Photosynthetic Characteristics and Dust Retention Capacity of 12 Evergreen Tree Species in Zhengzhou City in Winter: Postprint

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Abstract

To screen evergreen tree species with outstanding ecological benefits in winter for northern cities, providing scientific support for alleviating atmospheric CO2 and particulate matter pollution pressure, 12 evergreen species widely applied in landscaping in Zhengzhou City were selected. Using a LI-6400 portable photosynthesis system and the elution-mass difference method, their photosynthetic characteristics and dust retention capacity were measured in January 2019. Their photosynthetic parameters [net photosynthetic rate (Pn), transpiration rate (Tr), stomatal conductance (Gs), intercellular CO2 concentration (Ci)] and dust retention parameters (dust retention per unit leaf area, dust retention per single leaf, dust retention per unit canopy area) were calculated, and cluster analysis was conducted separately. The results indicated that the Pn, Tr, and Gs values of Ligustrum compactum, Buxus sinica, Pittosporum tobira, and Eriobotrya japonica leaves were all extremely significantly ($P < 0.01$) higher than those of other species; the Ci values of Cinnamomum camphora, Cinnamomum septentrionale, Buxus sinica, and Eriobotrya japonica leaves were extremely significantly ($P < 0.01$) higher than those of other species. Ligustrum compactum, Pittosporum tobira, and Photinia serrulata mesophyll cells maintained relatively high photosynthetic activity, whereas Cinnamomum camphora and Cinnamomum septentrionale leaves exhibited weaker photosynthetic activity with obvious low-temperature inhibition. At 7 d and 14 d after washing, the dust retention parameters of Eriobotrya japonica, Magnolia grandiflora, and Osmanthus fragrans were all extremely significantly ($P < 0.01$) higher than those of other species. At 14 d after washing, the cumulative dust retention per unit canopy area of Eriobotrya japonica, Magnolia grandiflora, and Osmanthus fragrans reached over 6.65 g · m ^{2} · crown ^{1}, demonstrating strong dust retention capacity; the dust retention per unit canopy area of

Photinia serrulata, Cinnamomum septentrionale, Ligustrum compactum, Viburnum odoratissimum, and Buxus sinica was over 3.99 g · m ^{2} · crown ^{1}. Through cluster analysis, Buxus sinica, Ligustrum compactum, and Pittosporum tobira showed obvious advantages in photosynthetic characteristics, followed by Viburnum odoratissimum, Magnolia grandiflora, Eriobotrya japonica, Photinia serrulata, and Parakmeria lotungensis; Magnolia grandiflora, Osmanthus fragrans, and Eriobotrya japonica possessed the strongest dust retention capacity, followed by Ligustrum compactum, Viburnum odoratissimum, Photinia serrulata, and Cinnamomum septentrionale. Comprehensive analysis demonstrated that Ligustrum compactum, Magnolia grandiflora, Eriobotrya japonica, Viburnum odoratissimum, Buxus sinica, and Photinia serrulata make significant contributions to improving winter air quality and dust retention in northern cities, with strong ecological regulation capacity, and can be prioritized as selected species for landscaping.

Full Text

Preamble

Photosynthetic Characteristics and Dust Retention Capacities of 12 Evergreen Tree Species in Zhengzhou City During Winter

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Abstract

To screen for evergreen tree species with outstanding ecological benefits in northern Chinese cities during winter, providing scientific support for mitigating atmospheric CO and particulate pollution, we selected 12 widely-used evergreen species in Zhengzhou' s urban landscaping. Using a LI-6400 portable photosynthesis analyzer and the elution-mass difference method, we measured photosynthetic characteristics and dust retention capacity in January 2019. We calculated photosynthetic parameters [net photosynthetic rate (Pn), transpiration rate (Tr), stomatal conductance (Gs), intercellular CO concentration (Ci)] and dust retention parameters (dust retention per unit leaf area, per single leaf, and per unit crown area), followed by cluster analysis for each parameter. Results showed that *Ligustrum lucidum*, *Buxus sinica*, *Pittosporum tobira*, and *Eriobotrya japonica* had Pn, Tr, and Gs values significantly higher ($P < 0.01$) than other species. *Cinnamomum camphora*, *C. septentrionale*, *B. sinica*, and *E. japonica* showed significantly higher Ci values ($P < 0.01$). The mesophyll cells of *L. lucidum*, *P. tobira*, and *Photinia serratifolia* maintained high photosynthetic activity, while *C. camphora* and *C. septentrionale* showed weaker activity with obvious low-temperature inhibition. At 7 and 14 days post-washing, *E. japonica*, *Magnolia grandiflora*, and *Osmanthus fragrans* had significantly higher dust retention parameters ($P < 0.01$) than other species. After 14 days, these three species accumulated over 6.65 g · m ^{2} · crown ^{1} in crown area dust retention, demonstrating strong capacity. *Photinia serratifolia*, *C. septentrionale*, *L. lucidum*, *Viburnum odoratissimum*, and *B. sinica* exceeded 3.99 g • m ^{2} • crown ^{1}. Cluster analysis revealed that *B. sinica*, *L. lucidum*, and *P. tobira* had the strongest photosynthetic characteristics, followed by *V. odoratissimum*, *M. grandiflora*, *E. japonica*, *P. serratifolia*, and *Parakmeria lotungensis*. For dust retention, *M. grandiflora*, *O. fragrans*, and *E. japonica* were strongest, followed by *L. lucidum*, *V. odoratissimum*, *P. serratifolia*, and *C. septentrionale*. Overall, *L. lucidum*, *M. grandiflora*, *E. japonica*, *V. odoratissimum*, *B. sinica*, and *P. serratifolia* make significant contributions to improving winter air quality and dust retention in northern cities, demonstrating strong ecological regulation capacity and should be prioritized for urban landscaping.

Keywords: evergreen tree species, winter photosynthesis, dust retention, environmental pollution, ecological regulation, plant ecology

Introduction

Rapid global industrialization and urbanization have severely damaged Earth' s ecological environment and atmospheric climate, with atmospheric CO and particulate pollution representing the most critical urban air quality issues (Huang et al., 2011). Atmospheric particulates indirectly affect global climate by absorbing or scattering solar radiation, generating photochemical smog, intensifying local "heat island effects," and triggering chemical reactions that worsen air pollution, creating a series of environmental problems (Stoker & Seager, 1972; Kalnay & Cai, 2003). Suspended particulates smaller than 100 m directly reduce atmospheric ventilation and have extremely complex compositions, serving as carriers for heavy metals, polycyclic aromatic hydrocarbons, bacteria, viruses, and other toxic substances. Some particulates are inherently toxic, particularly inhalable fine particles (PM , diameter < 10 m) and lung-penetrating particles (PM . , diameter < 2.5 m) (Sehmel, 1980; Yu et al., 2004; Pang et al., 2009; Wu et al., 2018). Research indicates that particles smaller than 5 m can bypass upper respiratory tract protection and enter the lungs, 0.5–5 m particles deposit in bronchioles and are expelled within hours by ciliary action, while particles < 0.5 m can reach and remain in alveoli for months or years, significantly impacting human health (Nowak et al., 2014).

Given the severe air pollution challenges in urban living environments, relying solely on pollution source control is unrealistic. Utilizing natural plant mechanisms has become an effective approach for alleviating urban environmental pressure (Liu et al., 2004; Wang & Li, 2006; Li & Liu, 2008). The dust reduction and retention functions of urban green space systems have become important quantitative indicators for measuring ecological benefits (Freer-Smith et al., 1997).

Green plants assimilate CO through chloroplasts, providing O , energy, and organic matter, thus playing crucial ecological regulation roles in mitigating global warming, stabilizing and reducing atmospheric greenhouse gas concentrations, and purifying air (Yu & Wang, 2010; Zhang et al., 2013; Yin et al., 2019). Tree canopies directly absorb, block, and alter air circulation while reducing noise, acting as filters for air pollutants (Beckett et al., 1998; Nowak et al., 2006; Popek et al., 2013; Zhao et al., 2013). Leaf surface characteristics and certain moisture levels are well-suited for atmospheric particulate deposition. When air flows through canopies, some larger dust particles are directly blocked and settle, while others remain on branch and leaf surfaces before being washed away by rain (Stoker & Seager, 1972). Long-term plant dust accumulation can reflect cumulative particulate pollution in atmospheric environments (Pang et al., 2009; Wu et al., 2018). Nowak et al. (2013) demonstrated that vegetation in ten U.S. cities directly retained 4.7–64.5 t of PM . annually, with roadside vegetation showing more pronounced effects. Dust retention capacity depends not only on green volume, regional conditions, and spatial structure, but is also closely related to species-specific capabilities, which are associated with physiological and growth characteristics (Givoni, 1991; Chen et al., 2003; Li & Liu, 2008; Jim & Chen, 2008). Comprehensive evaluation of greening species' ecological benefits has become a research hotspot.

Northern Chinese cities frequently suffer severe winter air pollution from haze and dust storms, seriously threatening residents' health and quality of life, during which evergreen species play vital ecological regulation roles. This study measured winter photosynthetic characteristics and dust retention capacity of 12 evergreen species in Zhengzhou, conducting cluster analysis to screen for superior species that effectively improve winter air quality and mitigate particulate pollution. The results provide a basis for further research on evergreen trees' ecological benefits and scientific support for evergreen plant applications in northern cities.

1.1 Study Area Overview

Zhengzhou City (112°42 -114°14 E, 34°16 -34°58 N) has a temperate-subtropical, humid-semi-humid monsoon climate with short spring and autumn seasons and distinct four seasons. Winters are cold, dry, and experience little snow; springs are dry and windy; summers are hot and rainy; and autumns are sunny with long sunshine hours.

The test and sampling site was located within the enclosed campus of Henan Academy of Forestry, east of China Mobile Henan Company, west of Zhengzhou Zoo, and surrounded by residential communities on the north and south sides.

1.2 Species Selection

Twelve evergreen tree species were selected. For each species, three individual plants with consistent growth environments and conditions, solitary planting, good growth, symmetrical crowns, and over six years of planting time were selected as fixed test specimens. General information on the test plants is shown in Table 1.

Table 1 General Information of Test Plants of Evergreen Species (Mean ± SE)

Species	Growth Form	Height (m)	Crown Height (m)	Crown Width (m)	Age (a)	Crown Shape	Abbreviation
Buxus sinica	Shrub	2.42±0.08	1.80±0.05	5.13±0.51	9.01±0.74	Spherical	BS
Pittosporum tobira	Shrub	2.35±0.05	1.62±0.08	3.83±0.29	5.77±0.25	Spherical	PT
Cinnamomum camphora	Shrub	2.15±0.13	2.12±0.18	4.27±0.25	7.20±0.26	Broadly ovate	CC
Ligustrum lucidum	Shrub	1.80±0.05	2.43±0.08	3.77±0.15	6.73±0.25	Ovate	LL
Ilex latifolia	Shrub	2.12±0.18	3.10±0.36	2.80±0.20	4.60±0.17	Umbrella	IL
Osmanthus fragrans	Shrub	8.67±0.29	5.67±0.21	9.17±1.04	9.17±1.04	Ellipse	OF
Photinia serratifolia	Shrub	5.53±0.55	3.60±0.40	7.13±0.71	7.90±0.79	Broad sphere	PS
Viburnum odoratissimum	Shrub	6.80±0.30	3.55±0.05	6.23±0.25	7.13±0.71	Obovate	VO
Cinnamomum septentrionale	Shrub	7.30±0.53	3.20±0.26	2.10±0.38	2.80±0.20	Broad ovate	CS
Eriobotrya japonica	Shrub	3.83±0.29	3.07±0.40	4.57±0.31	5.17±0.21	Broad umbrella-shaped	EJ
Magnolia grandiflora	Shrub	5.67±0.21	3.80±0.20	9.17±1.04	9.17±1.04	Broad sphere	MG

Species	Growth Form	Height (m)	Crown Height (m)	Crown Width (m)	Age (a)	Crown Shape	Abbreviation
Parakmeria lotungensis	Shrub	5.13±0.51	2.80±0.20	2.80±0.20	4.57±0.31	Narrow ovate	PL

1.3 Measurement Indices and Methods

1.3.1 Photosynthetic Characteristics Measurement

On January 23, 2019, at 10:00 AM, photosynthetic characteristics were measured using a LI-6400 portable photosynthesis analyzer (LI-COR, USA) with an open gas pathway. Healthy functional leaves from test plants were selected as measurement targets, with 3–5 leaves randomly chosen from the upper, east, south, west, and north directions of the canopy periphery, with three replicates per species.

1.3.2 Physiological Indices and Calculations

Leaf net photosynthetic rate (Pn), transpiration rate (Tr), stomatal conductance (Gs), and intercellular CO concentration (Ci) were measured. After instrument readings stabilized for approximately 3–4 seconds, six consecutive data points were recorded, and results were averaged.

1.3.3 Dust Retention Measurement

Research indicates that rainfall exceeding 15 mm can wash dust from plant leaves clean, allowing dust accumulation to restart (Zhang et al., 1997). Based on Zhengzhou' s weather patterns and precipitation characteristics, on January 9, 2019, natural precipitation and supplemental tap water washing were used to clean dust from leaves, achieving an initial zero-dust state (assuming zero dust load at this time) (Zhang et al., 1997). Sampling was conducted at 7 days (January 16) and 14 days (January 23) post-washing.

1.3.3.1 Sample Collection From the upper, east, south, west, and north directions of the canopy periphery, 2–4 branches were selected. Depending on leaf size, 30–60 leaves were randomly collected from the upper and middle portions of branches (Fan et al., 2017), with three plants sampled per species. Leaves were sealed immediately to avoid shaking and transported to the laboratory (each sealed bag was pre-weighed and labeled).

1.3.3.2 Sample Processing Using a bag-included weighing method, dust-laden leaves were first weighed on a 1/10,000 precision balance. The bag mass was subtracted to obtain initial dust-laden leaf mass (W). Leaves were quickly rinsed twice with distilled water, then thoroughly wiped with moist alcohol cotton balls to remove retained dust. The second weighing determined dust-free mass (W). Random measurements were taken for each species with three replicates, averaging across three plants.

1.3.3.3 Index Measurement and Calculation **Leaf area measurement:** Processed leaves were measured using a handheld laser leaf area meter (CI-203, CID, USA). Each leaf was measured three times and averaged to represent single-leaf area (S). The average leaf area for each species' test samples was calculated, averaging across three plants to obtain mean sample leaf area (S).

Leaf count per unit crown area (30 cm thickness): For each test plant, 1 m × 1 m quadrats were delineated on the canopy exterior from upper, east, south, west, and north directions, extending 30 cm into the canopy depth. Standard branch stratification was used to count leaves within the canopy space, with leaves potentially counted multiple times across different directions. Branches were hierarchically classified until reaching easily countable standard twigs. Random sampling counted branch numbers per layer, and 3–5 standard twigs (30 cm length) were randomly selected to count leaves, calculating total leaf number within the quadrat space. The average across five directions represented leaf count per m^2 of 30 cm-thick crown space, averaged across three plants per species (Fan et al., 2017).

Dust retention capacity calculation: Using the mass difference method (Fan et al., 2017), dust retention per unit leaf area (DPLA, $g \cdot m^{2}$), per single leaf (DPL, $g \cdot leaf^{1}$), and per unit crown area (DPC, $g \cdot m^{2} \cdot crown^{1}$) were calculated as follows:

- Dust retention per unit leaf area: DPLA = (W - W) / (N × S)
- Dust retention per single leaf: DPL = (W - W) × S / (N × S)
- Dust retention per unit crown area: DPC = N × (W - W) / N

Where: W = leaf mass before wiping; W = leaf mass after wiping; S = average single leaf area; S = mean sample leaf area for the species; N = number of test leaves; N = average leaf count per unit crown area for the species.

1.4 Statistical Analysis

Data were processed, statistically analyzed, and graphed using Excel, SPSS, and DPS software, with standard errors indicated.

2.1 Photosynthetic Characteristics

Figure 1 Photosynthetic characteristic parameters of each evergreen tree species.

As shown in Figure 1, photosynthetic parameters varied significantly among the 12 evergreen species. Pn values ranked: *Ligustrum lucidum* > *Buxus sinica* > *Pittosporum tobira* > *Eriobotrya japonica* > *Photinia serratifolia* > *Parakmeria lotungensis* > *Viburnum odoratissimum* > *Magnolia grandiflora* > *Osmanthus fragrans* > *Ilex latifolia* > *Cinnamomum septentrionale* > *Cinnamomum camphora*. *L. lucidum*, *B. sinica*, and *P. tobira* showed Pn values of

Note: Figure translations are in progress. See original paper for figures.

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