in accordance with KS F 2198 (2022).

$$Air-dry\ specific\ gravity = \frac{oven-dry\ mass(w_o)}{air-dry\ volume(V_a)} \quad (1)$$

Table 1. Information on Habitats and Average Ages of Selected Wood Species

Generic name	Scientific name	Classification		Address	Age (Years)
Korean red pine	*Pinus densiflora* Siebold & Zucc.	Coniferous tree		San 80-1, Jinjo-ri, Bongpyeong-myeon, Pyeongchang-gun, Gangwon-do	42
Korean red pine	*Pinus densiflora* Siebold & Zucc.			San 37-1, Seobu-ri, Yeongyang-eup, Yeongyang-gun, Gyeongsangbuk-do	32
Korean pine	*Pinus koraiensis* Siebold & Zucc.			San 1, Baegam-ri, Baegun-myeon, Jinan-gun, Jeollabuk-do	37
Japanese larch	*Larix kaempferi* (Lamb.) Carriere			San 80-1, Guhak-ri, Bongyang-eup, Jecheon-si, Chungcheongbuk-do	41
Pitch pine	*Pinus rigida* Mill.			San 87, Yeongdong-ri, Maryang-myeon, Gangjin-gun, Jeollanam-do	39
Rigitaeda pine	*Pinus rigida* Mill. x *P. taeda* L.			San 12, Sandae-ri, Yeongam-eup, Yeongam-gun, Jeollanam-do	24
Japanese false cypress	*Chamaecyparis obtusa* (Siebold & Zucc.) Endl.			San 96, Jang'an-ri, Songgwang-myeon, Suncheon-si, Jeollanam-do	51
Japanese cedar	*Cryptomeria japonica* (Thunb. ex L.f.) D.Don			San 5-2, San 2-1, Hannam-ri, Namwon-eup, Seogwipo-si, Jeju-do	37
Tulip tree	*Liriodendron tulipifera* L.	Deciduous tree	*Diffuse porous wood*	San 49-1, Myeongju-ri, Chilnyang-myeon, Gangjin-gun, Jeollanam-do	28
East Asian white birch	*Betula pendula* Roth		*Diffuse porous wood*	1767-10, Sapgyo-ri, Dunnae-myeon, Hongcheon-gun, Gangwon-do	35
Mossy locust	*Robinia pseudoacacia* L.		*Ring porous wood*	San 81, Gachun-ri, Eomjeong-myeon, Chungju-si, Chungcheongbuk-do	32
Sawleaf zelkova	*Zelkova serrata* (Thunb.) Makino		*Ring porous wood*	San 1, Baegam-ri, Baegun-myeon, Jinan-gun, Jeollabuk-do	64
East Asian ash	*Fraxinus rhynchophylla* Hance		*Ring porous wood*	San 1-1, Unhak-ri, Mureungdowon-myeon, Yeongwol-gun, Gangwon-do	50
Oriental cork oak	*Quercus variabilis* Blume		*Ring porous wood*	San 114, Geumban-ri, Hyucheon-myeon, Haman-gun, Gyeongsangnam-do	41
Sawtooth oak	*Quercus acutissima* Carruth.		*Ring porous wood*	San 18-1, Sangho-ri, Geumsa-myeon, Yeoju-si, Gyeonggi-do	28
Mongolian oak	*Quercus mongolica* Fisch. ex Ledeb.		*Ring porous wood*	San 1-1, Jikdong-ri, Sansol-myeon, Yeongwol-gun, Gangwon-do	36

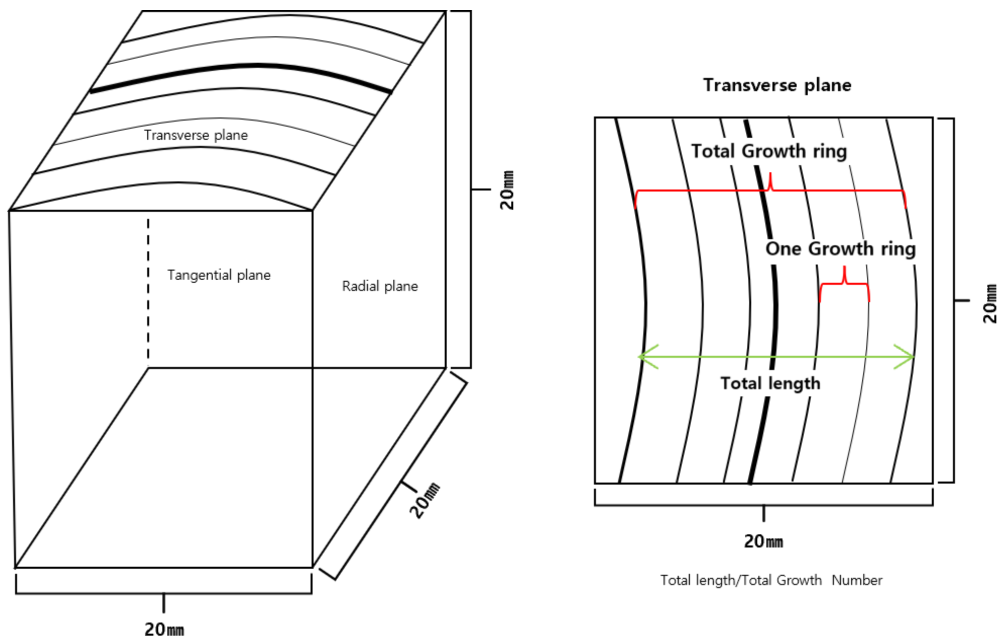


Fig. 1. Measurement of the number of rings in the cross-section

Data Analysis

The SPSS Statistics software (IBM, USA) was used to analyze the correlation and regression between air-dry specific gravity and average annual ring width. The average annual ring width was entered as the independent variable, while the air-dry specific gravity was set as the dependent variable. Pearson's correlation coefficient was primarily used for correlation analysis, and statistical significance was determined at a significance level of 0.05. Regression analysis was performed using the linear regression module in SPSS. Residual analysis and diagnostic statistics were conducted to assess the model's fit, with the significance level set at 0.05. Although R^2 values are reported, the interpretation of statistical significance relies on the p-values, which are directly related to the regression slopes.

RESULTS AND DISCUSSION

Relationship between the Average Annual Ring Width and Air-dry Specific Gravity of Coniferous trees

Table 2 presents the tested number of coniferous wood specimens, as well as the mean and standard deviation of their average annual ring width and air-dry specific gravity. The correlation coefficients and regression analysis results for the relationship between average annual ring width and air-dry specific gravity are shown in Table 3 and Fig. 2.

Linear regression was conducted with air-dry specific gravity as the dependent variable and average annual ring width as the independent variable. The p-value associated with the slope of the linear regression line indicates whether the relationship between air-dry specific gravity and average annual ring width is statistically significant.

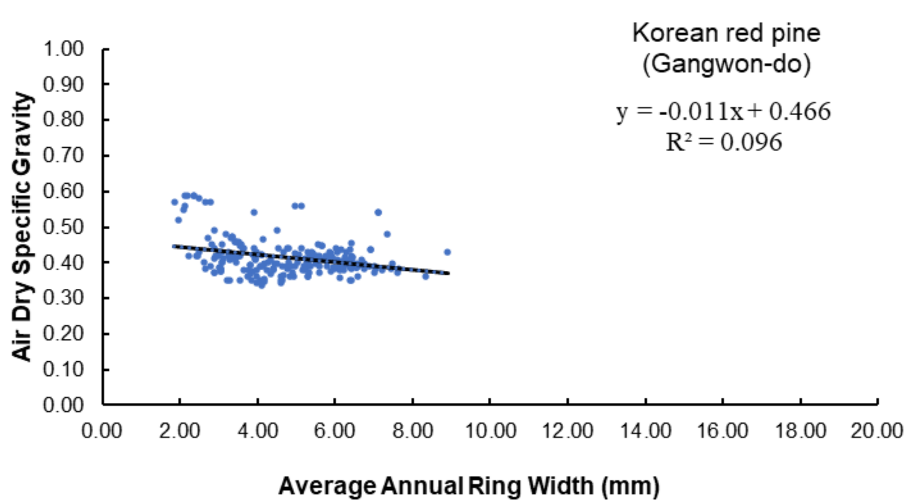
Table 2. Average Annual Ring Width and Air-dry Specific Gravity of Tested Coniferous Species

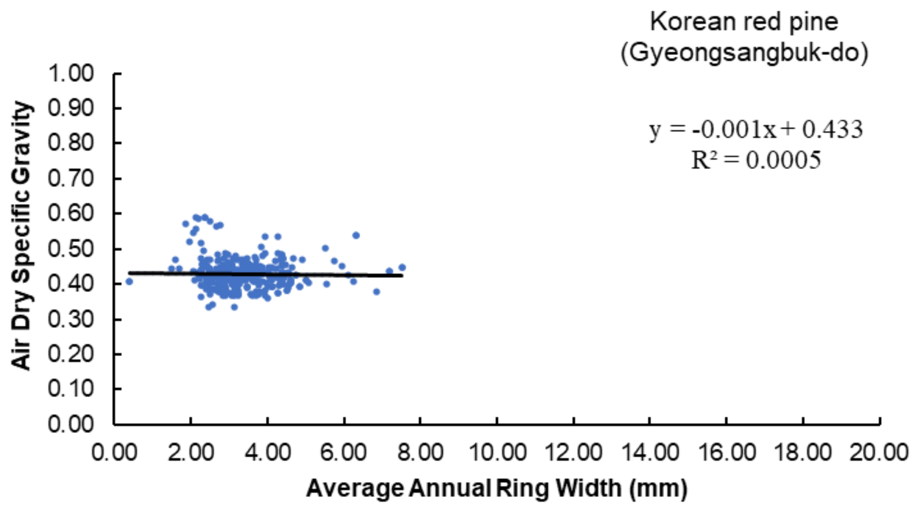
Species	Number of specimens	Average annual ring width (mm)	Air-dry Specific gravity
Korean red pine (Gangwon-do)	228	4.74 (1.47)*	0.41 (0.05)
Korean red pine (Gyeongsangbuk-do)	375	3.42 (0.93)	0.43 (0.04)
Korean pine	244	5.23 (0.93)	0.41 (0.03)
Japanese larch	265	5.19 (1.56)	0.54 (0.08)
Pitch pine	250	4.36 (1.72)	0.49 (0.05)
Rigitaeda pine	415	5.86 (2.08)	0.44(0.06)
Japanese false cypress	251	4.77 (1.55)	0.41 (0.03)
Japanese cedar	283	7.20 (2.90)	0.33 (0.04)

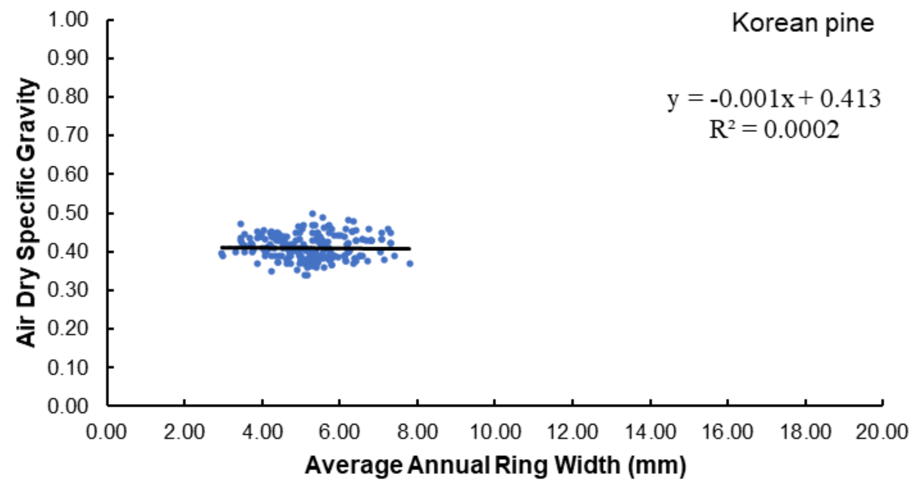
* Standard deviation

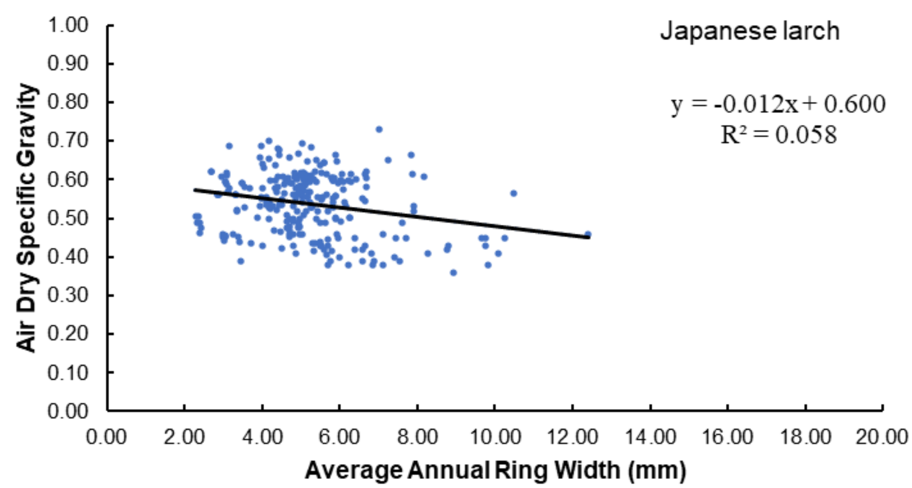
Table 3. Correlation and Regression Analysis of Coniferous Species

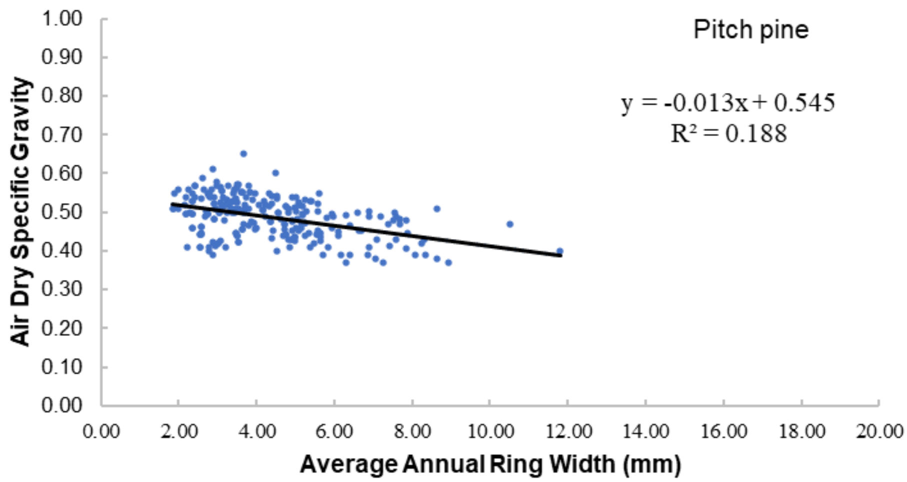
Wood Species	Pearson's r	p-value	Equation	R^2
Korean red pine (Gangwon-do)	-0.311	0.001	Y= -0.011x+0.466	0.096
Korean red pine (Gyeongsangbuk-do)	-0.022	0.670	Y= -0.001x+0.433	0.0005
Korean pine	-0.016	0.805	Y= -0.001x+0.413	0.0002
Japanese larch	-0.240	0.001	Y= -0.012x+0.600	0.058
Pitch pine	-0.433	0.001	Y= -0.013x+0.545	0.188
Rigitaeda pine	-0.438	0.001	Y= -0.013x+0.520	0.191
Japanese false cypress	-0.034	0.594	Y= -0.001x+0.416	0.001
Japanese cedar	-0.059	0.322	Y= -0.001x+0.336	0.003

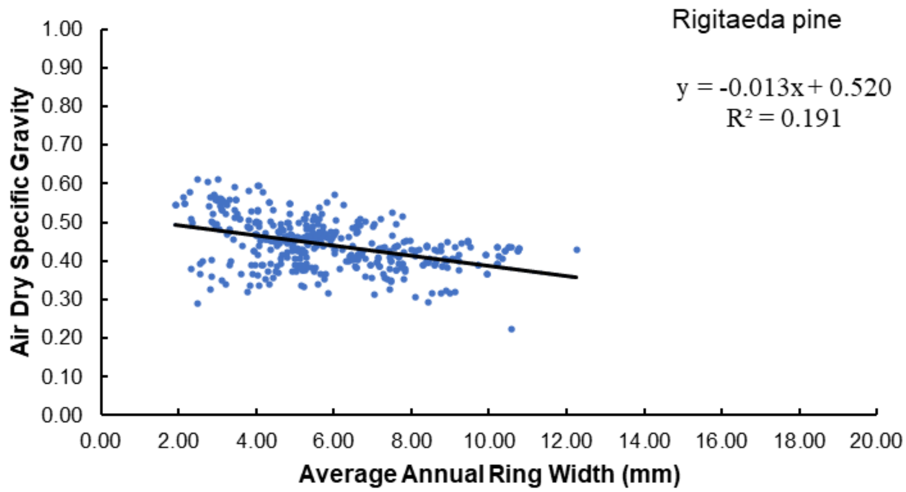



Korean red pine
(Gyeongsangbuk-do)
y = -0.001x + 0.433
R² = 0.0005
Air Dry Specific Gravity
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
0.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00
16.00
18.00
20.00
Average Annual Ring Width (mm)


Korean pine
y = -0.001x + 0.413
R² = 0.0002
Air Dry Specific Gravity
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
0.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00
16.00
18.00
20.00
Average Annual Ring Width (mm)


Japanese larch
y = -0.012x + 0.600
R² = 0.058
Air Dry Specific Gravity
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
0.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00
16.00
18.00
20.00
Average Annual Ring Width (mm)


Pitch pine
y = -0.013x + 0.545
R² = 0.188
Air Dry Specific Gravity
Average Annual Ring Width (mm)
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
0.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00
16.00
18.00
20.00


Rigitaeda pine
y = -0.013x + 0.520
R² = 0.191
Air Dry Specific Gravity
Average Annual Ring Width (mm)
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
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2.00
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12.00
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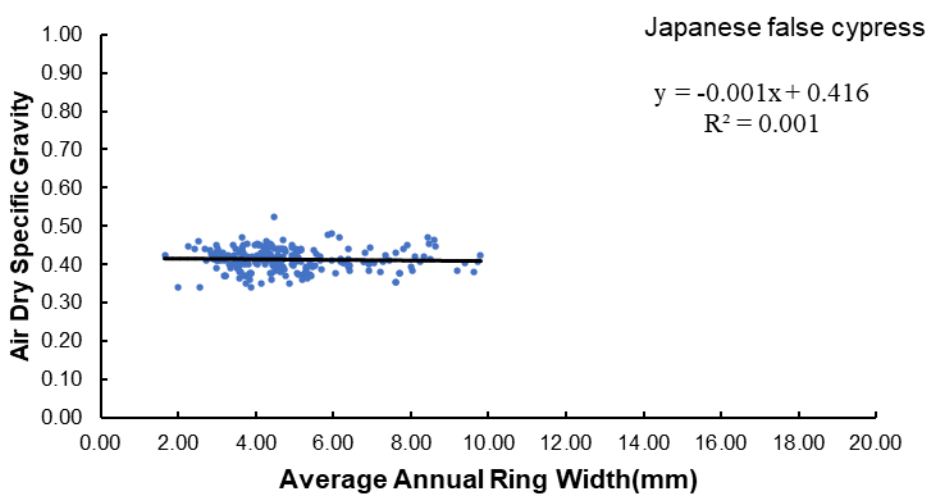
16.00
18.00
20.00


Japanese false cypress
y = -0.001x + 0.416
R² = 0.001
Air Dry Specific Gravity
Average Annual Ring Width(mm)
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
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2.00
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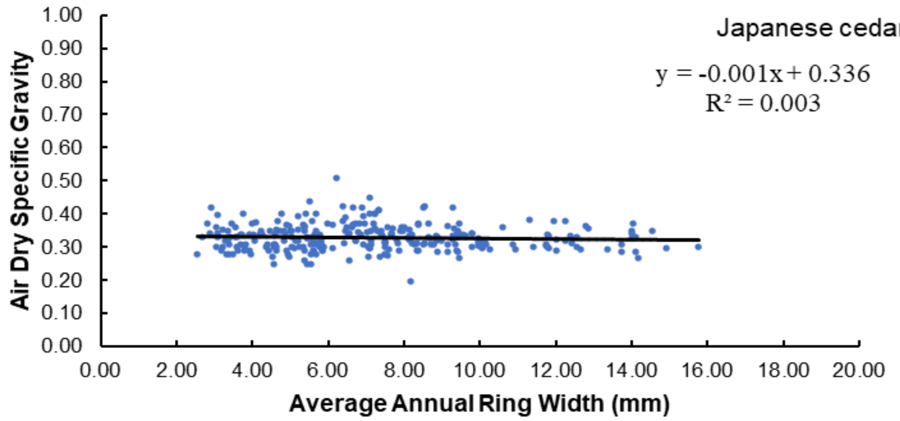


Fig. 2. Regression analysis of average annual ring width and air-dry specific gravity of South Korean coniferous trees

The results indicate that *Pinus densiflora* Siebold & Zucc., *Larix kaempferi* (Lamb.) Carriere, and *Pinus rigida* Mill. exhibited a strong negative correlation between average annual ring width and air-dry specific gravity, whereas *Pinus koraiensis* Siebold & Zucc., *Chamaecyparis obtusa* (Siebold & Zucc.) Endl., and *Cryptomeria japonica* (Thunb. ex L.f.) D.Don showed a weak negative correlation. Among these species, *Pinus densiflora* (Gangwon region), *Larix kaempferi*, *Pinus rigida*, and *Pinus rigida* × *Pinus taeda* exhibited statistically significant correlations at the 0.05 significance level. Overall, coniferous species with wider average annual ring widths, indicative of faster growth, tended to have lower air-dry specific gravity.

Previous studies (Auty *et al*. 2014; Rodriguez *et al*. 2019; Wang *et al*. 2022) have also reported a negative correlation between average annual ring width and specific gravity in coniferous species. However, Dahlen *et al*. (2018) and Wimmer and Downes (2003) concluded that although a negative correlation exists, its strength is insufficient for average annual ring width to serve as a reliable predictor of wood specific gravity. This trend was also observed in *Pinus koraiensis* Siebold & Zucc., *Chamaecyparis obtuse* (Siebold & Zucc.) Endl., and *Cryptomeria japonica* (Thunb. ex L.f.) D.Don in the present study.

Han *et al*. (2016) reported that a negative correlation was observed between average annual ring width and oven-dry density in *Pinus densiflora* Siebold & Zucc. In this study, *Pinus densiflora* Siebold & Zucc. from the Gangwon region exhibited a negative correlation between average annual ring width and air-dry specific gravity, with statistical significance at the 0.05 level. However, *Pinus densiflora* from the Gyeongbuk region did not show a significant correlation between average annual ring width and air-dry specific gravity.

Kwon *et al*. (2004) reported no correlation between specific gravity and average annual ring width in *Pinus koraiensis*. In the study, *Pinus koraiensis* Siebold & Zucc did not show a significant correlation between air-dry specific gravity and average annual ring width.

Zhang *et al*. (2023) and Wang *et al*. (2022) confirmed that as the ring width decreases in *Larix kaempferi* L., latewood percentage increases, leading to a higher specific gravity. Similarly, in this study, *Larix kaempferi* L. exhibited a negative correlation between average annual ring width and air-dry specific gravity, which was statistically significant at the 0.05 level.

Pinus rigida Mill. showed a negative correlation between average annual ring width and air-dry specific gravity, with statistical significance at the 0.05 level. Rodriguez *et al*. (2019) reported a negative correlation between annual ring width and oven-dry specific gravity in *Pinus taeda*, while Dahlen *et al*. (2018) confirmed a negative correlation between ring width and specific gravity in *Pinus taeda* L. In this study, *Pinus rigida* × *Pinus taeda* exhibited a negative correlation, which was statistically significant at the 0.05 level. In this experiment, the correlation coefficient value was the highest between *Pinus rigida* Mill. And *Pinus rigida* × *Pinus taeda*.

Todoroki *et al*. (2015) reported that for Mexican cypress (*Cupressus lusitanica* Mill.) and Montery cypress (*Cupressus macrocarpa* Gordon.), juvenile wood shows a decline in wood specific gravity as ring width increases, whereas mature wood shows no correlation between ring width and specific gravity. Similarly, in this study, *Chamaecyparis obtusa* (Siebold & Zucc.) Endl. showed no significant correlation between air-dry specific gravity and average annual ring width.

Yasuda *et al*. (2024) observed that in *Cryptomeria japonica* D. Don, average annual ring width was associated with a distinct increase in specific gravity. However, in this study, which focused on *Cryptomeria japonica* D. Don grown in Jeju Island, the correlation between average annual ring width and air-dry specific gravity was the lowest among all species examined, indicating that average annual ring width is not a reliable predictor of air-dry specific gravity for this species.

Relationship between the Average Annual Ring Width and Air-dry Specific Gravity of Deciduous trees

Table 4 presents the number of deciduous wood specimens, as well as the mean and standard deviation of their average annual ring width and air-dry specific gravity. The correlation coefficients and regression analysis results for the relationship between average annual ring width and air-dry specific gravity are shown in Table 5 and Fig. 3.

Among the diffuse-porous species, *Betula pendula* Roth exhibited a negative correlation between average annual ring width and air-dry specific gravity. Among the ring-porous species, *Robinia pseudoacacia* L., *Zelkova serrata* (Thunb.) Makino, *Quercus variabilis* Blume, *Quercus acutissima* Carruth., and *Quercus mongolica* Fisch. ex Ledeb. also showed negative correlations. In contrast, the diffuse-porous species *Liriodendron tulipifera* L. and the ring-porous species *Quercus mongolica* Fisch. ex Ledeb. exhibited positive correlations between average annual ring width and air-dry specific gravity.

Table 4. Average Annual Ring Width and Air-dry Specific Gravity of Tested Deciduous Species

Wood Species	Number of specimens	Average annual ring width (mm)	Air-dry specific gravity
Tulip tree	173	6.80 (1.47)	0.43 (0.04)
East Asian white birch	380	3.86 (1.09)	0.47 (0.04)
Mossy locust	258	6.02 (1.74)	0.67 (0.04)
Sawleaf zelkova	233	4.58 (1.94)	0.64 (0.06)
East Asian ash	380	3.16 (1.29)	0.67 (0.09)
Oriental cork oak	226	3.57 (1.05)	0.80 (0.07)
Sawtooth oak	317	4.65 (1.45)	0.76 (0.05)
Mongolian oak	301	4.35 (1.48)	0.71 (0.03)

Table 5. Correlation and Regression Analysis of Deciduous Species

Wood Species	Pearson's r	p-value	Equation	R^2
Tulip tree	0.009	0.365	Y= 0.002x+0.416	0.005
East Asian white birch	-0.150	0.003	Y= -0.006x+0.496	0.022
Mossy locust	-0.276	0.001	Y= -0.006x+0.709	0.076
Sawleaf zelkova	-0.100	0.129	Y= -0.003x+0.659	0.010
East Asian ash	-0.323	0.001	Y= -0.021x+0.736	0.105
Oriental cork oak	-0.154	0.020	Y= -0.011x+0.842	0.024
Sawtooth oak	-0.141	0.012	Y= -0.005x+0.785	0.020
Mongolian oak	0.285	0.001	Y= 0.007x+0.683	0.081

Linear regression was conducted with air-dry specific gravity as the dependent variable and average annual ring width as the independent variable.

Giagli *et al.* (2018) reported that both the diffuse-porous *Fraxinus excelsior* L. (European ash) and the ring-porous *Quercus robur* L. (English oak) exhibited positive correlations between average annual ring width and oven-dry density. However, Romagnoli *et al.* (2014) found that *Castanea sativa* (European chestnut), a ring-porous species, exhibited a negative correlation between ring width and specific gravity, although this relationship varied by region. Additionally, Bouriaud *et al.* (2004) reported that *Fagus sylvatica* L. (European beech), a diffuse-porous species, exhibited a negative correlation between ring width and specific gravity. These findings suggest that the relationship between average annual ring width and air-dry specific gravity in deciduous species does not differ significantly between ring-porous and diffuse-porous wood types.

The correlation between average annual ring width and air-dry specific gravity was statistically significant at a 0.05 significance level for *Betula pendula* Roth, *Robinia pseudoacacia* L., *Quercus mongolica* Fisch. ex Ledeb., *Quercus variabilis* Blum, and *Quercus acutissima* Carruth. However, for *Liriodendron tulipifera* L. and *Zelkova serrata*(Thumb.) Makino, the correlation was not statistically significant at the 0.05 significance level.

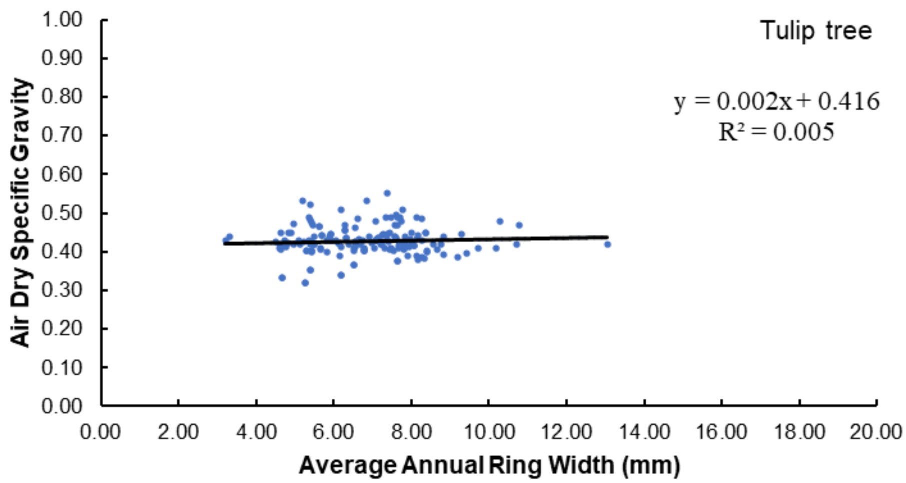
The diffuse-porous *Liriodendron tulipifera* L. did not exhibit a significant correlation between average annual ring width and air-dry specific gravity. The diffuse-porous *Betula pendula* Roth exhibited a negative correlation, which was statistically significant at the 0.05 level. Jones *et al.* (2024) reported that for *Betula pendula* Roth and *Betula pubescens* Ehrh., average annual ring width were associated with lower wood specific gravity.

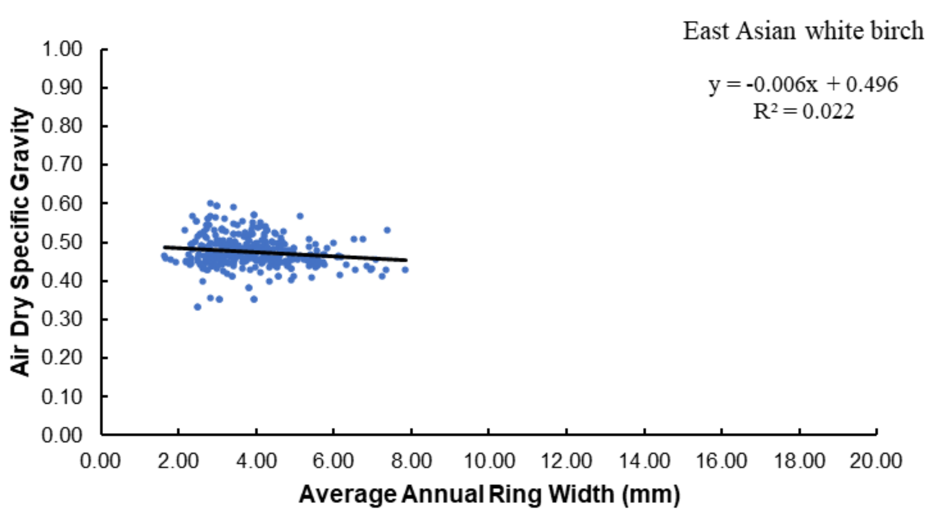
The ring-porous *Robinia pseudoacacia* L. exhibited a negative correlation. Adamopoulos *et al.* (2010) reported that in *Robinia pseudoacacia* L. (black locust), average annual ring width were associated with higher latewood percentage, leading to increased specific gravity. However, they also found that the correlation between average annual ring width and specific gravity varied significantly across different regions in Europe. This suggests that the relationship between average annual ring width and air-dry specific gravity in *Robinia pseudoacacia* L. may differ depending on the growth region.

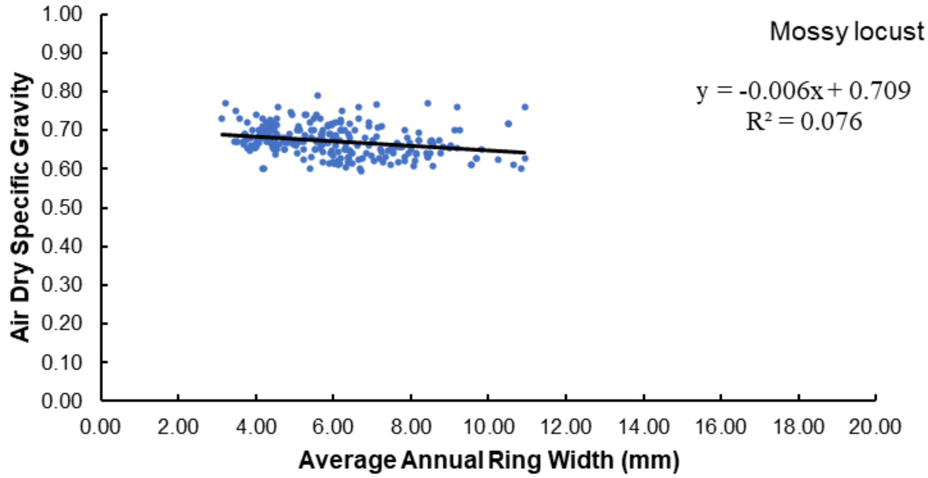
The ring-porous *Zelkova serrata* (Thumb.) Makino did not show a statistically significant at the 0.05 level. The ring-porous *Fraxinus excelsior* L. exhibited a negative correlation and was statistically significant at the 0.05 level. However, Giagli *et al.* (2018) reported that *Fraxinus excelsior* L. exhibited a positive correlation between ring width and oven-dry density.

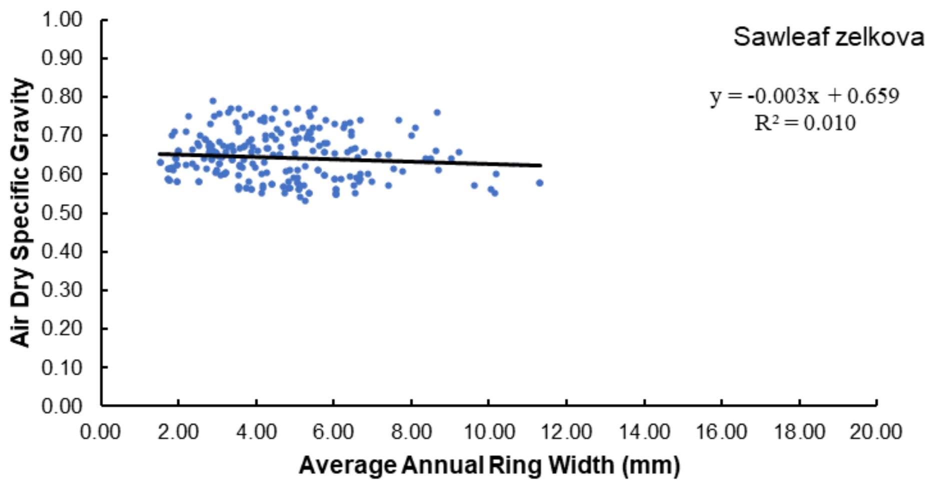
Among the ring-porous oak species, *Quercus variabilis* Blume exhibited a negative correlation between average annual ring width and air-dry specific gravity, which was statistically significant at the 0.05 level. Similarly, *Quercus acutissima* Carruth. exhibited a negative correlation with significance at the 0.05 level. However, *Quercus mongolica* Fisch. ex Ledeb. exhibited a positive correlation, which was statistically significant at the 0.05 level. Giagli *et al.* (2018) reported that *Quercus robur* (English oak) in the Czech Republic had a low correlation between average annual ring width and specific gravity. Furthermore, Knapic *et al.* (2007) concluded that *Quercus suber* (cork oak) did not exhibit a relationship between average annual ring width and specific gravity. These findings suggest that the correlation between average annual ring width and air-dry specific gravity in oak species can be either positive or negative and may vary depending on species and geographic region.

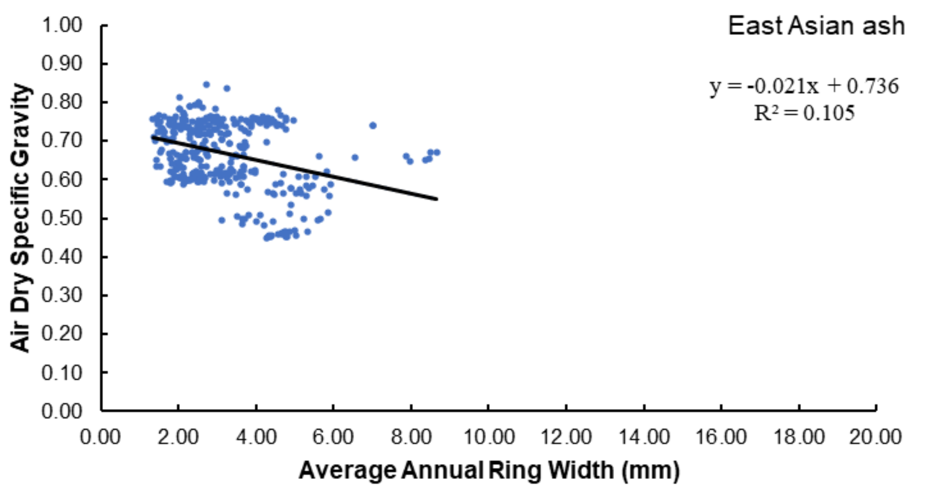
Similar to coniferous species, the relationship between average annual ring width and air-dry specific gravity in deciduous species varies by species, and in some cases, this relationship is not well-defined.






Mossy locust
y = -0.006x + 0.709
R² = 0.076
Air Dry Specific Gravity
Average Annual Ring Width (mm)
0.00
0.10
0.20
0.30
0.40
0.50
0.60
0.70
0.80
0.90
1.00
0.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00
16.00
18.00
20.00


Sawleaf zelkova
y = -0.003x + 0.659
R² = 0.010
Air Dry Specific Gravity
Average Annual Ring Width (mm)
0.00
0.10
0.20
0.30
0.40
0.50
0.60
0.70
0.80
0.90
1.00
0.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00
16.00
18.00
20.00


East Asian ash
y = -0.021x + 0.736
R² = 0.105
Air Dry Specific Gravity
Average Annual Ring Width (mm)
0.00
0.10
0.20
0.30
0.40
0.50
0.60
0.70
0.80
0.90
1.00
0.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00
16.00
18.00
20.00

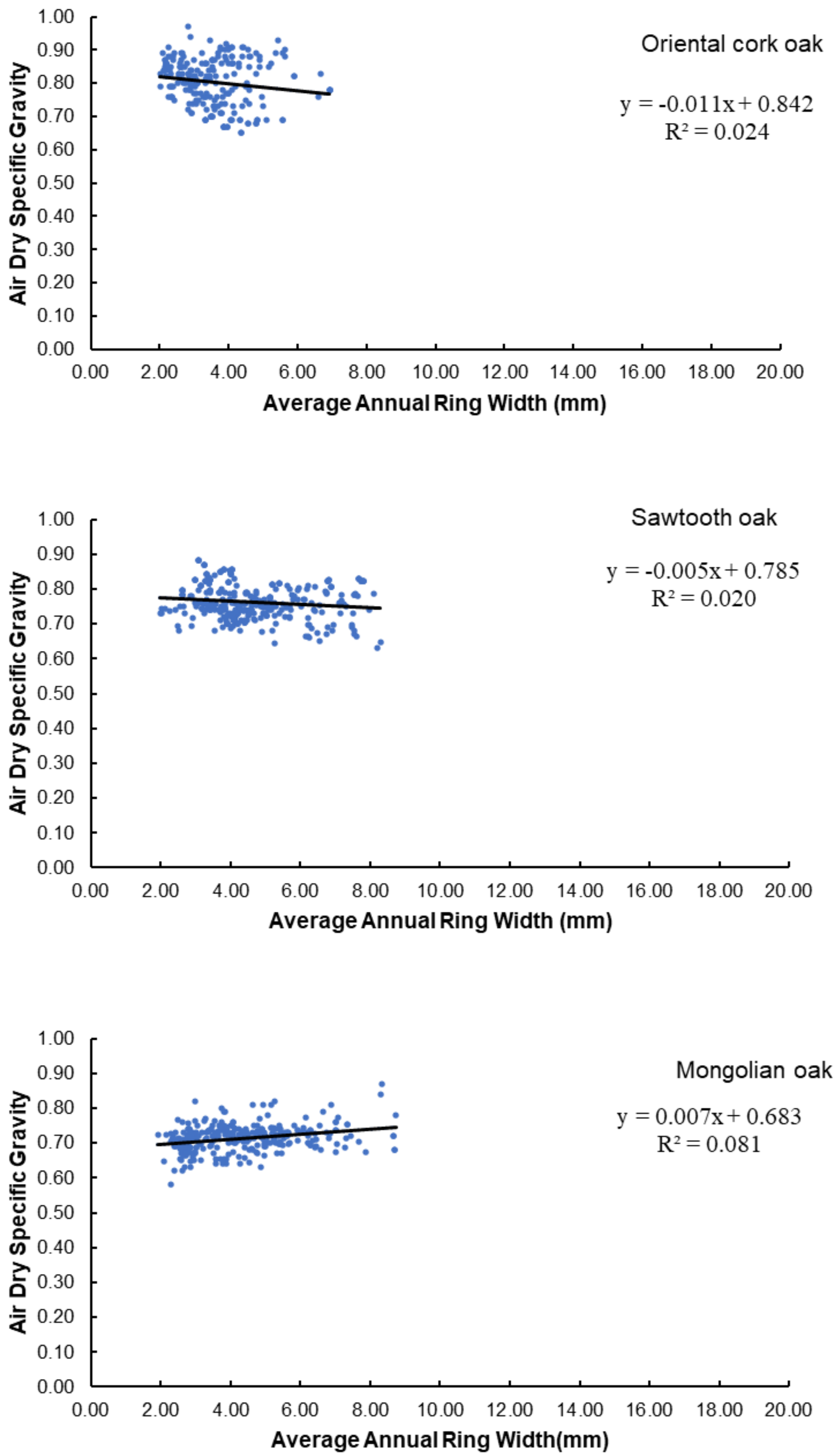


Fig. 3. Regression analysis of average annual ring width and air dry specific gravity of deciduous trees

CONCLUSIONS

1. In coniferous trees, specimens with smaller average annual ring widths tended to have higher specific gravity. However, species that exhibited a strong correlation between average annual ring width and air-dry specific gravity included *Pinus densiflora* Siebold & Zucc. (Gangwon region), *Larix kaempferi* (Lamb.) Carrière, *Pinus rigida* Mill., and *Pinus rigida* Mill. × *Pinus taeda* L. In contrast, *Pinus koraiensis* Siebold & Zucc., *Chamaecyparis obtusa* (Siebold & Zucc.) Endl., *Cryptomeria japonica* (Thunb. ex L.f.) D.Don, and *Pinus densiflora* Siebold & Zucc. (Gyeongbuk region) exhibited a weaker correlation. Among coniferous plantation species, both *Pinus rigida* Mill. and the hybrid *Pinus rigida* Mill. × *Pinus taeda* L. exhibited a strong correlation between air-dry specific gravity and average annual ring width. This indicates that managed growth conditions can significantly influence the relationship between specific gravity and ring width, likely by affecting wood formation processes and the balance between earlywood and latewood production.

2. Among deciduous species, the diffuse-porous *Liriodendron tulipifera* L. and the ring-porous *Quercus mongolica* Fisch. ex Ledeb. exhibited a positive correlation, indicating that specimens with larger average annual ring widths tended to have higher air-dry specific gravity. In contrast, the diffuse-porous *Betula pendula* Roth and the ring-porous *Robinia pseudoacacia* L., *Zelkova serrata* (Thunb.) Makino, *Fraxinus rhynchophylla* Hance, *Quercus variabilis* Blume, and *Quercus acutissima* Carruth. exhibited a negative correlation, where smaller average annual ring widths were associated with higher air-dry specific gravity. Among these species, *Robinia pseudoacacia* L., *Quercus mongolica* Fisch. ex Ledeb., *Betula pendula* Roth, and *Fraxinus rhynchophylla* Hance exhibited a very strong correlation, whereas *Quercus variabilis* and *Quercus acutissima* showed a strong correlation. However, *Liriodendron tulipifera* L. and *Zelkova serrata* (Thunb.) Makino were found to be unsuitable for evaluating air-dry specific gravity based on average annual ring width. Among diffuse-porous species, *Liriodendron tulipifera* L. did not exhibit a significant correlation. In contrast, *Betula pendula* Roth showed a significant negative correlation at the 0.05 level. For ring-porous species, *Robinia pseudoacacia* L., *Fraxinus rhynchophylla* Hance, *Quercus variabilis* Blume, and *Quercus acutissima* Carruth. all demonstrated statistically significant negative correlations at the 0.05 level. *Quercus mongolica* Fisch. ex Ledeb. displayed a significant positive correlation at the same significance level. *Zelkova serrata* (Thumb.) Makino did not show a significant correlation.

3. Excluding *Liriodendron tulipifera* L. and *Quercus mongolica* Fisch. ex Ledeb., temperate-zone coniferous and broadleaf species in South Korea generally exhibited a trend in which smaller average annual ring widths corresponded to higher air-dry specific gravity. These results suggest that the average annual ring width of temperate-zone coniferous and deciduous species can serve as a reference for evaluating air-dry specific gravity.

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