Research report of particulate matter deposited on leaf surface of major ecological tree species

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Abstract. With 11 kinds of common ecological tree species in Hunan Province as the research object, the absorption amount of PM2.5 particles in the air per unit leaf area were studied to reveal the main ecological tree species in Hunan Province to reduce the air PM2.5 particles capacity. The results showed that the adsorption amount of PM2.5 per unit leaf area of different tree species each were not identical, mainly effected by foliage microstructure, branches and leaves density, leaf texture and the leaf angle. The order of PM2.5 adsorption quantity per unit leaf area of selected tree species for Cunninghamia lanceolate >Pinus massoniana > Cyclobalanopsis glauca > Castanopsis sclerophylla >Liquidambar formosana > Robinia pseudoacacia > Schima superba > Paulownia tomentosa > Pinus elliottii=Cupressus funebris > Alnus cremastogyne.

1. Introduction
In recent years, many cities in China have put on a ‘lost in fog’, and the primary task of dealing with smog pollution and improving air quality is to control PM2.5. In 2012, the Chinese government had promulgated the national standard for PM2.5 (0.035mg•m-3•a-1 and 0.075 mg•m-3•d-1), and began nationwide regular monitoring in 2016, and reported monitoring data to the public. The green plant has the ability to absorb, retain and filter PM2.5 due to its special leaf surface characteristics and canopy structure. At present, some researches have been carried out on the particulate matter retention ability [1-4], retention efficiency [5-8] and functional mechanism [9-11] of vegetation in China and abroad, mainly focusing on the total amount of particulate matter retention in leaf surface or the composition of particle size [12-14]. For the study of PM2.5 retention quantity, we only saw the researches on PM2.5, PM10-1000 and PM2.5-1 retention in unit leaf area of 47 trees and shrubs in Poland and Norway [15], and on multi-scale comparison of PM2.5 retention capacity of different green tree species in Beijing [16]. In this paper, the adsorption action and adsorption capacity of PM 2.5 of different tree species in Hunan Province were studied to provide a basis for the regional tree species selection.
2. Materials and Method

2.1. Overview of research area
The research area is located in the Nverzhai small watershed of Wuling Mountain Area in the middle reaches of the Yangtze river (110°10'E, 29°30'N), and the Dujia chong experimental forest farm of Hunan Forestry Academy (113°01'E, 28°06'N). The research area has abundant rainfall, with an average annual rainfall of about 1400 mm. The soil is mainly red soil, yellow soil and yellow brown soil. It is a region with abundant forest type distribution in Hunan Province. The tree species are relatively complete, and the flora is mainly composed of Lauraceae and Fagaceae. Broadleaf species are mainly Liquidambar Formosana, Camellia oleifera, Castanea millesima, Alnus cremastogyne, Cinnamomic camphora, Schima superba, Elaeocarpus sylvestris and so on. Coniferous species are mainly Cunninghamia lanceolata, Pinus elliottii, Pinus massoniana, and economic forest fruit tree species such as orange, grapefruit, and shrub tree species such as Loropetalum chinense var. rubrum.

2.2. Research method

2.2.1. Sample set, survey and standard tree sampling. A 25m×40m sample plot was set, and the sample tree was determined through each tree investigation. Sample leaves were collected from the upper, middle, lower and east, south, west, north orientation of sample tree respectively. Sampling time was April 8, 2016, a week after the latest rainfall. There was obvious accumulation of particulate matter on the leaf surface when sampling, and the sampling was completed in one day. The height of the sample tree was 2–6m, the average tree age was 8-year-old, and the sample leaves quantity was according to the size of unit leaf area of each species. 10 trees of each species were selected as samples, and the sample leaves were mixed, then put into the plastic bag and sealed [16].

2.2.2. Area determination of sample leaf and PM2.5 adsorption measurement on unit leaf area of tree species. The sample leaves were placed in the aerosol regenerator (QRJZF-Ⅱ) material box, according to the principle of wind erosion, the retention particles in the leaf were blown up and mixed, and the aerosol was produced again, with 3 replications for each species. The environmental dust detector connected to the aerosol regenerator was used to test the PM2.5 amount in the aerosol.

The measured leaves of broadleaf trees were put into the scanner (Canon Cano Scan LiDE 90), and the scanned images were processed using Adobe Photoshop software, and the leaf area S (cm2) was calculated using leaf area analysis software. The leaf area of conifer was calculated by using Vernier caliper to measure its length and diameter.

The adsorbed particulate matter amount was calculated according to the following formula:

\[ M_i = \sum_{j=1}^{n} m_{ij} / S_i \]  

In the formula, \( M_i \) is the mass of particulate matter adsorbed by the unit leaf area of different tree species (μg·cm⁻²), \( i \) is different tree species, \( j \) is the type of particle, \( n = 3 \).

Data statistical analysis mainly adopted SPSS 19.0 and Microsoft Office Excel 2007.

3. Results and Discussion

3.1. Major tree species characteristics
Among the 11 selected species, there were significant species differences. Among them, the average single leaf area above 4cm² were Robinia pseudoacacia, Paulownia spp., the average single leaf area below 4cm² were Liquidambar formosana, Alnus cremastogyne, Schima superba, Castanopsis sclerophylla, Cyclobalanopsis glauca, Cunninghamia lanceolata, Pinus massoniana, Pinus elliottii,
Cupressus funebris, and the life style was dominated by arbor. Deciduous species included Paulownia spp., Liquidambar formosana, Robinia pseudoacacia and Alnus cremastogyne. Evergreen species included Cupressus funebris, Castanopsis sclerophylla, Cyclobalanopsis glauca, Cunninghamia lanceolata, Pinus massoniana, Pinus elliottii and Schima superba (Table 1).

### Table 1. Basic information of the investigated tree species.

| Species          | Family          | Leaf habit | Leaf type   | Leaf shape                                      | Phyllo-taxis | Leaf texture | Average single leaf area | Average height | Average DBH | Crown |
|------------------|-----------------|------------|-------------|-------------------------------------------------|--------------|--------------|--------------------------|----------------|-------------|-------|
| Liquidambar formosana | Hamamelidaceae | Deciduous  | Simple leaf | Broadly ovate                                    | Alternation  | Leathery     | 3.5                      | 8              | 10          | 2×3   |
| Robinia pseudoacacia | Leguminosae    | Deciduous  | Compound leaf | Oval, long-oval or ovate                        | Alternation  | Papery       | 4                        | 7              | 6           | 2×2   |
| Alnus cremastogyne    | Betulaceae     | Deciduous  | Simple leaf | Obovate, obovate-oblung, obovate-oblance-olate or oblong | Alternation  | Papery       | 1.9                      | 8              | 8           | 2×1   |
| Schima superba | Theaceae       | Evergreen  | Simple leaf | Oval                                             | Alternation  | Leathery or thinly leathery | 1.9          | 9              | 12          | 2×3   |
| Castanopsis sclerophylla | Fagaceae   | Evergreen  | Simple leaf | Long-oval, ovate-elliptic or obovate-elliptic  | Alternation  | Leathery     | 1.8                      | 5              | 6           | 3×3   |
| Cyclobalanopsis glauca | Fagaceae   | Evergreen  | Simple leaf | Obovate-elliptic or long-oval                    | Alternation  | Leathery     | 1.4                      | 6              | 8           | 2×1   |
| Paulownia spp. | Scrophulariaceae | Deciduous  | Simple leaf | Long ovoid heart-shaped or ovoid heart-shaped    | Opposition   | Thinly leathery | 23.9                     | 9              | 12          | 3×3   |
| Cunninghamia lanceolata | Taxodiaceae   | Evergreen  | Needle leaf | Lanceo-late or strip lanceo-late               | Helical alteration | - | 0.15                      | 8              | 8           | 2×1   |
| Pinus massoniana   | Pinaceae       | Evergreen  | Needle leaf | Acicular                                        | Fasciculate  | -            | 0.3                      | 6              | 6           | 2×2   |
| Pinus elliottii   | Pinaceae       | Evergreen  | Needle leaf | Acicular                                        | Fasciculate  | -            | 0.6                      | 7              | 8           | 2×2   |
| Cupressus funebris | Cupressaceae   | Evergreen  | Scale leaf | Scaly, imbricate                                | Alternation  | -            | 0.05                     | 4              | 5           | 2×1   |

#### 3.2. The PM2.5 adsorbed amount of unit leaf area from different tree species

The change of PM2.5 retention amount of unit leaf area from different tree species was 0.005–0.131 μg·cm⁻². Among them, the PM2.5 adsorbed amount above 0.1 μg·cm⁻² was only Cunninghamia lanceolata, the PM2.5 adsorbed amount between 0.03–0.1 μg·cm⁻² were Cyclobalanopsis glauca and Pinus massoniana, and the PM2.5 adsorbed amount of the remaining eight species were lower than 0.03 μg·cm⁻².

The unit leaf area of Cunninghamia lanceolata had the largest PM2.5 adsorbed amount, reached to 0.131 μg·cm⁻², while the smallest was Alnus cremastogyne, only 0.005 μg·cm⁻². The PM2.5 adsorbed amount of unit leaf area of each tree species was sorted by Cunninghamia lanceolata (0.131 μg·cm⁻²) > Pinus massoniana (0.041 μg·cm⁻²) > Cyclobalanopsis glauca (0.032 μg·cm⁻²) > Castanopsis sclerophylla (0.023 μg·cm⁻²) > Liquidambar formosana (0.016 μg·cm⁻²) > Robinia pseudoacacia.
(0.014μg·cm⁻²) > Schima superba (0.013μg·cm⁻²) > Paulownia spp. (0.007μg·cm⁻²) > Pinus elliottii (0.006μg·cm⁻²) = Cupressus funebris (0.006μg·cm⁻²) > Alnus cremastogyne (0.005μg·cm⁻²)

4. Conclusion
The absorbing dust capability per unit leaf area of different tree species are not identical, which is related to leaf surface microstructure, leaf texture and so on. If the leaf has the characteristics of surface course, tomentose and ridges like groove, grease mucus and petiole short, it could adsorb dust particles. There were significant differences in PM2.5 retention amount of unit leaf area in 11 tree species in Hunan Province, with the largest PM2.5 adsorbed amount in the unit leaf area of Cunninghamia lanceolata, reaching 0.131μg/cm², and the smallest in Alnus cremastogyne, only 0.005μg/cm².

To choose the Cunninghamia lanceolata, Pinus massoniana, Cyclobalanopsis glauca with strong ability of absorbing PM2.5 as the main tree species in Hunan Province, could produce better efficiency to purify air, and increase the function of vegetation to reduce haze and the governance effect.

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