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An Experimental Study on the Noise Reductive Characteristics of Indoor Foliage Plants

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Summary

Because of the growing population and the increased use of machinery, indoor noise which is invisible pollution, is threatening human health. Indoor noise can absorb, deflect, refract, and reflect sounds. In addition, the vibration of a sound wave is absorbed by leaves, branches and soil.

Therefore, in order to understand the properties of indoor sound environment in accordance with the availability of indoor plants, a basic study on the indoor noise reduction effect of plantation in an indoor space was conducted. In this study, experiments were conducted in three different environments : space with no plantation, a space where 3% of the total room volume was planted with both Spathypyllum and Araucaria, and a space where 3% of the total room volume was deployed with paper-based structures. A high frequency non-directional sound source (Supper Tweeter Source) was set up in an indoor space (5.0m×5.0m×2.5m) to measure indoor noise.

The results showed the change of 1) NRC, RT, EDT, D50 with plantation in a room, and 2) in particular, it was much more effective in a low frequency band. Overall, it showed that it is effective in reducing the amount of noise stress that people under go when they occupy a room.

1. Introduction

The quality of the Indoor environment for occupants has been one of the most significant issues recently due to the qualitative improvement of the standard of living. Furthermore, a survey, suggesting that indoor noise accounts for the highest rate of dissatisfaction in residential environments, indicates that indoor noise can be considered to be a significant factor for the improvement of indoor environment.

In order to promote a comfortable indoor acoustical environment, much research related to the practical reduction policy, the development of a construction method for the improvement of sound-insulating performance of conventional apartments and the development of a prediction method for sound-insulating performance have been widely conducted.

Recently, the use of plants for indoor comfort has been actively suggested since the research on green building design enabling the organic relationship between nature and human beings has been widely conducted to provide an environmentally sound space inside and outside buildings.

In addition to the function of being just an ornamentation, indoor plants have an improved effect on the indoor environment such as the reduction of indoor pollutants, the adequate control of temperature and humidity, the purification and filtering of polluted air, and the insulation of noise.

According to the existing research on the effect of indoor plants on noise reduction characteristics, a sound absorbing effect of about 8dB can be obtained for different shapes of fences and 1~2dB can be obtained in forests with a width of 23m thanks to the sound absorbing effect of a forest. Moreover, according to an investigation suggesting that not only the reduction of sound-insulation range by 20% but also a mental sound reduction effect can be obtained by using forests, indoor plants as the sound-insulating effect has been actively considered among experts.

Therefore, in this study, the acoustic absorption characteristics with and without indoor plants is investigated in order to provide basic data on the sound-insulating effect of indoor plants in conventional residences and office buildings.

Table 1 shows the flower study chart

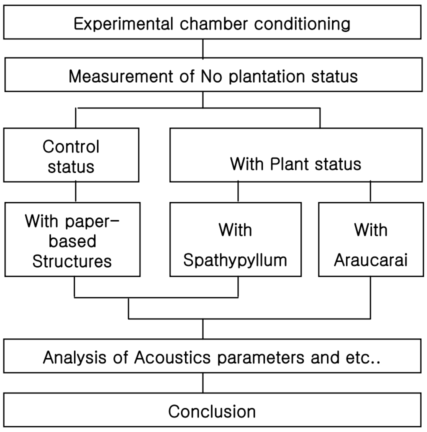


Figure 1 Flower chart

2. Experimental method and the scope

2.1 Experimental conditions

In this study, the experiment was conducted in an architectural environmental chamber (in Hanyang University) in order to determine the indoor noise characteristics under different arrangement types with and without indoor plants.

The condition of the experimental chamber with 5m x 5m x 2.5m was set at 22℃ and 60%. The chamber had a sandwich panel(steel plate 1mm+insulator 30mm+steel plate 1mm) and access floor.

Spathyphyllum 7"pot(length 50±5cm) and Araucaria(length 70±5cm) were selected and the paper-based structure with relatively high acoustic absorption was selected as the control status.

Additional finishing materials were not pasted inside the chamber in order to minimize the effect of other factors other than plants, and the sound loss was prevented by using stone material for diffusers on the floor.

The plan of the experimental chamber and sound source of plants were presented in fig. 2 and fig. 3 respectively.

The volume of the plant status and the control were set at 3% of the total volume of the experimental room with 62.5m^3(5m x 5m x 2.5m).

In order to find out the effect of the arrangement type, the experiment was conducted under different arrangement conditions : a condition without plants(type A), a linear arrangement(type B), a symmetric double-lined arrangement(type C), and an equally distributed arrangement into three parts(type D)

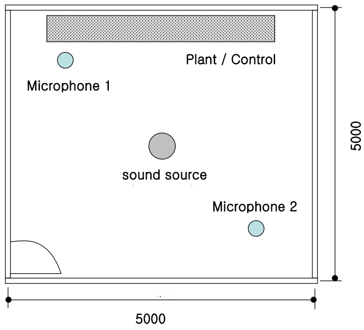


Figure 2 Plan of Experimental Chamber inscribed

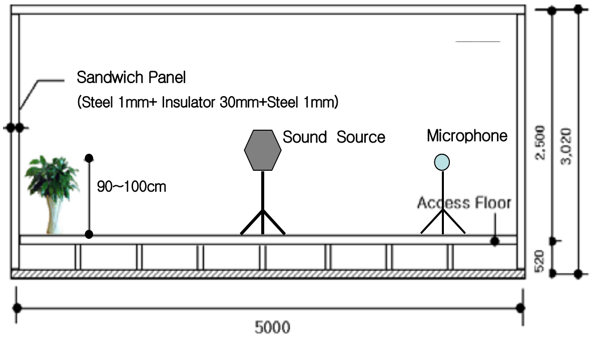


Figure 3 Section of Experimental Chamber

2.2 Experimental method

The measurement and analysis were conducted on the basis of the acoustic parameter and method used in the conventional indoor noise measurement.

The sound source was MLS when measuring Spathypyllum, and the sound was generated using an undirectional speaker. Balloons were used as the sound source when measuring Araucaria.

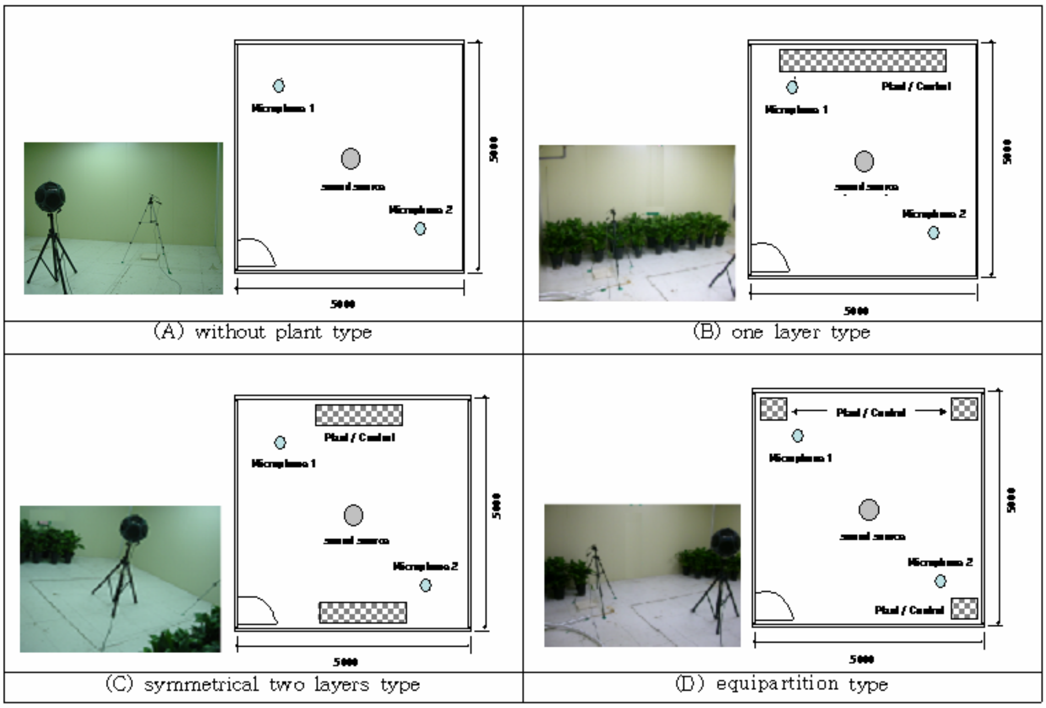
An undirectional microphone was installed 1.5m above the floor and the measured results was averaged after the measurement.

Fig. 2 and fig. 4 present the location of the sound source point, which were 50cm apart from the corner.

Measurement and analysis equipment were Symphonie system(01dB) and dB BATI respectively.

The determination of the sound source point and equipment for the measurement of reverberation time, sound pressure level, and other indoor noise are presented in table 1.

Table 2 summarizes the conventional indoor acoustic parameters. In this study, RT, EDT, and D50 were measured, compared and analyzed.



(A) without plant type

(B) one layer type

(C) symmetrical two layers type

(D) equipartition type

Figure 4 Chamber Plan of the arrangement types in this study

Table 1 The measurement specification

Specification		Equipment
Chamber size	62.5 m^3	•Balloon •Mic. 2ch. (GRAS) •Amplifier (ITEC) • Symphonie system (01dB) • Sound source (CESVA) • dB BATI
Sound Source Point	Center (1 point)	
Microphone Point	With a 50cm radius from corners (2point)	

Table 2 Acoustics Parameters

Classification	Parameters	Definition
The amount of reverberation	RT (Reverberation time)	The time it took the sound to decay the estimated 60dBof its initial sound level was measured by chronograph and defined by Sabin .
	EDT (early decay time)	It's the exact amount of time it takes for a sound from a musical note to decay 10dB after it's cut off. 10dB of decay occurs in time period that required for 60dB of decay.
Definition	D50 (definition)	The distinctness ratio. It's the ratio of the sound energy in the first 50msec after arrival of the direct sound at a listener's position to the total sound energy arriving.

3. Experimental results

3.1 The amount of reverberation

3.3.1 RT

(1) plant 1 : Spathypillum

Fig. 5 presents RT under a different frequency range with and without plants. Type B and type B' with plants showed a uniform distribution compared to type A without plants.

Within the frequency range of 125Hz, 500Hz, and 8KHz, reverberation time decreased by 0.25~0.35, while within the frequency range of 250Hz and 2KHz, reverberation time decreased by 0.18~0.24.

In the frequency range of 2KHz and 4KHz in particular, the reverberation time was reduced by 0.91 and 0.63 respectively, indicating that plants have a significant effect on the reduction of reverberation time in a high frequency range.

Fig. 6 presents the difference of reverberation time under different arrangement types (type B, C, D)

In 125Hz, the difference between type A and type D was 0.53 which is the highest reduction effect. In 250Hz, type D also showed the highest reduction effect of 0.51, and type B also showed a relatively successful reduction effect of 0.48. In 500Hz, the reduction effect showed 0.21~0.31 under all arrangement types. In 1KHz, the reduction effect showed 0.44~055 regardless of arrangement type, indicating that the reduction effect was higher than the case of 500Hz. The plant arrangement type showed the highest reduction effect in 2KHz: 0.81~0.94. Finally, the reduction effect was 0.59~0.70 in 4KHz and was 0.22~0.34 in 8KHz.

The reduction effect showed a significantly high value in 1KHz, 2KHz, and 4KHz by plants, while the arrangement type a had considerable effect on reverberation time in a low frequency range.

Fig. 7 presents the difference of reverberation time between type A and the control of each type B', C', D'. Type C' showed the highest reduction effect in 125Hz, and the three types of arrangement type showed a similar value to each other in 250Hz. In 500Hz, type B' and type C' showed a similar reduction effect, while type D' did not show reduction effect. In 1KHz~4KHz, three types showed a similar value to each other. In 8KHz,the reduction effect was 0.18~0.25, which is the lowest value.

Similarly, the control showed a significant reduction effect in 1KHz, 2KHz, and 4KHz, and the arrangement type had a considerable effect on the reverberation time in a low frequency range.

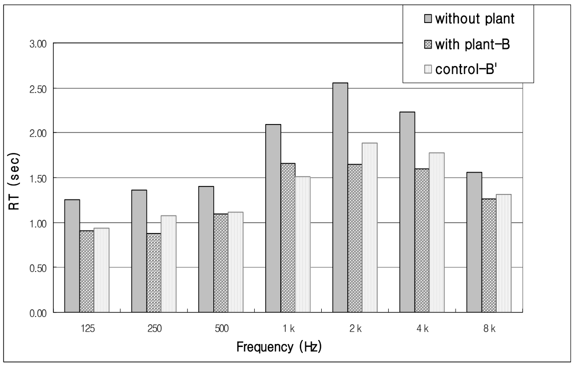


Figure 5 Change of RT with indoor plantation

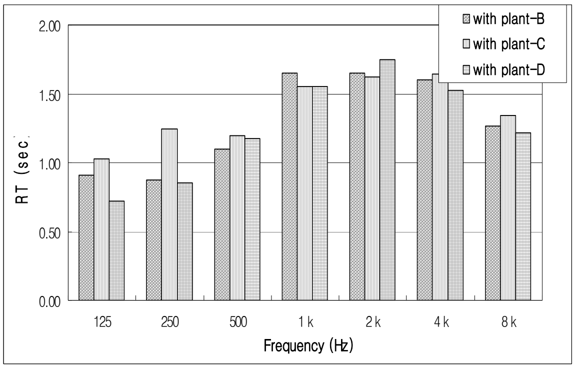


Figure 6 Change of RT by the arrangement types

(With plants status)

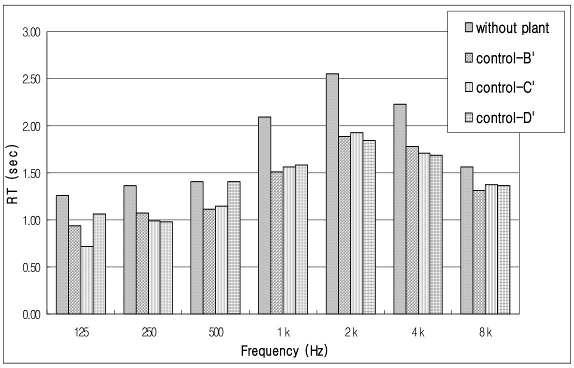


Figure 7 Change of RT by the arrangement types

(With control status)

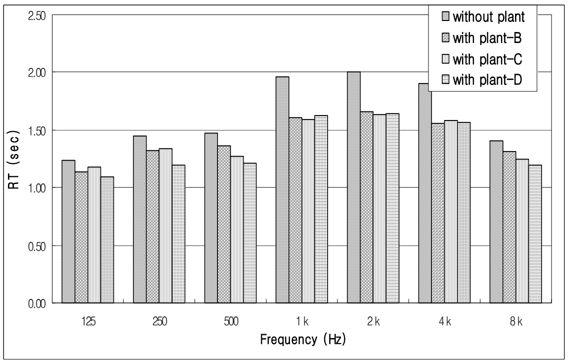


Figure 8 Change of RT by the arrangement types

(With plants status)

(2) plant 2 : Araucaria

Fig. 8 presents the difference of reverberation time under different arrangement types(type B, C, D), indicating that plants significantly reduce the reverberation time. In 125Hz, the reduction did not show a high difference among arrangement types. In 250Hz and 500Hz, type C showed the highest reduction effect: 0.24 and 0.26 respectively. In 1KHz ~ 4KHz, it showed 0.32~0.37 regardless of arrangement type, indicating reduction effect was higher than that in a low frequency range.

3.1.2 Acoustic absorption

Indoor noise characteristics of each arrangement type were analyzed by calculating acoustic absorption with the Sabin equation.

This experiment used mean acoustic absorption since every wall is considered to have mean acoustic absorption of an in diffusion sound field. The determination of acoustic absorption used the reverberation time in a different frequency range under different arrangement types in fig. 6~fig. 8. The following shows the Sabin equation.

$$A = \bar{\alpha} \cdot S = 0.161/T\ [\mathrm{m^2}] \quad \cdots\cdots (1)$$

$$\therefore\ \bar{\alpha} = 0.161V/ST \quad \cdots\cdots (2)$$

(1) plant 1 : Spathypillum

Measured RT was used to calculate acoustic absorptivity. Fig. 9 shows the difference of acoustic absorptivity with and without plants. In 125Hz, type D showed 0.06 which was the highest acoustic absorptivity. In 250Hz, type B and D increased by 0.04, and type C increased by 0.01.

In 500Hz~8KHz, acoustic absorptivity rose by 0.01~0.02 regardless of the arrangement type.

The arrangement type showed a higher difference of acoustic absorptivity in a low frequency range than in a high frequency one. Type D showed the highest acoustic absorptivity in 125Hz and in low frequency range.

Fig. 10 shows the difference of acoustic absorptivity between the type without plants and the control.

In 125Hz, type C increased by 0.06, which is the highest value. In 250Hz, acoustic absorptivity increased regardless of arrangement types.

In 500Hz, only type B' and type C' increased by 0.02. In 1KHz~8KHz, acoustic absorptivity increased similarly regardless of arrangement type.

The different of acoustic absorptivity under different arrangement types was higher in a low frequency range than in high frequency one. Among them, type C' showed the highest acoustic absorptivity in low a frequency range, especially in 125Hz.

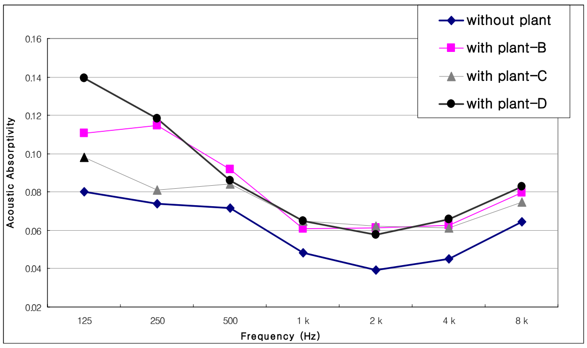


Figure 9 Change of acoustic absorptivity

(with plants status)

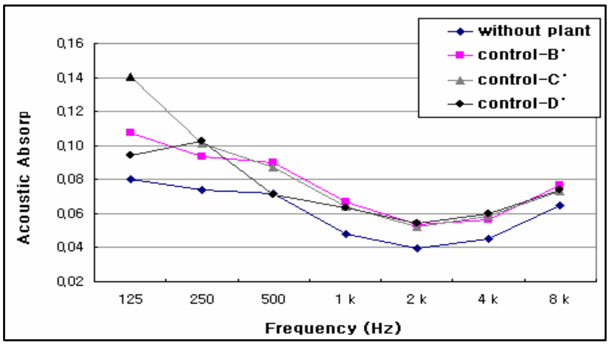


Figure 10 Change of acoustic absorptivity

(With control status)

(2) plant 2 : Araucaria

Fig. 11 shows the difference of reverberation time under different arrangement types, suggesting that plants have a reduction effect on acoustic absorptivity.

In 125Hz~500Hz, acoustic absorptivity was 0.07~0.09. In 1KHz~4KHz and in 8KHz, acoustic absorptivity was 0.06 and 0.08 respectively, indicating that there was not a substantial difference between low a frequency range and a high frequency one.

3.1.3 NRC comparison under different arrangement types

(1) plant 1 : Spathypillum

In the cases of both plants and control, NRC was higher than the background NRC of 0.06, and there was not a substantial difference between plants and control. However, the linear arrangement type showed the highest NRC value.

(2) plant 2 : Araucaria

Like plant 1, NRC was higher than background NRC of 0.06 without plants. Table 3 presents the NRC value of plants (Spathypillum, Araucarai) and control under different arrangement methods.

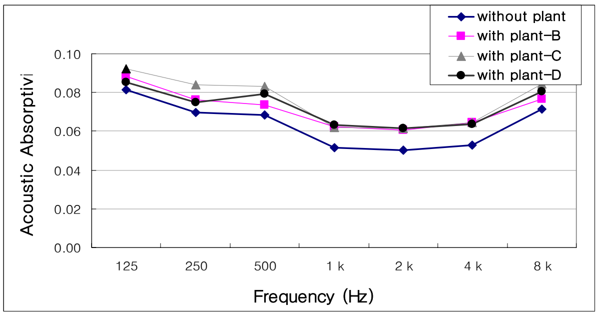


Figure 11 Change of acoustic absorptivity

(with plants status)

Table 3 NRC by setting Type

Division	without plant	with plant case1, case2*			Control		
NRC	A	B	C	D	B'	C'	D'
NRC	0.06	0.08 0.07*	0.08 0.07*	0.07 0.08*	0.08	0.07	0.08

3.1.4 EDT

(1) plant 1 : Spathypillum

EDT results are presented in fig. 12 ~ fig. 15.

Fig. 12 shows frequency-dependent EDT with and without plants. The case with plants decreased compared to the case without plants in most frequency ranges. In 125Hz, type B did not show a substantial difference from type A without plants, but type B' decreased by 1.1. Both type B and type B' decreased by 0.3 and 0.5 in 250Hz and 500Hz respectively. Fig. 13 shows EDT variation among different arrangement types(type B, C, D). Regardless of the type, EDT was lower than that of type A without plants, but type B and type D considerably increased in 125Hz.

From 250Hz to a high frequency range,the reduction effect of EDT under different types showed a similar value to each other.

Moreover, from 1KHz to 4KHz, EDT decreased by 0.6~1, which is considered to be a relatively high value.

Fig. 14 presents EDT difference under different arrangement types(type B', C', D') of the control. Regardless of the type, EDT was lower than the case without plants.

In 125Hz, EDT value considerably decreased. From 250Hz to a high frequency range,the reduction effect was similar to each other regardless of arrangement types, but from 1KHz to 4KHz EDT decreased by 0.3~0.7.

With regard to EDT comparison between plants and control, there was not a substantial difference, but from 1KHz to 4KHz the reduction effect of plants was higher than that of the control.

(2) plant 2 : Araucaria

Fig. 15 presents EDT difference under different arrangement types(type B, C, D). Regardless of the type, EDT was lower than that of type A without plants. In 250Hz, type D showed the highest reduction of EDT by 0.55. In 500Hz, type C showed a reduction of EDT by 0.33, and type B and D showed a similar reduction to each other. In 1KHz, type C showed the highest reduction of EDT by 0.40. In both 4KHz and 8KHz, there was not a substantial difference among arrangement types.

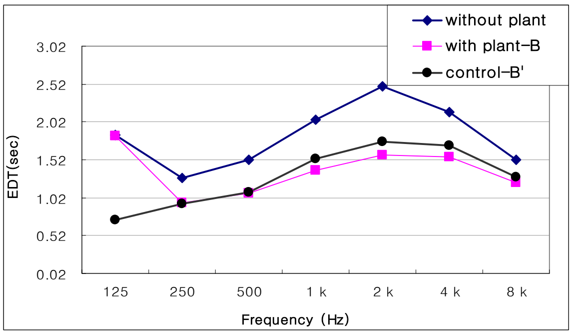


Figure 12 Change of EDT with indoor plantation

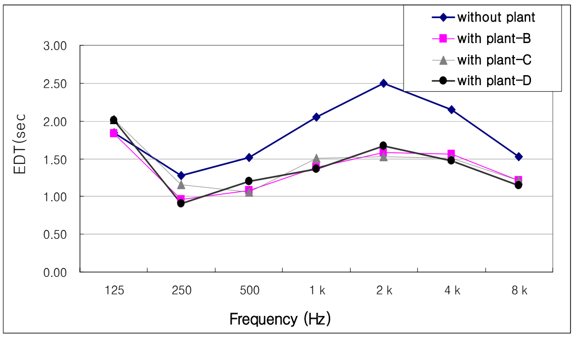


Figure 13 Change of EDT RT by the arrangement types

(With plants status)

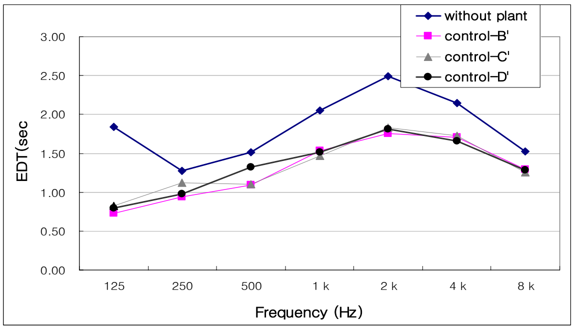


Figure 14 Change of EDT RT by the arrangement types

(With control status)

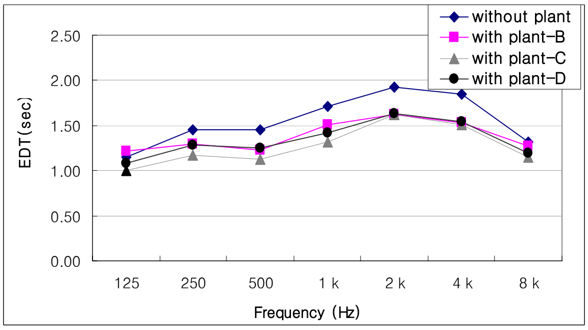


Figure 15 Change of EDT RT by the arrangement types

(With plant status)

3.2 Definition (D50)

D50 values are presented in fig. 16 ~ fig. 19.

(1) plant 1 : Spathypillum

Fig. 16 shows the reverberation time under different frequency ranges with and without plants. Regardless of the frequency range, RT of type B and type B' was longer than that of type A without plants.

The definition of type B was better than that of type B' in a low frequency range, while the definition of type B' was better than that of type B in a high frequency range.

Fig. 17 shows D50 difference of each arrangement type (type B, C, D). Regardless of the type, D50 was higher than that of type A without plants. In 125Hz, 250Hz, 4KHz and 8KHz, there was not a substantial difference of D50 value.

In 500Hz, type D increased by 6%, and in 1KHz and 2KHz type D increased by 17.4% and 10.3% respectively, indicating that the definition was the lowest in a middle frequency range.

Fig. 18 shows D50 difference of each arrangement type (type B', C', D') of the control. Regardless of the type, D50 was higher than that of the type without plants, and there was a significant difference among arrangement types. In 125Hz, type B' showed the highest difference, having the best definition. In 250Hz, type B' also had the best definition among the three arrangement types. In 500Hz, type D' showed the highest increase rate. In a high frequency range, D50 did not show a substantial difference, and in 1KHz and 2KHz type B' and type C' increased by 10% and 6.5% respectively. In 4KHz and 8KHz three arrangement types did not show D50 value, but type B' showed the best definition.

(2) plant 2 : Araucaria

Fog. 19 presents D50 difference of each arrangement type(type B, C, D). D50 showed a larger difference in a low frequency range than in a high frequency one.

In 125Hz, type D showed the best definition. In 250Hz D50 of type B increased, but D50 of type C and type D decreased.

In 500Hz, D50 of type C increased by 3.58%, and in 1KHz ~ 2KHz type D showed the highest decrease rate. In 8KHz, type C showed the highest increase rate.

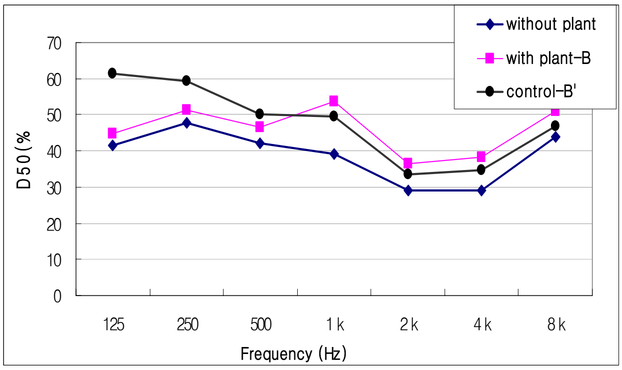


Figure 16 Change of D_{50} with indoor plantation

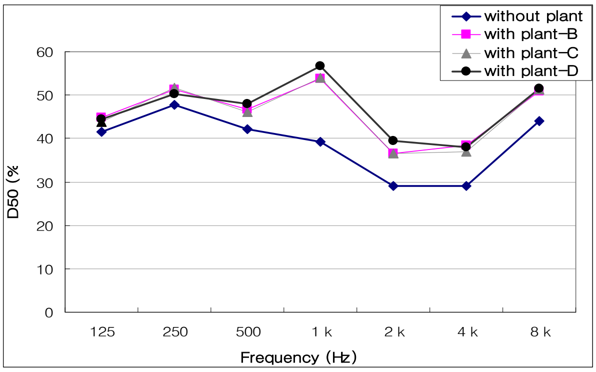


Figure 17 Change of D_{50} by the arrangement types

(With plant status)

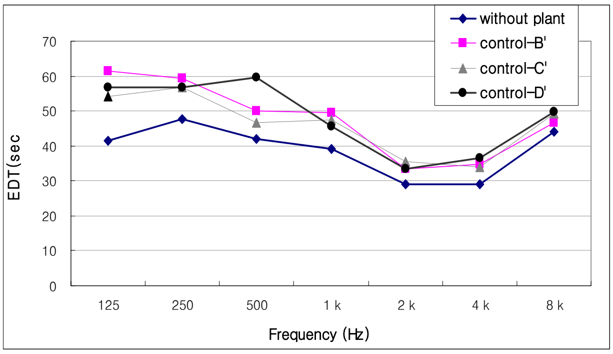


Figure 18 Change of D_{50} by the arrangement types

(With control status)

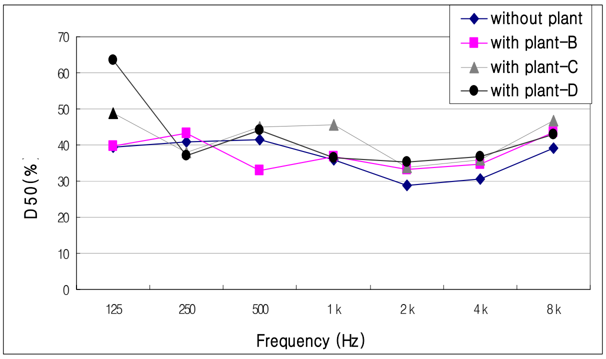


Figure 19 Change of D_{50} by the arrangement types

(With plant status)

4. Conclusion

In this study reverberation time, acoustic absorption, EDT, D50 characteristics with and without indoor plants is investigated in order to provide basic data on the sound-insulating effect of indoor plants in conventional residences and office buildings.

1) The reverberation time of the case with plants decreased, and both acoustic absorption and NRC of the case with plants increased in comparison with the case without plants, indicating that indoor plants have a noise reducing performance.

2) Indoor plants were more effective in reducing acoustic absorption in a low frequency range than in a high frequency one. The linear arrangement type was the most effective in case of plant 1, while there was not a significant difference among arrangement types in case of plant 2.

3) Regarding D50 and EDT difference, indoor plants may have a partial noise reducing performance under different frequency ranges.

4) NRC value of both plants and control was around 0.07~0.08 and did not show a significant difference, indicating that sound absorbing materials emitting indoor pollutants can be replaced effectively.

On the basis of this study, indoor plants can significantly improve indoor environment. Therefore, further research should be carried out on the accumulation of experimental database related to the relationship with acoustic parameters and the investigation of leaf shape, height of plants and acoustic absorption of the soil.

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