Surface microcosmic structure and dust retention amounts of five evergreen species

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Abstract. With the acceleration of urbanization, air pollution is getting worse especially during winter, which causes serious threat to people’s health. Large numbers of studies showed that green plants had a significant species on the retention of particulate matters. In view of this, this study selected five evergreen plants to explore the dust retention amounts of PM₁₀, PM₂.₅, PM₁ per unit leaf area and the microstructure of leaf surface. The results showed that: 1. Within the unit leaf area: the dust retention amount (PM₁₀, PM₂.₅, PM₁) of Yucca gloriosa was the highest, followed by Buxus sinica, and that of Ligustrum lucidum, Buxus megistophylla and Phyllostachys propinqua was relatively few. 2. The roughness of the leaf surface, the waxy layer, the stomata protruded, the number of stomata, stomata density, and stomatal opening and closing degree would affect the retention of particulate matter. The results obtained scientific guidance for plants collection in landscape greening with brilliant dust retention ability, and maximized the ecological effect of greening plants to mitigate air pollution.

1. Introduction

With the continuous development of industrialization and urbanization, air pollution becomes a hot issue of worldwide concern. The massive emissions of automobile exhaust and industrial waste gas increase the frequency of haze weather during winter, which exerts huge impacts on economic development and people's health [1-2]. In order to improve and control air pollution, China has formulated relevant laws and regulations. Urban greening plants play significant effects on atmospheric particulates retention, thereby decreasing urban air pollution [3-8]. At present, many scholars have studied the mechanism and ability difference of plant dust retention. Wu [9] found that plants had the ability to purify atmospheric particulates; Hong [10] found that plant leaf surface structure also affected the sedimentation of atmospheric particles; etc. Most plants in northern China are deciduous, so in winter, evergreen plants are particularly important. At present, the research on the dust retention of evergreen plants and its influencing factors are still weak, lacking strong reference basis and scientific guidance.

In view of this, this study selected representative evergreen species, and explored the amount of PM₁₀, PM₂.₅, PM₁ per unit leaf area and surface microcosmic structure of five plant species. This study found that evergreen plants had a significant impact on particulate matter retention and could improve air pollution to a certain extent.

2. Materials and Methods

2.1 Study area

Tianjin is located at the northeast of the North China Plain, with developed transportation. In the long-term development, it forms an industrial structure with a high proportion of industries and a coal-based energy structure. The prosperity of these industries causes certain pollution to the atmosphere. Smog is easy to occur in windless weather. In winter, cities are easy to form a temperature inversion layer. The stable atmospheric structure is easy to cause pollutants to gather. Therefore, smog occurs frequently and pollution is serious.

2.2 Materials and methods

2.2.1 Collection of leaf samples

The leaf samples were collected on January 9, 2019, in the middle of the plant crown, in the east, south, west and north directions to collect three times respectively. Each plant sampled four leaves at a time and ensured the integrity of the leaves. The collected leaves were immediately sent to the laboratory for analysis and determination. The leaves were stored in a refrigerator at 4°C, and all determination work were completed within one week after collection.
2.2.2 Determination of plant leaf area

The leaf area adopted the method of combining scanning and imaged processing software. The cleaned leaves were pasted on A4 paper, and scanned into black and white pictures with the accuracy of 300 dpi by the scanner. The picture was opened with Photoshop, the image characteristic was adjusted to pixel/cm (78.74dpi/cm at this time), the blade scan's black part was selected by using magic wand tool, the software could automatically calculate the total pixel of the area just selected, used Excel to record the data and calculate, divided the total pixel by 78.74 square to get the leaf area.

2.2.3 Analysis of dust retention per unit leaf surface

The blades were cleaned and filtered with microporous membranes and microporous membrane filtration devices with pore sizes of 10 μm, 2.5 μm, 1 μm and 0.1 μm in turn (dried in an oven at 90°C 30 minutes in advance until weighed) completely. After each cleaning or filtration, the experimental equipment was cleaned again to reduce experimental error. The filtered membrane was dried in an oven at 90°C for 1 h to constant weight. Retained particles were of poor quality compared to clean membranes. The filter membrane was weighed with an analytical balance with an accuracy of 0.0001 g, and the particles on the microporous filter membrane with a pore size of 10 μm, 2.5 μm, 1 μm and 0.1 μm were regarded as particles. Since the particles with a mass less than 0.1 um accounted for a small proportion in the collected particles and were not easy to filter, they were ignored. Therefore, the calculation formulas of plant leaves SPM1, SPM2.5, and SPM10 are:

\[
SPM = \frac{(W_1 - W_0)}{S} \tag{1}
\]

Where, \(W_1\) is the mass of filter membrane dried to constant weight after filtration (unit: g), \(W_0\) is the mass of filter membrane dried to constant weight (unit: g), \(S\) is the sum of measured leaf areas (unit:m²). SPM (Surface particulate matter) is the mass of particulate matter retained per unit area of the blade (unit: g/m²).

2.2.4 Blade scanning electron microscope (SEM)

Plant leaves were processed into several 5 mm x 5 mm square plant tissue samples, soaked and marked in test tubes containing 2.5% glutaraldehyde solution, and placed in a 4°C refrigerator. The sheet sample was fixed on the electron microscope stage with double-sided conductive tape, and placed in an automatic sputtering instrument for gold spraying treatment to improve the conductivity of the sheet surface and improve image quality. The stage was placed in a high-resolution environmental scanning electron microscope (SEM) to vacuumize, operated at a voltage of 3 KV, and selected a field of view to observe the blade surface structure and took photos at the magnification of 50, 200 and 500 respectively (see Figure 2).

3. Results and Discussion

3.1 Study on influence of plant species on dust retention

As seen in Figure 1, Yucca gloriosa had the most outstanding ability in retention of PM1 (A), PM2.5 (B), PM10 (C) retention. The amount of dust retention for any particulate size was the highest of Yucca gloriosa. While Ligustrum lucidum, Buxus megistophylla and Phyllostachys propinquia were poor in the retention, and the differences in their dust retention were not obvious.

Zhang [11] found that the dust retention per unit area of plant leaves Yucca gloriosa was greater than that of Buxus megistophylla, which was consistent with the experimental results. The research by Ji j [12] showed that the amount of dust retention of Yucca gloriosa was 4.4 times higher than that of Buxus megistophylla, which was consistent with the experimental results. Yang [13] found that the amount of dust retention of Buxus megistophylla was greater than that of Buxus sinica and Yucca gloriosa, which was inconsistent with the experimental results, but the experimental results of Buxus sinica were similar with those of this paper. The reason was that the experiment of Yang was carried out in autumn, while our experiment was carried out in winter, and the atmospheric conditions were different due to different seasons.

3.2 Study on the influence of leaf surface microstructure on dust retention

In order to study the effect of leaf surface structure on...
total dust retention more clearly, the method of electron microscope was used for further research. The following were the leaf surface structure images of five evergreen plants. The following conclusions were obtained from the analysis of the images. (a-upper surface of plant; b-lower surface of plant)

Figure 2. Leaf surface structure images of five evergreen plants

<table>
<thead>
<tr>
<th>Plant name</th>
<th>Leaf surface structural characteristics</th>
<th>Dust retention</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ligustrum lucidum</td>
<td>Smooth, with waxy surface and small verrucous tissue</td>
<td>common</td>
</tr>
<tr>
<td>Yucca gloriosa</td>
<td>Rough, with irregular protrusions; the stomata are olive-shaped protrusions, large and dense</td>
<td>higher</td>
</tr>
<tr>
<td>Buxus megistophylla</td>
<td>Flat, with wax layer</td>
<td>common</td>
</tr>
<tr>
<td>Buxus sinica</td>
<td>Flat, with wax layer</td>
<td>middling</td>
</tr>
<tr>
<td>Phyllostachys propingua</td>
<td>Thin trench-like tissue, with less stomata and beaded protrusions; almost closed</td>
<td>common</td>
</tr>
</tbody>
</table>

As seen in Table 1, referring to Figure 1 and Figure 2, the surface of the leaves of the Yucca gloriosa was rough, and the stomata were protruding and dense, which was conducive to the retention of small particles, so the proportion of PM$_{2.5}$ and PM$_{1}$ in the retained particles was very high. The upper surface of the leaves of Buxus sinica was smooth, but the stomata on the lower surface were round and large and dense, so the proportion of PM$_{2.5}$ in the retained particles was relatively high. The leaf surface of Phyllostachys propingua was covered with strip groove tissue, but the stomata were almost closed. Therefore, PM$_{10}$ was the main particulate matter retained by it, and PM$_{2.5}$ and PM$_{1}$ were relatively low. The upper surface of Buxus megistophylla leaves was smooth, and the stomata on the lower surface were not prominent, so its dust retention was low, PM$_{10}$ was the main particle in the retention, and PM$_{2.5}$ and PM$_{1}$ were very low. The upper surface of Ligustrum lucidum leaves was smooth and had verrucous tissue, which was not conducive to the retention of particles. The lower surface of the leaves was covered with fine trench tissue, which was conducive to the retention of fine particles. However, with reference to Figure 1, the proportion of retained PM$_{2.5}$ and PM$_{1}$ was very low. The reason was that atmospheric particles were easy to deposit near the surface, and the crown of Ligustrum lucidum was far from the near surface, so the dust retention was small.

4. Conclusion

The dust retention amount per unit area of Yucca gloriosa was the largest, regardless of the particle size. The dust retention of Ligustrum lucidum, Buxus
megistophylla, and *Phyllostachys propinqua* was relatively low, but the difference was not significant. Through the exploration of leaf surface structure on dust retention, we could conclude that roughness of leaf surface, number of stomata, number of stomatal protrusions, number of leaf surface groove tissue, closure of stomata, and presence or absence of wax layer had a great impact on PM retention. This study provided scientific guidance for the selection of plants with brilliant dust retention.

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**References:**

10. Hong X L. Research on atmospheric particulates such as PM$_{2.5}$ retained by community scattered forest leaves[D]. Beijing: Beijing Forestry University, 2015.