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Particulate Matter Capture and Air Pollution Tolerance of Six Roadside Plants in Cheongju, South Korea

ABSTRACT

Particulate matter (PM), a highly hazardous air pollutant with known adverse health effects, has been proven to be effectively mitigated by using plants. This study aimed to evaluate the capacity of various plants in capturing PM and their tolerance to air pollution. This will facilitate the selection of suitable species for roadside planting. Accordingly, this research quantified the accumulation of particulate matter in six different plant species. Four biochemical parameters [total chlorophyll, leaf pH extract, relative water content, and ascorbic acid] were evaluated to determine the Air Pollution Tolerance Index (APTI), PM accumulation results varied among the plant species. The tolerance level was categorized into four groups: tolerant, moderately tolerant, intermediate, and sensitive. Ligustrum obtusifolium demonstrated the highest PM accumulation and tolerance index values. The presence of leaf hair and roughness on leaf surfaces was observed to facilitate higher PM accumulation in certain plants. PM accumulation on leaves was significantly correlated with biochemical parameters and APTI of plants. Based on these outcomes, Ligustrum obtusifolium, Hibiscus syriacus, and Chamaecyparis obtusa were identified as suitable for roadside planting to mitigate atmospheric particulate matter.

Keywords: *air pollution, biochemical parameters, landscaping planting, Ligustrum obtusifolium, Hibiscus syriacus, Chamaecyparis obtusa*

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INTRODUCTION

Rapid urbanization and industrialization bring many environmental problems and cause increasing air pollution in urban areas (*Pacheco et al. 2017*). Anthropogenic activities, such as traffic emissions, heating systems, shipping emissions, and industrial combustion are among the primary sources of particulate matter (PM) (*World Health Organization 2018, Viana et al. 2020*). The increased levels of air pollution in urban areas present a significant challenge for governments globally due to its detrimental health effects on people. Air pollution is linked to a variety of diseases, including respiratory and cardiovascular diseases, as well as lung cancer, and adversely affects urban ecosystems (*Myong 2016, Beelen et al. 2014, Cesaroni et al. 2014*). Controlling sources of PM proves particularly difficult in developing countries. Consequently, an effective and feasible solution is required to mitigate PM concentrations and improve air quality.

Utilizing plants represents an economical and effective strategy for reducing atmospheric particulate matter. They purify the air, reduce air pollution, temperature, and noise (*Barwise and Kumar 2020; Zhang et al. 2020*). In urban areas, plants significantly reduce PM from the atmosphere through adsorption and deposition on leaf surfaces and wax layers (*Moya et al. 2019*). Alongside roads, plants serve as biofilters for air pollutants, functioning as green belts or vegetation traffic barriers (*Kwon et al. 2020; Popek et al. 2023; Steinparzer et al., 2023)*. The efficacy of plants in air pollution reduction depends on leaf characteristics, such as roughness, stomatal density, the presence of leaf hairs, and the contact angle (*Weerakkody et al. 2018a; Zhang et al. 2020*). The PM accumulation on leaves is enhanced by high levels of roughness and the presence of leaf hairs (*He et al. 2019; Zhang et al. 2017*).

The capacity for PM accumulation across different plant species has been extensively studied, aiming to identify species with high PM accumulation effectiveness (*He et al. 2019; Popek et al. 2013; Zhang et al. 2017*). Nonetheless, the growth, physiological, and biochemical parameters of plants are also adversely affected by air pollution (*Pandit et al. 2020; Popek et al. 2013; Zhang et al. 2017*). Key parameters, such as total chlorophyll (TChl), leaf pH extract (pH), relative water content (RWC), and ascorbic acid (AA) have demonstrated close correlations with plant tolerance but are impacted by PM deposition on leaves (*Bui et al. 2021; Ter et al. 2020*). For instance, PM accumulation on leaves can decrease light absorption, subsequently reducing photosynthesis efficiency. Furthermore, gaseous air pollutants such as SO_2, NO_x, and heavy metals influence plants' pH and ascorbic acid levels, which are directly related to plant sensitivity. Acidic such as SO_2 and NO_x, interact with cellular water that diffuses and forms acid radicals in the leaf, causing changes in the plant's physiology (*Rai 2016*). RWC is essential for maintaining plant physiology, and the reduced RWC leads to a decrease in the transpiration rate of plants (*Sahu et al. 2020*). Under conditions of air pollution stress, the impact of PM levels on individual plant species varies according to their tolerance levels. Parameters, such as TChl, pH, RWC, and AA are used to assess this tolerance level. However, it is difficult to determine the tolerance level of plants by isolating these parameters individually.

The Air Pollution Tolerance Index (APTI) was used to assess the tolerance level of plants to air pollution. The APTI values are calculated using the four specific plant parameters: TChl, pH, RWC, and AA. Based on these APTI values, plants are classified into various tolerance levels (**Table 1**). Plants with high APTI values means increased tolerance for air pollution. Conversely, plants with low APTI values showed sensitivity to air pollution (*Karmakar et al. 2019; Sahu et al. 2020*). The tolerance and sensitivity of various plant species can be used as biofilters for PM or indicators in high air pollution concentration areas, such as roadside and industrial areas (*Das et al. 2018; Zhang et al. 2020*).

This study aimed to assess the PM accumulation capacity of the leaves of different plant species and determine their tolerance levels using the Air Pollution Tolerance Index (APTI). Six plant species with broad and needle leaves that grew on the roadside were selected for this study. The plants' tolerance levels were categorized based on their APTI values. This classification aimed to identify plant species suitable for roadside planting, thereby contributing to the reduction of particulate matter in urban environments.

Table 1. The tolerance levels of plants based on Air Pollution Tolerence Index.

Tolerance Level	Calculated Method
Tolerant (T)	APTI > mean APTI + SD
Moderately tolerant (MT)	Mean APTI < APTI< mean APTI + SD
Intermediate (I)	Mean APTI − SD < APTI< mean APTI
Sensitive (S)	APTI< mean APTI - SD

SD means standard deviation.

MATERIALS AND METHODS

Study Site and Leaf Sampling

The study site was located on the roads surrounding the north side of Chungbuk National University (CBNU) in Cheongju, the largest city in Chungcheongbuk-do, Korea (**Figure 1**). The sampling was conducted in July 2021. The road selected for leaf sampling has heavy traffic, leading to Chungbuk National University Hospital and the CBNU tailgate, and it also accommodates additional intercity bus traffic. Six plant species commonly used for landscape planting in Korea were chosen for collecting leaf samples (**Table 2**). Four healthy plants, free from pests and diseases, were randomly selected for each species (four replicates). Approximately 300-400 cm^2 of leaf area from each sample was cut and stored in separate paper bags. These samples were then transported to the laboratory for analysis.

Quantification of PM Accumulation on Leaf Surface

This study applied the methodology described by *Dzierzanowski et al.* (*2011*) to quantify PM accumulation on leaf surfaces (sPM). Approximately 300 cm^2 of leaf area was collected for each plant and placed in a glass beaker. Then, 250 mL of distilled water was added, and the leaves were washed by manual agitation for 60 seconds. Afterward, the glass beakers were placed in an analog ultrasonic (WUC- A22H, Daihan Scientific, Wonju, Korea) for six minutes to wash off all PM from the leaf surfaces (*Liu et al. 2018*). Then, the resulting washing solution was passed through a metal sieve with a 100 µm diameter mesh to remove larger particles (diameter >100 µm). The collected solution was filtered by two different filter paper types, Type 91 and Type 42 (Whatman, UK), with pore sizes of 10 µm and 2.5 µm, respectively. Then, the paper filter was weighed again to calculate the collected PM from each solution corresponding to each leaf sample. All paper filters were placed on a general desiccator (DH.DeBG1K, Daihan Scientific, Wonju, Korea) for 48 hours before weighing using semi-microelectronic balance (EX125D, Ohaus, Parsippany, NJ, USA). PM was obtained on the leaf surface in two sizes, large PM and coarse PM, corresponding to two types of paper filters. A leaf area meter (LI-3100C, LI-COR Biosciences, Lincoln, NE, USA) was used after washing with water to calculate the leaf area of each leaf sample.

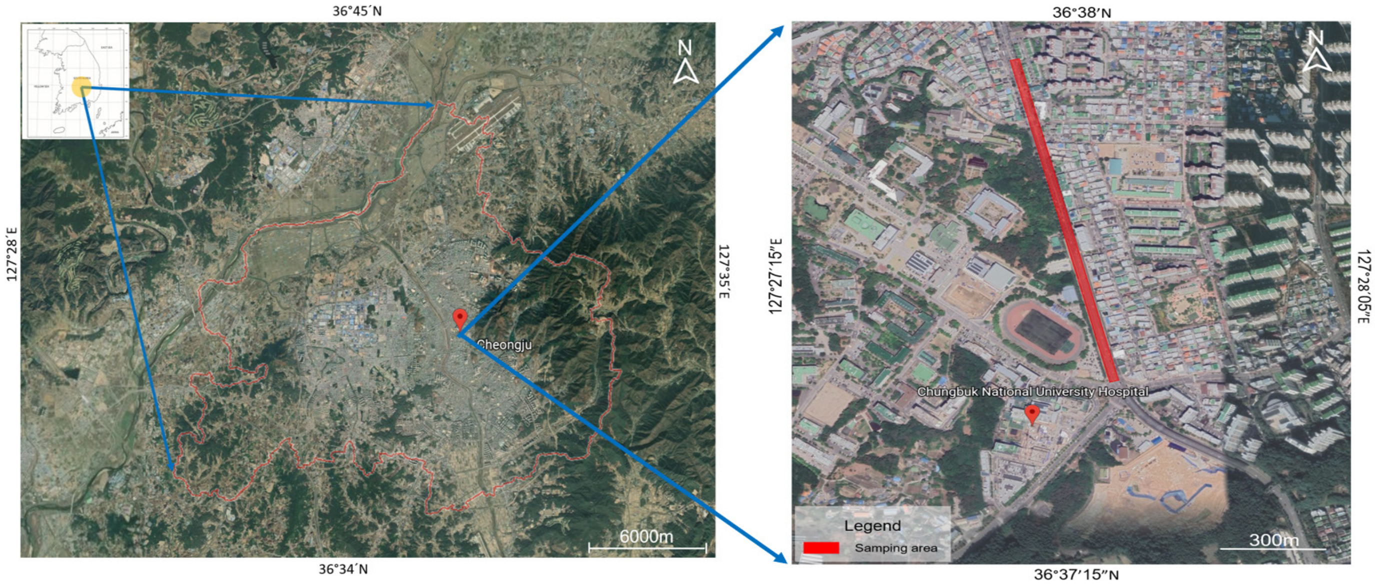


Figure 1. Location of the study area in Cheongju City, South Korea (Map data: Google Earth. Accessed in 2022).

Table 2. Details and characteristics of the six sampling plants.

Plant Species	Family	Habit	Type
Liriope muscari (Decne.) L.H. Bailey	Liliaceae	Herb	Deciduous
Ligustrum obtusifolium Siebold & Zucc.	Oleaceae	Shrub	Deciduous
Hibiscus syriacus L.	Malvaceae	Shrub	Deciduous
Platycladus orientalis (L.) Franco	Cupressaceae	Tree	Evergreen
Taxus cuspidata Siebold & Zucc.	Taxaceae	Tree	Evergreen
Chamaecyparis obtusa (Siebold & Zucc.) Endl.	Cupressaceae	Tree	Evergreen

Total Chlorophyll (TChl)

According to the method described by *Khoyerdi et al.* (*2016*), 0.05 g leaf sample was ground with liquid nitrogen. Subsequently, 10 mL of acetone was added to extract the solution. The collected solution was then centrifuged at 2,700 rpm for 10 minutes. Next, the absorbance of 10 mL of the supernatant at 470 nm, 616. 6 nm , and 644 .8 nm was determined using a spectrophotometer (UV-1800, Simazuda, Japan) (*Lichtenthaler et al. 1987*). TChl was calculated using the following formula:

$$\text{Chl a} = (11.24 \times A_{616.6}) - (2.04 \times A_{644.8}) \quad (1)$$

$$\text{Chl b} = (20.13 \times A_{644.8}) - (4.19 \times A_{616.6}) \quad (2)$$

$$\text{Chl a + b} = (7.05 \times A_{616.6}) + (18.09 \times A_{644.8}) \quad (3)$$

where $A_{616.6}$, $A_{644.8}$ and A_{470} refer to the absorbance values of the corresponding wavelengths and 11.24, 2.04, 20.13, 4.19, 7.05, 18.09 refer to the specific absorption coefficients in acetone solvent in various wavelengths.

Leaf Extract pH (pH)

Using the method by *Rai et al.* (*2013*), 1 g of the fresh leaf was crushed in 10 mL of distilled water and centrifuged at 2,700 rpm for 6 min. Then, a pH meter (HI8424, Hanna Instruments, Woonsocket, RI, USA) was used to determine the pH value of each sample leaf.

Relative Water Content (RWC)

The RWC was calculated using the method proposed by *Li et al.* (*2009*). A total of 1 g of fresh leaves (fresh weight, FW) were immersed in distilled water in darkness at 4°C for 24 hours. After soaking, the leaves were removed and weighed (turgid weight, TW). Then, the samples were dried in an oven at 80°C for 24 h and and weighed again (dry weight, DW). The RWC was determined using the formula below:

$$\text{RWC (\%)} = \frac{FW-DW}{TW-DW} \times 100 \quad (4)$$

where FW is the fresh weight, TW is the turgid weight, and DW is the dry weight.

Ascorbic Acid (AA)

Using the method described by *Dinesh et al.* (*2015*), the AA level of each leaf sample was calculated using the following formula:

Amount of ascorbic acid content (mg/100g)=

$$\frac{500 \times V2 \times 100}{V1 \times 5 \times 5} \tag{5}$$

where 500 µg of standard ascorbic acid taken for titration, V1: the value of dye consumed by 500 µg of standard ascorbic acid; V2: the value of dye consumed by 5 mL of the test sample, 25: corresponds to the total volume of the extract, 100: ascorbic acid content /100 g of the sample, 5: the weight of sample for extracted, and 5: the value of the test sample taken for titration.

Air Pollution Tolerance Index (APTI)

The APTI value was determined by incorporating four parameters: RWC, pH, TChl, and AA (*Singh et al. 1991*). The method described by *Yadav and Pandey* (*2020*) was used in this study, and the following formula was used to calculate the APTI values:

$$\mathbf{APTI} = \frac{A \times (T + P) + R}{10} \tag{6}$$

where A is ascorbic acid, T is TChl, P is leaf extract pH, and R is the RWC of the leaf.

APTI Classification

The APTI of each plant was classified into four tolerance levels (tolerant, moderately tolerant, intermediate, and sensitive) (*Yadav and Pandey 2020*). The classification followed the method described by *Ghafari et al.* (*2021*). The tolerance level was divided into four different levels (**Table 1**).

Statistical Analysis

All data were analyzed using SAS software 9.4 version (SAS Institute, USA) for Duncan's multiple range test (DMRT), and a significance level of 5% ($p<0.05$). Pearson's correlation analysis was conducted to explore the relationship between PM accumulation on leaves and four biochemical parameters, as well as the APTI.

RESULTS AND DISCUSSION

PM Accumulation on Leaf Surfaces of Six Plant Species

The study found significant variations in PM accumulation on the leaf surfaces of six different plant species. The amount of large PM accumulated washigher than that of coarse PM. Specifically, the large PM ranged from 6.92 to 30.55 µg cm^{-2} across the species. *L. obtusifolium* showed the highest large PM accumulation, followed by *H. syriacus* and *C. obtusa*. Conversely, *P. orientalis* had the lowest PM accumulation among the species studied. Similarly, the accumulation of coarse PM ranged from 0.75 to 8.72 µg cm^{-2}, with *L. obtusifolium* again showing the highest accumulation, while *L. muscari* accumulated the least. The total PM accumulation observed on the leaf surfaces was highest for *L. obtusifolium* and the lowest for *L. muscari* (**Table 3**).

Using plants to improve air quality has proven to be an effective strategy, offering numerous long-term benefits for people's health and ecological systems, particularly in urban environments. The extent of PM accumulation on plant leaves varies among species and is influenced by the surrounding environmental conditions (*Kong et al. 2019; Przybysz et al. 2014*). Moreover, plants in areas with higher pollution levels tend to accumulate more PM than those in environments with lower pollution concentrations (*Sæbø et al. 2012:Rahul and Jain 2014*). Within the same environmental conditions, the amount of PM accumulation varied among plant species due to differences in species type and leaf structure (*Weerakkody et al. 2018a*). Needleleaf plants showed more effective PM accumulation than broad-leaf plants due to their

Table 3. Amount of of large PM, coarse PM,and total PM accumulation on the leaves of six plant species.

Plant Species	Large PM (µg cm^{-2})	Coarse PM (µg cm^{-2})	Total PM (µg cm^{-2})
L. muscari	7.04 ± 0.87^{c}	0.75 ± 0.31^{f}	7.79 ± 0.74^{d}
L. obtusifolium	30.55 ± 6.12^{a}	8.27 ± 0.91^{a}	38.82 ± 6.47^{a}
H. syriacus	19.48 ± 3.88^{b}	6.12 ± 0.74^{b}	25.60 ± 4.46^{b}
P. orientalis	6.92 ± 1.72^{c}	3.65 ± 0.15^{d}	10.57 ± 1.75^{d}
T. cuspidata	8.03 ± 0.66^{c}	1.97 ± 0.13^{e}	10.00 ± 0.63^{d}
C. obtusa	14.38 ± 5.04^{b}	4.76 ± 0.61^{c}	19.14 ± 5.24^{c}
Significance	***	***	***

Note: In DMRT, different letters in the same column indicate significant differences according to Duncan's multiple range test; *** indicate significance at $p < 0.001$; large PM indicate particulate matter 100 µm or less in diameter; coarse PM indicates particulate matter 2.5 µm or less in diameter; Total PM indicate the sum of particulate matter on the leaf.

leaf structure (*Popek et al. 2019*). The rougher texture of needleleaf leaves facilitates greater PM deposition compared to the smoother leaves of broad-leaf plants. *Sæbø et al.* (*2012*) observed that trees typically accumulate more PM than shrubs; however, in this study, shrubs demonstrated higher effectiveness in PM accumulation. Shrubs growing low to the ground are presumably more exposed to soil splashes on the leaves than trees with an upright growth habit, which could increase PM accumulation on the leaves of these plants (*Sæbø et al., 2012*). Therefore, it has been suggested that the leaf structure of shrubs helps plants accumulate more PM than other plant species (*Chen et al. 2015*). Additionally, the presence of hair on the leaf surfaces of *L. obtusifolium* likely contributed to increased PM deposition (**Figure 2**). This is because leaf hair helps increase the leaf area for PM accumulation and reduces the influence of wash-off PM from leaves due to rain or wind (*Sgrigna et al. 2020*).

In the case of *H. syriacus*, deep grooves were found surrounding the stomata, which may cause increasing PM accumulation on the leaves. These grooves create areas for PM accumulation on the leaf and keep PM inside the grooves (*Weerakkody et al. 2018b*). The leaf surfaces of *C. obtusa* were covered by small hair and had high stomatal concentrations. This caused *C. obtusa* to accumulate PM more than other plant species. According to *Chen et al.* (*2015*), the amount of PM accumulation in plants is significantly impacted by leaf surface structure. Therefore, combining shrubs with trees could be an effective solution for mitigating PM in polluted areas.

Biochemical Characteristics of Plants

Total Chlorophyll (TChl). The TChl of the six plant species ranged from 0.26 to 0.11 mg cm^{-2}. Additionally, *T. cuspidate* showed the highest TChl value. Conversely, *C. obtusa* had the lowest TChl value (**Figure 3**). TChl values are presented for the growth and development capabilities of plants. TChl is an important photosynthetic pigment that determines the photosynthetic capacity of plants (*Das et al. 2018*). TChl can be impacted by many environmental conditions, such as temperature, light, and air pollution (*Popek et al. 2018*). The amount of PM accumulation on the surfaces of leaves led to less absorbed light, causing a decrease in TChl. Besides, PM blocking on the stomata of plants caused the reduction of TChl due to decreasing stomatal conduction (*Pandit and Sharma 2020*). The same tendency was found in this study, while the high PM accumulation plant species showed lower TChl than others. However, TChl also increased under high air pollution levels because of the adaptation of plants to air pollution (*Rahul and Jain 2014*).

Leaf Extract pH (pH). The pH values of the six plants ranged between 5.47 and 6.26, with highest and lowest

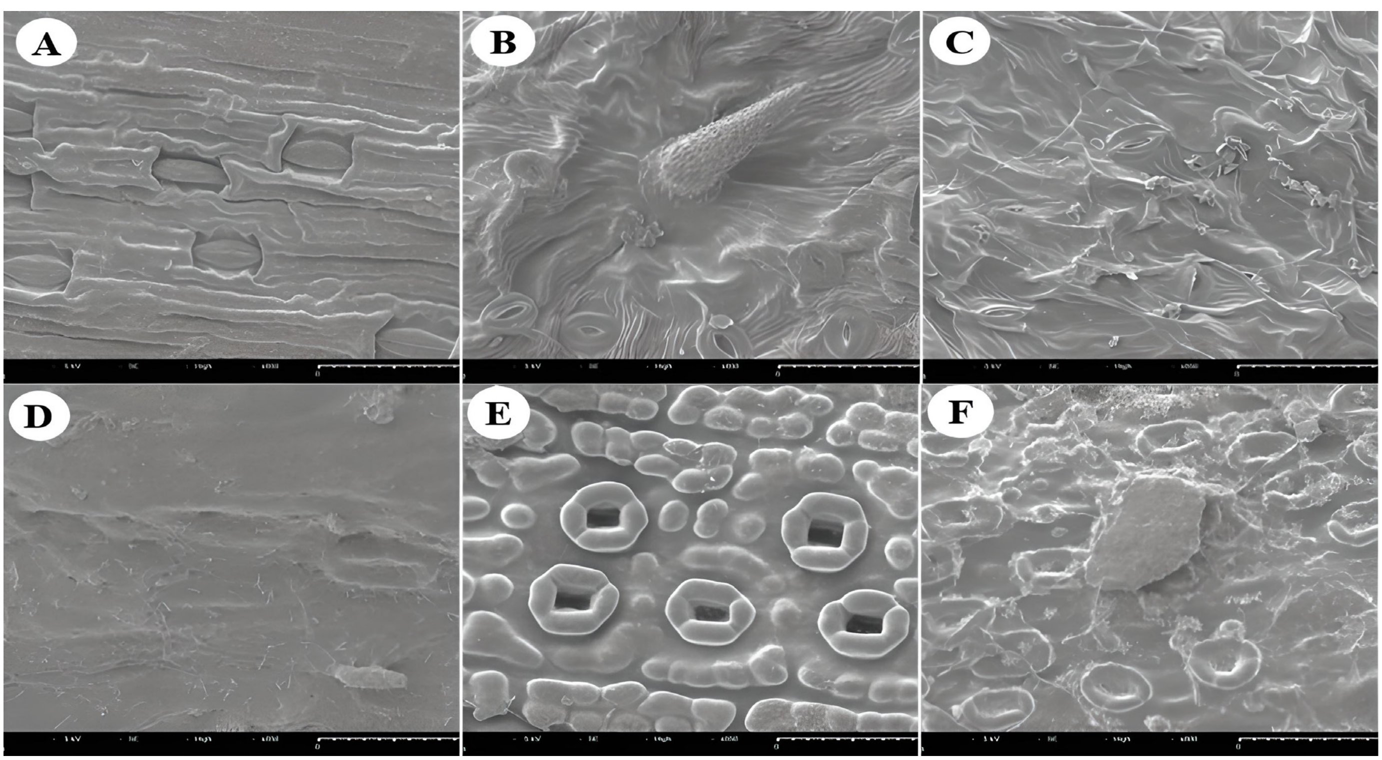
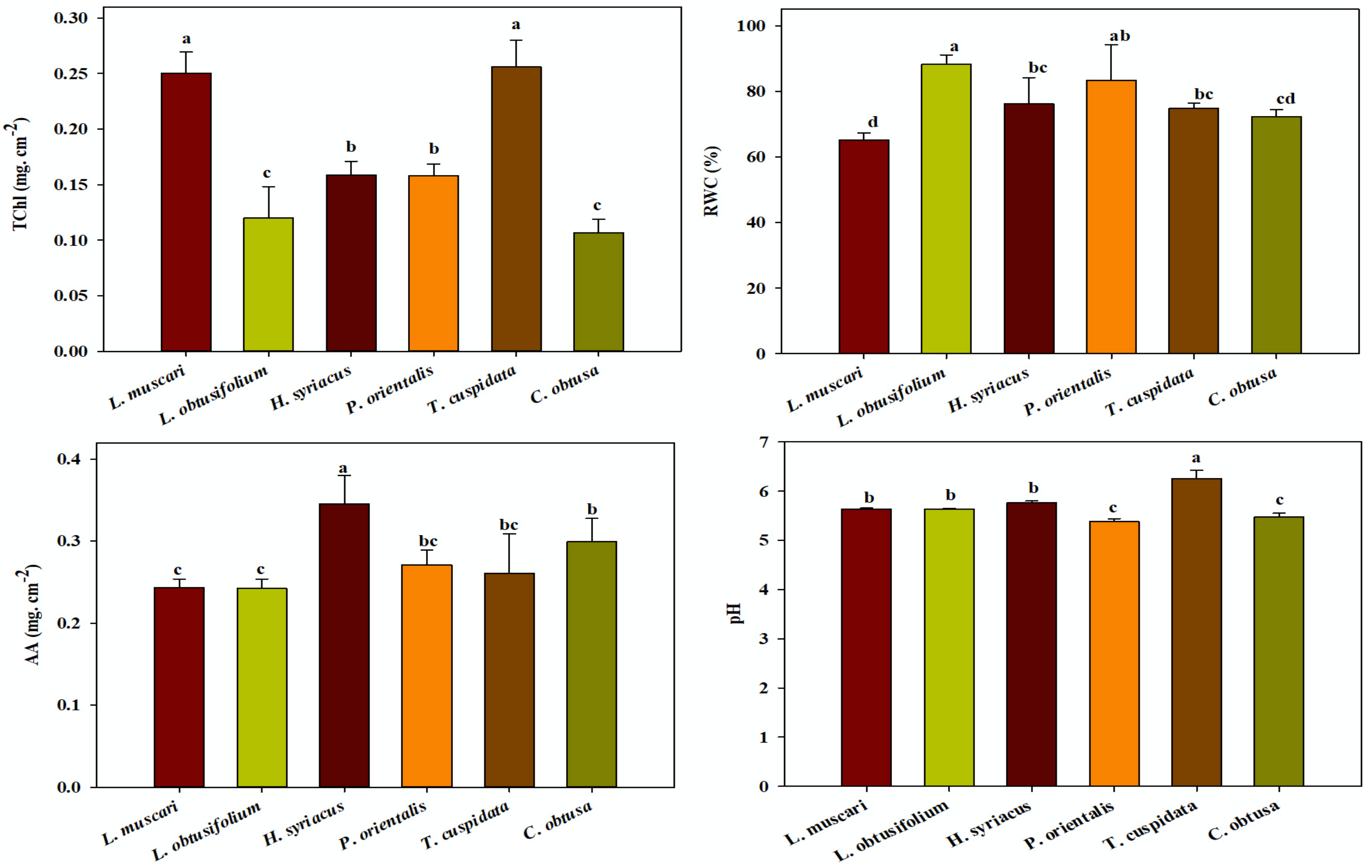


Figure 2. Scanning electron microscopy showing the leaf morphology structure of the abaxial leaf surface of six plant species: A) *L. muscari*, B) *L. obtusifolium*, C) *H. syriacus*, D) *P. orientalis*, E) *T. cuspidate*, and F) *C. obtusa*. The scale bar is 50 µm.



Note: Different letters indicate significant differences between the six plant species assessed by Duncan's multiple range test; bold values indicate $p < 0.05$; AA: ascorbic acid; TChl: total chlorophyll; pH: leaf pH; RWC: relative leaf water content

Figure 3. Biochemical characteristics of six plant species.

pH values were observed in *T. cuspidata* and *C. obtuse*, respectively (**Figure 3**). pH serves as an indicator of air pollution in plants. It affects stomatal sensitivity that impacts photosynthesis (*Bharti et al. 2018*). When plants are exposed to acidic air pollution, especially SO_2, the H^+ reacts with SO_2, forming H_2SO_4, and decreasing the pH of plants (*Panda et al. 2018*). Moreover, the high pH of plants could enhance the conversion of hexose sugar to AA, thereby increasing the tolerance of plants (*Nawaz et al. 2022*). In this study, plants such as *T. cuspidate* and *C. obtuse* with higher pH values demonstrated greater tolerance compared to species with lower pH values.

Relative Water Content (RWC). The RWC of the six plant species ranged from 65.19 to 88.19%. The highest and lowest RWC values were detected in *L. obtusifolium* and *L. muscari*, respectively (**Figure 3**). All four characteristics play a critical role in plant growth. The RWC reflected the water status that ensured plants' physiological balance (*Hozhabralsadat et al. 2022*). Plants with high RWC can maintain physiological equalization under environmental stress, such as air pollution (*Mullan and Pietragalla 2012*). Air pollutants such as PM blocks the stomata of plants causing reduction in their stomatal conduction, leading to a decrease in the RWC value. Plants with low RWC could lose the plant motor that pulls water from roots for the photosynthesis process due to the senescence of leaves (*von Schneidemesser et al. 2019*). In this study, *L. obtusifolium* and *C. obtuse* showed significantly higher RWC values than other plant species due to their tolerance to air pollution. However, *L. muscari* showed the lowest RWC value due to the sensitivity of the plant species.

Ascorbic Acid (AA). The AA values of the six plant species were also significantly different, while the AA values ranged between 0.35 and 0.24 mg cm^{-2}. The AA value of *H. syriacus* was the highest among the six plant species, and the plant with the lowest AA value was *L. obtusifolium* (**Figure 3**). AA is an antioxidant that plays a vital role in plant synthesis, cell wall, and cell division (*Nawaz et al. 2022*). High AA could increase plants' tolerance to environmental stress by protecting them from oxidative damage (*Tripathi and Gautam 2007*). The AA of the plants depended on their pH levels. In a high-air-pollution environment, plants with high-level AA could be considered more tolerant, while plants with low-level AA showed more sensitivity to air pollution (*Sahu et* *al. 2020*). In this study, higher AA levels in *H. syriacus* indicated greater environmental tolerance compared to other species.

Correlation of large PM and coarse PM with APTI and Leaf Traits of Plants

In this study, large PM and coarse PM accumulation found on the leaves of six plants had a negative correlation with TChl and a positive correlation with the RWC of plants (**Table 4**). Additionally, there was a significant positive correlation with large PM and coarse PM accumulation in the leaves of plants. Plants significantly reduce PM from the atmosphere, but PM also adversely affect plants (*Pandit and Sharma 2020*). PM accumulation on leaves causes changes in leaf structure (e.g., leaf size and the structure of the wax layer) (*Chaturvedi et al. 2013*). Under environmental stress, the four biochemical characteristics (RWC, pH, TCh, and AA) were also changed to adapt to adverse factors, such as air pollution (*Yadav and Pandey 2020*).

Air Pollution Tolerence Index

In this study, the APTI values of six plant species were found to vary, ranging from 6.66 to 8.96. The highest APTI values were observed in *L. obtusifolium, P. orientalis*, and *H. syriacus*. In contrast, *L. muscari* showed the lowest APTI value. Based on these values, the tolerance levels of six plant species were categorized into four groups: tolerant (*L. obtusifolium*), moderately tolerant (*P . orientalis*), intermediate (*H. syriacus, T. cuspidata,* and *C. obtusa*), and sensitive (*L. Muscari*). (**Table 5**).

The value of APTI was different depending on plant type, species, and environmental conditions, indicating the tolerance levels of plants (*Das et al. 2018*). Under high air pollution environments , plants with high APTI could grow so that they can be used as biofilters for air pollution. However, plant species with low APTI could die. APTI can be used as an indicator of air pollution (*Prajapati et al. 2008*). Therefore, *L. obtusifolium*, with a high tolerance level, could be planted as a biofilter for air pollution in high air-polluted areas.

CONCLUSION AND RECOMMENDATIONS

This study demonstrated that PM accumulation and the Air Pollution Tolerence Index vary significantly among analyzed plant species. *L. obtusifolium* and *H. syriacus* exhibited the highest PM accumulation on their leaves. It appears that the leaf structure, including characteristics like leaf hair and surface roughness, is a primary factor influencing each species' capacity for PM accumulation. The study found a positive correlation between PM accumulation on leaves and both APTI and RWC of the plants, and a negative correlation with TChl. Specifically, *L. obtusifolium, H. syriacus* and *C. obtusa* had more PM accumulation capacity and higher tolerance to air pollution compared to the other plant species studied. Therefore, these plant species are recommended for use as biofilters for urban greening in high-level air pollution areas. Nevertheless, further research is necessary to explore the impact of heavy metals on the leaf structure and, subsequently, on APTI and PM accumulation capacities. Such studies can help in the selection of the most suitable plant species to enhance the mitigation of ambient PM.

Table 4. Pearson correlation analysis of PM accumulation on leaf surfaces based on the four biochemical characteristics and Air Pollution Tolerence Index of six plant species.

PM	AA	TChl	pH	RWC	APTI
Large PM	0.024 ns	−0.556*	−0.065ns	0.499*	0.496*
Coarse PM	0.244 ns	−0.764***	−0.250ns	0.621**	0.623**

Note: Large PM: particulate matter accumulation on leaf with diameter ranging from 10 to 100 μm; Coarse PM: particulate matter accumulation on leaf with diameter ranging from 2.5 to 10 μm; AA: ascorbic acid; TChl: total chlorophyll; pH: leaf pH; RWC: relative leaf water content; APTI: air pollution tolerance index; ns, *, **, and ***: nonsignificant, significant at $p < 0.05$, $p < 0.01$, and $p < 0.001$, respectively.

Table 5. The Air Pollution Tolerence Index values of six plant species in Choengju, Chungcheongbuk-do, Korea.

Plant Species	APTI Value	Tolerance Levels
L. muscari	6.66 ± 0.21^{d}	Sensitive
L. obtusifolium	8.96 ± 0.29^{a}	Tolerant
H. syriacus	7.82 ± 0.81^{bc}	Intermediate
P. orientalis	8.48 ± 1.10^{ab}	Moderatly tolerant
T. cuspidata	7.64 ± 0.16^{bc}	Intermediate
C. obtusa	7.40 ± 0.22^{cd}	Intermediate

Note: Different letters indicate significant differences between the six plant species assessed by Duncan's multiple range test; bold values indicate $p < 0.05$.

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