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# Pollution resistance assessment of existing landscape plants on Beijing streets based on air pollution tolerance index method

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ABSTRACT

Various plant species of green belt in urban traffic area help to reduce air pollution and beautify the city environment. Those plant species growing healthily under long-term atmospheric pollution environment are considered to be resilient. This study aims to identify plant species that are more tolerant to air pollution from traffic and to give recommendations for future green belt development in urban areas.

Leaf samples of 47 plant species were collected from two heavy traffic roadside sites and one suburban site in Beijing during summer 2014. Four parameters in leaves were separately measured including relative water content (RWC), total chlorophyll content (TCH), leaf-extract pH (pH), and ascorbic acid (AA). The air pollution tolerance index (APTI) method was adopted to assess plants' resistance ability based on the above four parameters. The tolerant levels of plant species were classified using two methods, one by comparing the APTI value of individual plant to the average of all species and another by using fixed APTI values as standards. Tolerant species were then selected based on combination results from both methods.

The results showed that different tolerance orders of species has been found at the three sampling sites due to varied air pollution and other environmental conditions. In general, plant species *Magnolia denudata*, *Diospyros kaki*, *Ailanthus altissima, Fraxinus chinensis* and *Rosa chinensis* were identified as tolerant species to air pollution environment and recommend to be planted at various location of the city, especially at heavy traffic roadside.



## 1. Introduction

Beijing, as the capital of China, has been suffering heavy air pollution due to fast urbanization and transportation. In recent years, the main components of air pollution are featured by particulate matter (PM) (Yang et al., 2010; Liang et al., 2014), which are composed of a mixture of heavy metals, black carbon, polycyclic aromatic hydrocarbons and other substances suspended in the atmosphere (Bell et al., 2011). Considering more than 5.57 million vehicles in Beijing by August 2015 (Beijing Traffic Management Bureau, 2015), vehicle exhaust emissions has become one of the most important air pollution sources, which poses heavy adverse effects on human health (Pathak et al., 2010).

In addition to measures taken to control the air pollution sources, vegetation plays important roles on remediating air pollution after the emission occurs. Green belts beside urban roads can mitigate air pollution by filtering, intercepting and absorbing pollutants in a sustainable manner (Prajapati and Tripathi, 2008). They are composed of trees, shrubs and herbs, appearing as different phytocoenoses. It is reported that trees can remove 772 tons of $PM_{10}$ (particulate matter with nominal mean aerodynamic diameters $\leq 10\ \mu m$) annually in urban area of Beijing (Yang et al., 2005). When comparing remediation effect of green spaces on $PM_{2.5}$ (particulate matter with nominal mean aerodynamic diameters $\leq 2.5\ \mu m$), multi-layer structure with high canopy density was found more efficient than single-layer ones with low canopy density (Li et al., 2014). Leaf morphology and size are also shown to be closely related to dust capture capability of trees (Liu et al., 2012).

Otherwise, air pollutants can directly affect plants' physiology via leaves' absorption (Liu and Ding, 2008a). Acid rain caused by air pollution is another factor to hurt plant individuals (Velikova et al., 2000). It acidifies the soil where many plants species are prone to absorb contaminants including heavy metals (Hajar et al., 2014; Singh et al., 2013), and damaged due to their morphological and anatomical changes (Thawale et al., 2011; Sharma and Tripathi, 2009; Mina et al., 2015). These plant species could be adopted as biological indicator to assess air pollution. Meanwhile,

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some other plant species are more resistant to the above condition or air pollution and more popular to be planted at air pollution areas, and these plants would normally keep healthy and less disturbed physiological features including leaf relative plasma membrane permeability (RPP) (Bai et al., 2006), the chlorophyll content (Chl) (Pospíšilová et al., 2001), superoxide dismutase (SOD) (Bedard and Krause, 2007), peroxidase (POD) (Bahari et al., 2015), ascorbate peroxidase (APX) (Ghozlene et al., 2014), relative water content (RWC) (Flexas et al., 2006) and ascorbic acid (AA) (Dolatabadian and Jouneghani, 2009).

Four physiological parameters were adopted to establish the air pollution tolerance index (APTI) method by Singh and Rao (1983), which has been applied to evaluate the tolerance of plant species in many studies (Singh et al., 1991; Pandey et al., 2015). The calculation of APTI involved four parameters AA (Kanayama et al., 2013), TCH (Puniran-Hartley et al., 2014), RWC (Penella et al., 2015) and leaf-extract pH (pH) (Gałuszka et al., 2011). AA acts as a coenzyme reactant by which carbohydrates, fats and protein metabolize and nucleic acid content especially RNA is produced. AA is also beneficial to the photosynthesis process of plants and to promote their growth (Mazher et al., 2011). Moreover, AA functions as a strong reductant to detoxify the polluted plants by reducing $SO_2$ content (Keller and Schwager, 1977). As one of the main essential parts of energy production in green plants, TCH directly reflects plant health status (Suo et al., 2010) with its content being significantly affected by environmental conditions (Agbaire and Akporhonor, 2014). RWC is a useful indicator of the plant protoplasmic permeability (Nayak et al., 2014). Thus plants with higher RWC values are possibly more tolerant to pollutants (Pandey et al., 2015). pH of plants has a strong relationship with air pollution especially with $SO_2$. It was reported that plants with lower pH are more susceptible, while those with pH around 7 are more tolerant (Swami and Chauhan, 2015).

In order to ease road traffic pressure, 6 ring roads have been set up in Beijing together with green belts alongside as climatic mediators and air cleaners. Plant species with strong tolerance of air pollution could play efficient role in urban environmental mediation and ecosystem health protection. This study aims to evaluate the tolerance of existing plant species near ring roads using the APTI method, and to provide useful information/suggestions for the government, policy makers and related bodies on future choices of urban vegetation types in the capital Beijing and other cities within the country.

## 2. Material and methods

### 2.1. Study area

After investigating plant species near all five ring roads in Beijing (1st to 5th), two busy traffic sampling sites Bai-Zhi-Fang Riverfront Park (BZF, 39.89N, 116.35E) and the north of Yue-Ge-Zhuang Bridge (YGZ, 39.88N, 116.28E), and one suburb sampling site the Milu Park (MLP, 39.78N, 116.47E) were chosen due to the availability of plenty varieties of plants for comparison. Site BZF is located close to the west-2-ring road with 6 lanes, about 28 bus lines passing through every day, and frequent traffic jams especially during the morning and evening rush hours. The largest railway station Beijing West is situated only about 4.6 km to the south of the site with 300 thousand tourists per day during the summer vacation. About 3 km away to the south of the site is an intersection of the west-2-ring road and Jing-Kai Freeway, a main road links Beijing and Henan Province, with heavy traffic passing in and out of Beijing. Site YGZ is located near the west-4-ring road, which crosses with the 8 lane Jing-Gang-Ao Freeway, a main road links Beijing and Hong Kong. Jing-Gang-Ao Freeway is one of the oldest freeways in the city, and it runs through the south-west of Beijing including Feng-Tai and Fang-Shan Districts. The suburban site MLP is situated 2 km to the south of the south-5-ring road, and surrounded by Nan-Hai-Zi Suburb Milu Park and wetland with much less traffic.

### 2.2. Plant species sampling

In total, leaf samples of 47 plant species were collected from the three sites (Table 1) from June 15th to July 20th 2014. Triplicate samples were collected for each plant species at each site by referring to the method in VDI-Guideline 3975 Part 11 (2007) basically. The replicate plants were considered as those individuals bearing similar height, trunk diameter and environmental status of water, soil and wind conditions etc. All trees sampled were lived at the sites for at least 2 years. At least 20 g leaves have been collected for each sample in order to have enough for analysis. Healthy and mature plants and fully developed leaves were chosen. Healthy-looking leaves were collected randomly on different directions with all samples were completely exposed to sunlight. Meanwhile, plants near busy lines and leaves facing the traffic were considered when sampling at the roadside sites BZF and YGZ. In addition, the sampling area at sites BZF and YGZ appears as zonal distribution, covering a length of 1.1 km and 536 m respectively. At site MLP leaves of plant species were collected both in the Milu Deer protection core area and the office buildings area, covering up to 200,000 $m^2$. After being sampled, about 5 g leaves were immediately put into weighing bottles, which were weighed and numbered in advance, sealed immediately and then stored in thermal insulation box and transported to the lab for relative water content measurement. About 15 g leaves were placed into sealed plastic bags and kept in a portable ice-box at −10 °C to 4 °C, then transferred to the lab for physiological and chemical analysis in 30 min.

### 2.3. RWC, TCH, pH, AA and APTI determination

RWC of leaves were determined as $RWC=(W_f - W_d)^{*}100/(W_t - W_d)$, where $W_f$ is the leaf fresh weight, $W_d$ is the dry weight of leaves undergone 3-h oven-drying treatment at 105 °C, and $W_t$ is the leaf turgid weight obtained by overnight immersion in de-ionized water (Department of Biology, East China Normal University, 1980; Liu and Ding, 2008a).

Chlorophyll content was determined following the spectrophotometric method by Arnon (1949). 3 g of fresh leaves were crushed with a mortar and extracted with 10 mL of 80% acetone for 15 min. The extracted solution was centrifuged at 2500 rmp (F=34.9 g) for 3 min (Agbaire and Esiefarienrhe, 2010) and measured at wavelength 643 nm, 645 nm and 663 nm using a spectrophotometer (METASH™ UV-6100A). Calculations were conducted using the formula below.

$\text{Chl a}\,(\text{mg/L}) = 12.7\,A_{643} - 2.69A_{645}.$

$\text{Chl b}\,(\text{mg/L}) = 22.9A_{645} - 4.68A_{663}.$

$C_T\,(\text{mg/L}) = \text{Chl a} + \text{Chl b}.$

$\text{Chlorophyll Content}\,(\text{mg/g}) = C_T{*}V/W/1000$ Where Chl a and Chl b refer to the concentration of chlorophyll a and chlorophyll b of the extracted solution at $A_{643}$, $A_{645}$ and $A_{663}$ refer to the absorbance of the measured solution at wavelength 643 nm, 645 nm and 663 nm; $C_T$ (mg/L) is the total chlorophyll concentration of the solution, whereas V represents the total volume of the extracted solution (mL) and W the weight of the leaf extracted (g). The final result, Chlorophyll Content (mg/g) refers to the chlorophyll content each gram leaf sample contains.

To measure extract pH, about 4 g of fresh leaves was soaked in 40 mL deionized water and centrifuged at 7000 g. The resulted