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Characteristic of Soil and Cambial Electrical Resistance for Investigation on Defect Cause of Planting Tree in Apartment

Chi-Woung Cho, Sun-Ah Yoo, Jeong-Ho Kim^{1)*}

Department of Environment Horticulture, Sahmyook University, Seoul 139-742, Korea

¹⁾Green Technology Convergence Research Center, Rainbowscape Co., Ltd., Gyeonggi-do 463-856, Korea

Abstract

The purpose of this paper is to provide information on planting construction for healthy plant growth. To achieve this purpose, this study analyzed the planting type, planting density, withering rate, soil characteristics, and cambium electrical resistance (CER) of withered trees in an apartment complex with a high withering rate. The major plant groups examined consisted of native broad-leaved tree species (39.3%), native narrow-leaved tree species (24.2%), and native broad-leaved - exotic narrow-leaved tree species (16.4%). The planting density of the green area, where trees were planted from 0.0 to 0.3 trees per unit area, was measured as 98.4%. Withered trees were found in 19 of the 20 planted species, and the withering rate was 41.8% (610 withered/1,461 planted). Withering rates for tree species were measured as follows: *Sophora japonica* and *Salix babylonica* (100.0%), *Magnolia denudata* (84.3%), *Lindera obtusiloba* (74.7%), *Cornus kousa* (69.3%), *Acer triflorum* (69.2%), *Diospyros kaki* (66.7%), *Prunus yedoensis* (62.8%), *Acer palmatum* (52.6%), *Prunus armeniaca* (51.1%), *Chaenomeles sinensis* (43.7%), *Ginkgo biloba* (40.9%), *Zelkova serrata* (31.0%), *Cornus officinalis* (28.6%), *Taxus cuspidata* (25.6%), *Pinus densiflora* (21.4%), *Pinus parviflora* (15.2%), *Pinus strobus* (14.6%), and *Abies holophylla* (10.3%). Soil chemical analyses for 18 samples revealed that as the withering rate increased, the following occurred: (a) the ratio of silt and clay in soil increased; (b) the soil pH, organic matter rate, nitrogen, available phosphorus, and cation exchange capacity (CEC) in samples were graded as “inadequate,” based on the plant grading evaluation; and (c) the NaCl and cation exchange capacity were evaluated as “somewhat satisfactory.” The measurement of CER for withering rate shows electrical resistance for higher withering rate are higher, which could predict that a tree will not grow well.

Key Words : Planting type, Planting density, Withering rate, Cambial electrical resistance(CER)

1. Introduction

Apartment complexes were created to improve the efficiency of land use in urban areas. The Mapo Apartment Complex, the first residential apartment complex in Seoul, was constructed in 1964, and large-scale construction of additional complexes began after the 1988 Seoul Olympics. Initially, apartment complexes were constructed from the perspective of economic efficiency, focused on

intensive land use and convenience. Since the external space was recognized as just leftover space after construction, the residential environment and ecological quality were worsened.

The change in the external areas around apartments began as part of a differentiated external space strategy that resulted from the oversupply of apartments following 2 million housing construction projects initiated by the government in the 1980s. Large theme parks, spaces for environmental education, lawn areas,

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*Corresponding author : Jeong-Ho Kim, Green Technology Convergence Research Center, Rainbowscape Co., Ltd., Gyeonggi-do 463-856, Korea
Phone: +82-31-768-1891(400)
E-mail: klab003@gmail.com

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cherry blossom fields, and hydroponic facilities were built in external areas; however, the attempt showed the limit on improvements in the environment and scenic beauty (Song and Yang, 2006). After the 1980s, research on eco-friendly technology and green area improvements for external spaces began. A green area around an apartment complex is the most important factor in total resident satisfaction. Kim et al. (2004) studied the changes in green area alignment and planting density depending on the periodic change in the floor-area ratio of apartments. In addition, Lee (2005), Lee et al. (2009), and Hong et al. (2009) have conducted studies on a relationship between apartment green areas and plants.

Eco-friendly technology has been emphasized, and the importance of apartment green areas that occupy most external space has increased. However, standards and guidelines for tree planting, proper planting density (Lee and Lee, 1999), separation distance and shade hours (Yoon and An, 1996), ground structure (Cho, 2010), and soil property have not yet been determined. Kang (1984), Koo (1993), and Im (2000) studied the defects of planting and landscaping construction and presented major causes of the defects, such as selecting and planting types of tree without considering ecological characteristics or climate, as well as planting without providing essential nutrition. Kim (2006) analyzed the defects in trees planted around apartment complexes in 1994, 2006, and 2007. He revealed that the major trees with defects were *Pinus densiflora*, *Acer buergerianum*, *Diospyros kaki*, *Acer palmatum*, *Taxus cuspidata*, and *Pinus koraiensis*, and the major defect causes were environment, construction duration, and import status of trees. Kim suggested planting at the right time, providing a good state of preservation, and minimizing transport distance as solutions and proposed improving poor ground as the most important factor. Ku (1993) conducted a study on planting defects in a seaside landfill, and Cho (2010) presented

a study on tree growth characteristics depending on ground structure; however, no researcher has conducted a study on characteristics and solutions for poor tree growth depending on soil conditions in an urban apartment complex.

Therefore, this study selected an apartment complex where more than 50% of the trees were defective and hypothesized that poor tree growth results from poor soil conditions and poor drainage. Also, this study analyzed the quality of the green area, the state of planting, the state of withered trees, and the vitality of the trees around the apartment complex to assess and provide basic information for sound tree growth.

2. Materials and Methods

2.1. Investigation Timing and range

This study selected an area with a planting defect ratio of more than 40% among apartment complexes built in Seoul and the national capital region in 2011. Criteria for selecting the area were as follows: (a) the green area took up more than a certain ratio; (b) the planting defect ratio was more than 40% within one year of planting construction; (c) the state before and after the defects could be detected in detail; and (c) little if any plant management had been conducted after construction completion.

Fig. 1. Location map of survey site.

Based on the criteria, an apartment complex constructed near Kyomoon-dong Guri Gyunggi in 2011 was chosen for the study. The area size was 25,759.00 m², and the total number of households was 299. The size of the landscape area was 10,503.00 m², and 40.77% of that was land area. The size of the green area was 3,864.15 m², and the number of plants was 1,629 trees and 21,750 shrubs.

2.2. Analysis method

In this study, according to the studies of Kim (1999) and Nakashima(1992), the planting pattern was defined as native and exotic narrowleaf and broadleaf. Planting density was measured by the number of plants per unit area of a block. Withering rate was ordered into six classes based on the ratio of withered trees for a block: Class 1 (81~100%), Class 2 (61~80%), Class 3 (41~60%), Class 4 (21~40%), Class 5 (1~20%), and Class 0 (0%). Eighteen samples of soil were gathered from nine places at 20 cm and 40 cm below the ground surface. Depending on the analytical methods of soil and plant (National Institute of Agricultural Science and Technology, 2000), soil chemical properties, such as soil pH, conductance, organic matter rate, available phosphorus, and cambium electrical resistance (CER), were analyzed, and then the analyzed soil chemical properties were evaluated according to the classes of soil evaluation (The Korean Institute of Landscape Architecture, 2007). Vitality of the trees and withering rates were analyzed with all major tree species. Based on Lee et al. (1997), the measurement of CER was used to represent the vitality of the trees. CER was measured by a portable ohmmeter—the Shigometer, made by OSMOSE Co.—between 10:00 and 15:00, when metabolic activity was vigorous. To minimize error, CER was gauged at chest height from four directions, and then the averaged CER was calculated. Needle electrodes were pushed into the xylem in a perpendicular direction, and CER was

measured when the gauged value was stable. Temperature and humidity were recorded when CER was measured. Researchers conducted the survey of the green area, measured the vitality of the trees, and picked the soil samples in August 2011.

3. Results and Discussion

3.1. Planting type and density

Measurements of the apartment complex area size and rate of the tree planting pattern (observed for both exotic and native species and classified via narrow and broad leaves) are presented in Table 1. The largest area consisted of native broadleaf trees (39.3%; 4,308.9 m²), followed by native narrowleaf trees (24.2%; 2,650.7 m²), native broadleaf - exotic narrowleaf trees (16.4%; 1,682.9 m²), native narrowleaf- native broadleaf trees (9.3%); exotic narrowleaf trees (7.8%), native broadleaf - native narrowleaf trees (3.1%), exotic narrowleaf - native narrowleaf trees (0.6%), and grass (0.2%). Consistent with our results, a previous study on the green space arrangement and planting structure of a major apartment complex in Seoul (Lee, 2004) reported that 55.66-74.60% of deciduous broad-leaved trees were distributed in the designated landscape area, and another small area was developed with evergreen coniferous trees and herbaceous spaces. Recently, it has been pointed out as problem that just focus on the diversity of plant species through

Table 1. Area and rate by tree planting type

Type	Area (m ²)	Rate (%)
Exotic narrowleaf tree	878.5	7.8
Exotic narrowleaf - native narrowleaf tree	59.8	0.6
Native narrowleaf tree	2,650.7	24.2
Native narrowleaf - native broadleaf tree	1,020.2	9.3
Native broadleaf tree	4,308.9	39.3
Native broadleaf - native narrowleaf tree	336.1	3.1
Native broadleaf - exotic narrowleaf tree	1,682.9	16.4
Grass	19.7	0.2
Total	10,956.8	100.0

Fig. 2. Planting model in research area.

Fig. 3. Map of planting density in research area.

increasing the plant species of exotic garden trees for emphasizing a landscape without considering the growth of trees and ecological characteristics.

In 1999, the average planting density for trees per landscaped area was reported as 0.25 tree/m² for tree layers at 137 municipal areas nationwide (Choi, 1999). In addition, the standard for planting density for landscaped areas was a tree layer of 0.2 tree/m² and a shrub layer of 1.0 shrub/m² in residential spaces. According to Kim et al. (2004), planting density for trees was reported as 0.04~0.31 trees/m², and shrubs were 0.06~0.37 shrubs/m². In addition, the increased pattern for tree planting density from 5 trees/100 m² to 14.5 trees/100 m² in green areas around apartment complexes located in Seoul and the metropolitan area was exhibited by Lee et al. (2009).

In this study, we analyzed the planting trees for the tree layer in the chosen apartment complex, and the data for area and ratio by planting density are presented

in Table 2. The largest area was 51.8% (5,678.7 m²) for a planting density of 0.1~0.2 tree/m², followed by 25.4% (2,778.8 m²) for 0.0~0.1 tree/m², 21.2% (2,324.85 m²) for 0.2~0.3 tree/m², 1.4% for 0.3~0.4 tree/m², and 0.2% for others.

3.2. Withered trees and growth grade in planting space

3.2.1. Analysis of withering rate in major planted species

The total planted trees for the tree layer were 19 species (5 evergreen tree and 15 deciduous tree), and 19 tree species were withered (5 evergreen tree and 14 deciduous tree). The withering rate was 95%, meaning that almost all the tree layers were withered. Since the planting season was from March to May for the research area, we could not expect the major reasons for the defects of the trees to be general, such as planting season, planting method, and planting species (Kim, 2006), but instead to be the planting base (Ku, 1993). Also, we could consider that there was no relation between plant species and daylight hour (Yoon and An, 1996), judging from the fact that the withered trees were spread out across the entire area. The rate of withered trees per number of planted trees was 41.8% (610 withered trees out of 1,461 planted trees). Of the 19 species, the number of planted trees for each species was as follows: *Pinus*

Table 2. Area and ratio by planting density

Planting density(tree/m ²)	Area(m ²)	Ratio(%)
0.0~0.1	2,778.8	25.4
0.1~0.2	5,678.7	51.8
0.2~0.3	2,324.8	21.2
0.3~0.4	154.7	1.4
Others(grass etc.)	19.7	0.2
Total	10,956.8	100.0

strobis—171 trees; *Pinus parviflora*—125 trees; *Abies holophylla*—116 trees; *Magnolia denudata*—108 trees; *Pinus densiflora*—98 trees; *Cornus officinalis*—98 trees; *Prunus armeniaca*—94 trees; *Clethra barbinervis*—83 trees; *Cornus kousa*—75 trees; *Chaenomeles sinensis*—71 trees; *Ginkgo biloba*—66 trees; *Acer triflorum*—52 trees; *Diospyros kaki*—48 trees; *Prunus yedoensis*—43 trees; *Taxus cuspidata*—39 trees; *Zelkova serrata*—29 trees; *Sophora japonica*—7 trees; and *Weeping foliage*—1 tree. Among these, withered trees were found in *Magnolia denudata* (91 trees), *Acer palmatum* (72 trees), *Clethra barbinervis* (62 trees), *Cornus kousa* (52 trees), *Prunus armeniaca* (48 trees), *Acer triflorum* (36 trees), *Diospyros kaki* (32 trees), *Chaenomeles sinensis* (31 trees), *Cornus officinalis* (28 trees), *Prunus yedoensis* (27 trees), *Ginkgo biloba* (27 trees), *Pinus strobus* (25 trees), *Pinus densiflora* (21 trees), *Pinus parviflora* (19 trees), *Abies holophylla* (12 trees), *Taxus cuspidata* (10

trees), *Zelkova serrata* (9 trees), *Sophora japonica* (7 trees), and *Weeping foliage* (1 tree).

The withering rate per planted tree is presented in Fig. 4. Even though small numbers of trees were planted, the withering rate was 100% in both pagoda trees and weeping foliage. The remaining percentages of withering rate were found to be *Magnolia denudata* (84.3%), *Clethra barbinervis* (74.7%), *Cornus kousa* (69.3%), *Acer triflorum* (69.2%), *Diospyros kaki* (66.7%), *Prunus yedoensis* (62.8%), *Acer palmatum* (52.6%), *Prunus armeniaca* (51.1%), *Chaenomeles sinensis* (43.7%), *Ginkgo biloba* (40.9%), *Zelkova serrata* (31.0%), *Cornus officinalis* (28.6%), *Taxus cuspidata* (25.6%), *Pinus densiflora* (21.4%), *Pinus parviflora* (15.2%), *Pinus strobus* (14.6%), and *Abies holophylla* (10.3%).

Based on another study that examined defective plant species at apartment complexes in 1994, 1997, and 2006 (Kim, 2006), major defective plant species were *Pinus densiflora*, *Chaenomeles sinensis*, *Diospyros*

Fig. 4. Planted trees versus withering rate.

* Pd: *Pinus densiflora*, Tc: *Taxus cuspidata*, Pp: *Pinus parviflora*, Ah: *Abies holophylla*, Ps: *Pinus strobus*, Dk: *Diospyros kaki*, At: *Acer triflorum*, Zs: *Zelkova serrata*, Cs: *Chaenomeles sinensis*, Pa: *Prunus armeniaca* var. *ansu*, Lo: *Lindera obtusiloba*, Md: *Magnolia denudata*, Ck: *Cornus kousa*, Py: *Prunus yedoensis*, Gb: *Ginkgo biloba*, Ap: *Acer palmatum*, Sj: *Sophora japonica*, Apd: *Acer palmatum* var. *dessoctum*

kaki, jujube trees, *pinus parviflora*, *zelkova serrate*, maple trees, *cornus kousa*, *taxus cuspidata*, pagoda trees, ginkgo trees, plum trees, and *pinus koraiensis*. The major reasons for plant defects were poor soil ingredients and improper selection of species for planting, such as *diospyros kaki*, which is a southern species.

Although some fruit trees that grow well in southern regions, such as *Diospyros kaki* (Kim, 2006), were included in our research area, most of the planted tree species were suited for central regions. In addition, another study reported that the chance of shade hours causing withered trees is low (Yoon and An, 1996). Therefore, we determined that the major reason for the withered trees in our study was soil ingredients and drainage problems. A recent study by Kim (2006) suggested that drainage problems was improved since the soil ingredients were embarked above the artificial ground, but the drainage problem may cause withered trees if the soil includes a lot of clay. Continuation with the result, Cho (2010) suggested that artificial ground and soil were major reasons for growth defects.

3.2.2. Withering rate and grade in planting block

The grades of withered trees were analyzed at the planting block, which was selected for the study of planting type (Table 3 and Fig. 5). The grades of withered trees were divided into five grades (20% per grade). The 72% of total withering rate consisted of the following: grade 4 (withering rate 21-40%, ratio 24.2%, and area 2,650.6 m²) > grade 5 (withering rate 1-20%, ratio 23.9%, and area 2,618.3 m²) > grade 3 (withering rate 41-60%, ratio 23.8%, and area 2,612.8 m²). The remaining area was composed of grade 2 (6.7%) and grade 1 (3.8%). In the case of grade 1, the distribution of the grade of withered trees in the planting block was located in the north area of buildings 106 and 107. However, the daylight hours were estimated to be enough for plant growth based on the layout of the buildings. The other plant grades

were distributed among the entire planting area at each building in the apartment complex.

Table 3. Grade of withered tree, area, and ratio in planting block

Grade	Rate(%)	Area(m ²)	Ratio(%)
1	81~100	412.3	3.8
2	61~80	738.1	6.7
3	41~60	2,612.8	23.8
4	21~40	2,650.6	24.2
5	1~20	2,618.3	23.9
6	-	1,924.7	17.6
Total		10,956.8	100.0

Fig. 5. Distribution of grade of withered tree in planting block.

3.3. Characteristics of the soil in the planting space by grade of withered tree

3.3.1. Analysis of soil characteristics by soil structure profile in planting area per grade of withered tree

Depending on the amount of clay and silt, drainage problems could exist. Thus, in this study, the soil characteristics were analyzed. Soil from 20 cm and 40 cm below the surface of each grade of withered tree was selected for analysis.

As shown in Fig. 6, we analyzed the characteristics of soil taken from the two locations in the first grade of withered tree area. The amount of clay was 10.7~15.1% and 15.5~20.8% at 20 cm and 40 cm,

respectively. At grade 2, the amount of clay was 7.1~10.3% and 9.4~11.2% at 20 cm and 40 cm, respectively. At grade 3, the amount of clay was 9.7~10.8% and 10.5~13.8% at 20 cm and 40 cm, respectively. At grade 0 (no withered trees), the amount of clay was 6.6% and 5.9% at 20 cm and 40 cm, respectively.

The silt and sand containment rate at 20 cm depth was 27.7%, 29.5~41.0% (average 32.25%), 29.2~33.7% (average 32.2%), and 27.6~33.2% (average 31.3%) in grade 0, 1, 2, and 3, respectively. At 40 cm depth, the silt and sand containment rate was 27.2%, 31.0~55.8% (average 43.4%), 30.6~41.3% (average 34.6%), and 28.1~44.2% (average 38.4%) in grade 0, 1, 2, and 3, respectively. These data show that the rate of withered trees was higher at the locations containing higher silt and sand rates in the soil structure profile. The presence of clay causing a drainage problem could be the reason.

According to Yoo (2002), the proper soil compositions for plant growth are 25% soil air

content, 25% soil water content, 45% inorganic constituents, and 5% organic constituents. Based on the present data, we could expect that the contents of silt and clay caused poor drainage and insufficient water and air in the soil. The chance of causing withered trees especially increases during the rainy season in summer due to temporary poor drainage conditions. Our data may have been affected by the rainy season causing insufficient air conditions in the soil due to poor drainage. A new system may be needed to improve the poor drainage and insufficient air conditions.

3.3.2. Soil chemical analysis by soil structure profile of planting area per classified grade of withered tree

The diagram of the characteristics of the soil chemical analysis and plant grading evaluation are presented in Fig. 7. The assessment factors were soil pH, organic matter content, nitrogen, available phosphorus, CEC, EC, and NaCl.

Soil pH is defined as the negative logarithm of the

Fig. 6. Analysis of granularity by soil characteristic based on the soil structure profile (20 cm, 40 cm) in grade of withered tree.

activity of hydrogen ions in the soil solution and is considered a principal value that indirectly indicates the concentration of hydrogen ions. The soil pH is an important chemical characteristic that affects the availability of nutrition and solubility of chemicals, controlling the chemical reactions in the plant root and microorganisms (The Korean Environmental Sciences Society, 2009). The recommended soil pH for landscape planting is pH 5.0~7.0 (Nakashima, 1992). According to the The Korean Institute of Landscape Architecture (2007), tree planting is available for the lowest grade of soil (pH 4.5~5.5 and 7.0~8.0) in our nation; however, a middle grade of soil (pH 5.5~6.0, 6.5~7.0) is recommended for general infertile land and embankmented land above artificial ground. In this study, the soil pH taken from 18 locations was

pH 7.2~8.6 (average value was 7.9 ± 0.5 and mode was pH 8.4). This value located at the lower grade was based on the grades given in the Landscape design standards (The Korean Institute of Landscape Architecture, 2007) and cannot satisfy for the range for pH 5.0~7.0 suggested by Nakashima(1992).

Organic matter (OM) is matter that comes from decay of fallen leaves and plant roots. The soil organic matter inhibits loss of nitrogen by absorption of ammonia and increases three- to five-fold the CEC compared to the same amount of clay. Also, it contributes to the improvement of the water-holding capacity since the soil organic matter is capable of absorbing a large amount of water. Fertile soil is considered soil that contains as much organic matter as possible (The Korean Environmental Sciences

Fig. 7. Diagram of characteristics of soil chemical analysis at 18 locations and plant grading evaluation.

Society, 2009). In the present study, the soil organic matter taken from 18 locations exhibited a range of 0.12~0.75% , the mode was 0.47%, and the average value was $0.40 \pm 0.2\%$. This result indicated that the value of the soil organic matter was at the lower level, which is insufficient for planting, according to the Landscape design standards (The Korean Institute of Landscape Architecture, 2007).

Nitrogen is an essential chemical element in the structure of amino acid to make protein for living organisms. Nitrogen deficiency in plants causes poor growth, such as small leaves and thin stems, and ultimately results in inferior flower blossoms and fruit (The Korean Environmental Sciences Society, 2009). The range of nitrogen content taken from 18 locations in this study was 0.003~0.060%. The mode was 0.007%, and the average value was $0.010 \pm 0.013\%$. As a result, the nitrogen content was low, indicating insufficient content for planting, according to the Landscape design standards (The Korean Institute of Landscape Architecture, 2007).

Phosphorus, a component of nucleic acid, protein, and phospholipid, is another essential element for the growth and reproduction of plant cells and requires carbohydrates and energy metabolism. A phosphorus deficiency in early growth of plants causes dwarf plants, a phenomenon that causes plants not to grow (The Korean Environmental Sciences Society, 2009). The range of available phosphorus taken from the 18 locations in this study was 10.0~91.0 mg/kg. The mode was 18.0 mg/kg, and the average value was 31.1 ± 21.1 mg/kg. The range of available phosphorus was low, indicating insufficient amounts for planting, according to the Landscape design standards (The Korean Institute of Landscape Architecture, 2007). In addition, the level of available phosphorus was lower than the nation's standard level of 5.6 mg/kg for forest soil in nonagricultural areas (Kim et al., 1995), 250 mg/kg for upland soil (Yoo, 2002), and 100 mg/kg for paddy soil (Yoo, 2002), but higher than the

suggested value (topsoil average 1.90~8.71 mg/kg and subsoil average 5.56~8.49 mg/kg) by Cho (2010), who analyzed the soil from planting bases in major apartment complexes in the metropolitan area. Taken together, we could expect that the available phosphorus content is generally low in green areas of apartments in South Korea. This low content level is important in explaining the reason why plants grow poorly after planting.

Cation exchange capacity (CEC), total volume of exchangeable cation in the amount of soil (Ryu, 2002), also indicates the volume of negative charge in the amount of soil. Soil with large CEC means there is exchangeable cation in the soil, so a fertile soil means a rich CEC. Therefore, large CEC helps increase the efficiency of fertilizer (The Korean Environmental Sciences Society, 2009). CEC in this research area was measured as 4.52~10.24 cmol/kg, compared to the average value range of 7.13 ± 1.46 cmol/kg. The CEC is graded as middle class in Landscape Design Standards, but CEC needs to be at least 12 cmol/kg in order to enhance plant growth and survival.

Exchangeable cation is absorbed cation due to electrical attraction of negatively charged soil surface (Yoo, 2002) and affects the soil characteristics and fertility. Among the exchangeable cations, potassium ion (K^+) contributes to the regulation of plants and transpires and activates the starch and amino acyl tRNA syntheses (Kim et al., 2011; Bamda and Malik, 1988). In our research area, the level of exchangeable potassium ion was measured as 0.23~0.55 cmol/kg, and showed a mode of 0.27 cmol/kg and an average of 0.30 ± 0.10 cmol/kg. This value was similar to the value of forest soil in nonagricultural areas, which is 0.25 cmol/kg (Kim et al., 1995), but lower than the standard value for planted areas, which is at least 0.6 cmol/kg (The Korean Environmental Sciences Society, 2009). The value was similar when compared with the suggested value (topsoil average 0.21~0.44

cmol/kg and subsoil average 0.17~0.34 cmol/kg) by Cho (2010), who analyzed the soil from planting bases in major apartments in the metropolitan area. An exchangeable sodium ion (K^+) causes poor drainage and soil aggregation through the dispersion of soil particles, thereby aggravating the congregation of soil water and decreasing the permeability coefficient (Frenkel et al., 1987). The value of exchangeable K^+ in the research area was measured as 0.06~0.25 cmol/kg, indicating optimal amounts, and showed a mode of 0.13 cmol/kg and an average of 0.20 ± 0.10 cmol/kg. Exchangeable nitrogen (Na^+) is a major element and highly reactive with alkali matter in soil, and the increased alkaline of soil is obstructive for plant growth (Ku et al., 1998). If the Na^+ content is increased in the soil solution, calcium ion among the exchangeable cation is absorbed and exchanged to Na^+ in the soil. Finally, the accumulated Na^+ is absorbed by plants and causes defects (The Korean Environmental Sciences Society, 2009). Calcium (Ca^{2+}) protects the cell wall and is as essential as organic matter or inorganic matter for stabilization of cell wall structure, regulation of ion transport, enzyme activity, and ion exchange (Demarty and Thellier, 1984). In the apartment complex selected for this research, the Ca^{2+} value was measured as 3.30~14.11 cmol/kg (average value was 8.06 ± 3.27 cmol/kg), and the grade was the higher class in the Landscape Design Standards. Magnesium (Mg^{2+}) is a major component of chlorophyll and affects the carbon dioxide assimilation (Lee, 1996). An Mg^{2+} deficiency exhibits leaf chlorosis (Kim et al., 2011). The Mg^{2+} value in the research area was measured as 0.23~1.85 cmol/kg and showed an average of 0.86 ± 0.46 cmol/kg and a mode of 0.35 cmol/kg. The value was similar to the average value (0.70 cmol/kg) for forest soil in the nation, and it was a higher class in the Landscape Design Standards.

Landfill areas and impoverished soil where high conductance is measured can inhibit plant growth.

Therefore, conductance of soil and irrigation water is used as important chemical indicators to judge salt damaged plant (Ryu, 2002). Generally, if conductance is less than 2.0 dS/m, tree planting is possible. If conductance is more than 4.0 dS/m, plant growth is not normal. If conductance is more than 8.0 dS/m, tree planting except flameproof species is difficult (Marucum and Murdoch, 1990; Tanji, 1990). The conductance in this research area was measured as 0.27~0.83 dS/m and showed a mode of 0.65 dS/m and an average of 0.57 ± 0.17 dS/m. This level of conductance can inhibit plant growth but is graded as middle class in the Landscape Design Standards. Proper NaCl for tree growth is less than 0.05% (The Korean Institute of Landscape Architecture, 2007). The research area showed 0.005~0.010% NaCl (average $0.008 \pm 0.001\%$), which indicated that the area was suitable for tree growth.

3.4. Viability analysis of trees

Ten major planted tree species (64 trees) were analyzed for viability. The Shigometer, a machine designed for measuring viability of trees, requires circumspection for the application, for instance, the need to consider the growth pattern and characteristics of the trees, the temperature condition of the trees, and the diameter of the trees (Ha, 2000). Therefore, trees of 5-12 cm diameter at breast height (DBH) from the same area at 1 year after planting were selected. Generally, the CER value is low in trees having good viability, and trees having poor viability show high CER values (Shigo, 1991). Since high temperature causes increased water potential, the CER values are decreased due to the increased concentration of the carrier positive ion in the cambium (Dixon et al., 1978). Therefore, the CER is lower when measuring in the summer season due to the increased temperature. In addition, dry conditions in the winter season is another reason for the higher CER value (Lindberg and Johansson, 1989).

Researchers have demonstrated that cambium of trees and CER values depend on the season and weather conditions (Caboun, 1996; Song et al., 2002). Lee et al. (1997) demonstrated that the CER value depended on the species of tree and seasonal variations using 20 different landscaping trees. Later, another study compared the CER values depending on seasonal variations, composition of trees, and grade of diameter using 19 different landscaping trees (Ha, 2000). Although there was little seasonal variation, the CER value of fast-growing trees such as metasequoia and tulip trees was lower, and the slow-growing trees such as ginkgo trees was higher than other trees (Ha, 2000).

Even though the previous study demonstrated that the comparison of CER by the different tree species was such a big meaning, we first measured the average CER values by tree species and then analyzed the value based on the grade of withered tree in this study. The CER was measured using trees in August with restricted conditions: similar DBH, a temperature of 30°C, and a relative humidity of 70% in the apartment complex. The order of average CER was *Prunus armeniaca* (25.6kΩ) > *Acer triflorum* (9.0 kΩ) > maple tree (8.9kΩ) > *Chaenomeles sinensis* (7.9 kΩ) > ginkgo tree (6.6kΩ) > *Cornus kousa* (6.4kΩ) >

Pinus parviflora (4.6kΩ) > *Zelkova serrata* (3.9kΩ) > cherry tree (3.6kΩ) > *Abies holophylla* (3.0kΩ). Similar results were obtained by Ha (2000), who studied CER values depending on different tree species.

The comparison of CER values by grade of withered tree was presented in Table 4, and the values were obtained from both deciduous broad-leaved trees (10 trees of 2 species) and evergreen coniferous trees (10 trees of 2 species). The distribution by grade of withered trees in the trees selected for study is shown in Fig. 9. In the case of maple trees, the CER value was measured using trees planted in grades 1, 2, and 3. The average CER values were 10.21 ± 0.41 , 9.76 ± 1.16 , and 8.77 ± 1.04 in grades 1, 2, and 3, respectively. The results demonstrate that the tree growth was good in the locations having a lower grade of withered trees due to the low value of CER. The CER for *Chaenomeles sinensis* was measured using grade 2, 4, and 5, and the average CER values were 7.92 ± 2.25 , 5.73 ± 0.81 , and 4.05 ± 0.78 in grade 2, 4, and 5, respectively. Results demonstrate that if there is a lower rate of withered trees, trees have decreased CER values. Among the evergreen coniferous trees, *Pinus parviflora* was measured using trees planted in grade 1, 2, 3, and 4, and the CER values were 6.40 ± 0.85 , 4.62 ± 1.00 , 4.23 ± 0.93 , and 3.90 ± 0.84 for grade 1, 2, 3, and 4, respectively. The CER value of *Abies holophylla* was shown as 8.40 ± 3.48 and 7.10 ± 2.04 for grade 2 and 4, respectively. Taken together, all the selected four species for analysis demonstrated that the lower the rate of withered tree, the more decreased the CER values. The results indicate that if the weather conditions and tree species are the same, the higher rate of withered trees reflects poor tree growth for growing trees.

Fig. 8. Distribution of average CER of major planted trees.

* Gb: *Ginkgo biloba*, Cs: *Chaenomeles sinensis*, Ah: *Abies holophylla*, Pp: *Pinus parviflora*, Ap: *Acer palmatum*, At: *Acer triflorum*, Pa: *Prunus armeniaca* var. *ansu*, Py: *Prunus yedoensis*, Zs: *Zelkova serrata*, Ck: *Cornus kousa*

Table 4. Variation of average CER value by grade of withered tree in major trees (unit k Ω)

Division		Grade of withered tree				
		1	2	3	4	5
<i>Acer palmatum</i>	Maximum	10.5	11.1	10.0		
	Minimum	9.9	8.8	8.0	-	-
	Average	10.21 $\pm$ 0.41	9.76 $\pm$ 1.16	8.77 $\pm$ 1.04		
<i>Chaenomeles sinensis</i>	Maximum		10.8		6.3	4.6
	Minimum	-	4.7	-	5.2	3.5
	Average		7.92 $\pm$ 2.25		5.73 $\pm$ 0.81	4.05 $\pm$ 0.78
<i>Pinus parviflora</i>	Maximum	7.0	5.5	5.9	5.5	
	Minimum	5.8	3.5	3.4	3.2	-
	Average	6.40 $\pm$ 0.85	4.62 $\pm$ 1.00	4.23 $\pm$ 0.93	3.90 $\pm$ 0.84	
<i>Abies holophylla</i>	Maximum		11.6		9.5	
	Minimum	-	4.7	-	5.6	-
	Average		8.40 $\pm$ 3.48		7.10 $\pm$ 2.04

Fig. 9. Distribution of viability for major planted trees by withered trees in the planted area.

4. Conclusions

This paper provides information on planting construction for healthy plant growth. To achieve this purpose, this study analyzed the planting pattern, planting density, withering rate, soil characteristics, and cambium electrical resistance in apartment complexes.

The major plant groups studied consisted of native broad-leaved tree species (39.3%), native narrow-

leaved tree species (24.2%), and native broad-leaved - exotic narrow-leaved tree species (16.4%). The planting density of the green area, where trees were planted from 0.0 to 0.3 trees per unit area, was measured as 98.4%.

Withered trees were found in 19 species among 20 planted tree species, and the withering rate was 41.8% (610 withered/1,461 planted). Withering rates for tree species were measured as follows: *Sophora japonica* and *Acer palmatum* var. *dessioctum* (100.0%), *Magnolia denudata* (84.3%), *Lindera obtusiloba* (74.7%), *Cornus kousa* (69.3%), *Acer triflorum* (69.2%), *Diospyros kaki* (66.7%), *Prunus yedoensis* (62.8%), *Acer palmatum* (52.6%), *Prunus armeniaca* (51.1%), *Chaenomeles sinensis* (43.7%), *Ginkgo biloba* (40.9%), *Zelkova serrata* (31.0%), *Cornus officinalis* (28.6%), *Taxus cuspidata* (25.6%), *Pinus densiflora* (21.4%), *Pinus parviflora* (15.2%), *Pinus strobus* (14.6%), and *Abies holophylla* (10.3%). The distribution of withering rate was evaluated as follows: Class 4 (24.2%), Class 5 (23.9%), Class 3 (23.8%), Class 2 (6.7%), and Class 1 (3.8%). Soil chemical analyses for the 18 samples in this study revealed that as the withering rate

increased, the following occurred: (a) the ratio of silt and clay in soil increased; (b) the soil pH, organic ingredient rate, nitrogen, available phosphorus, and CEC in samples were graded as “inadequate” according to the plant grading evaluation; and (c) the NaCl and cation exchange capacity were evaluated as “somewhat satisfactory.”

This study analyzed causes and features of withering trees at an apartment complex with a high withering rate. In the future, soil physical structure needs to be accurately analyzed with standards for measuring CER depending on seasons and tree species. In addition, causes of withering and growing of trees need to be studied based on relationship analysis between the factors.

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