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Impact of aerosols and atmospheric particles on plant leaf proteins

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HIGHLIGHTS

- We obtain atmospheric particles and aerosols data from 2007 to 2012.
- Strong and weak diffuse solar radiation regions are classified.
- Aerosols and atmospheric particles stimulate plant photosynthesis.

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ABSTRACT

Aerosols and atmospheric particles can diffuse and absorb solar radiation, and directly affect plant photosynthesis and related protein expression. In this study, for the first time, we performed an extensive investigation of the effects of aerosols and atmospheric particles on plant leaf proteins by combining Geographic Information System and proteomic approaches. Data on particles with diameters of 0.1–1.0 μm (PM_1) from different locations across the city of Beijing and the aerosol optical depth (AOD) over the past 6 years (2007–2012) were collected. In order to make the study more reliable, we segregated the influence of soil pollution by measuring the heavy metal content. On the basis of AOD and PM_1, two regions corresponding to strong and weak diffuse solar radiations were selected for analyzing the changes in the expression of plant proteins. Our results demonstrated that in areas with strong diffuse solar radiations, plant ribulose bisphosphate carboxylase was expressed at higher levels, but oxygen evolved in enhancer protein and light-harvesting complex II protein were expressed at lower levels. The expression of ATP synthase subunit beta and chlorophyll a–b binding protein were similar in both regions. By analyzing the changes in the expression of these leaf proteins and their functions, we conclude that aerosols and atmospheric particles stimulate plant photosynthesis facilitated by diffuse solar radiations.

1. Introduction

Aerosols and atmospheric particles are considered to have a significant influence on solar radiance incidents on the Earth's surface, as they can reduce total irradiance and diffuse solar radiations (Cohan et al., 2002). In ecosystems, plants intercept sunlight and utilize solar energy, which is the basis for photosynthesis. The efficiency of photosynthesis has direct implications for plant health, generally by inducing changes in protein expression. Previous reports have indicated that photosynthesis conditions can impact protein expression in plants (Jiang et al., 2001).

Several investigations on photosynthetically active radiation (PAR) have demonstrated that diffuse solar radiation facilitated by aerosols and atmospheric particles is more advantageous for plant photosynthesis (Hollinger, 1998; Gu et al., 2002; Rocha et al., 2004). The scattering effect of aerosols on light would reduce downwelling solar radiation, but simultaneously increase plant photosynthesis (Matsui et al., 2008). Since aerosols enhance solar radiation scattering, the plant productivity can increase ultimately (Roderick et al., 2001). In addition, aerosol optical depths (AOD) also tend to increase the daytime carbon sink that benefit plant photosynthesis (Niyogi, 2004). In contrast, some studies have reported a negative

Abbreviations: AOD, aerosol optical depth; ATP-SSB, ATP synthase subunit beta; Chl-ab, chlorophyll a-b binding protein; LC-MS/MS, liquid chromatography coupled to tandem mass spectrometry; LHC II, light-harvesting complex II protein; OEEP, oxygen evolved in enhancer protein; PAR, photosynthetically active radiation; PM, particulate matters; Rubisco, ribulose bisphosphate carboxylase; SDS-PAGE, sodium dodecyl sulfate-polyacrylamide gel electrophoresis.

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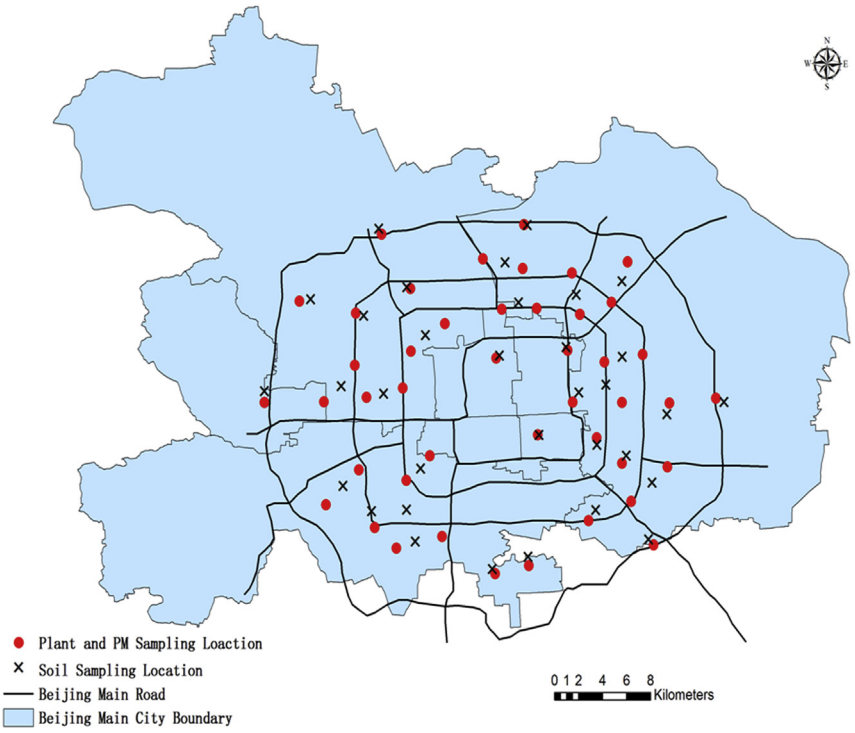

Fig. 1. Distributions of sampling locations in Beijing.

effect of aerosols and atmospheric particles on plant growth. Chameides (1999) found that aerosols in China could decrease crop productivity because they were always accompanied with other pollutants. Zhai et al. (2006) reported that heavy metals were widely found in atmospheric particles, and in response to heavy metal exposures plants usually decreased the synthesis of soluble proteins and chlorophyll. Kanniah et al. (2006) reported that high aerosol loadings can depress the carbon sink and is disadvantageous for plant photosynthesis.

To date, aerosols and atmospheric particles have been shown to have important effects on plant growth and health. Although McCree (1981) reported that particles with diameters of 0.1–1.0 μm had more efficient light-scattering ability and influenced plant photosynthesis, the mechanism by which they affect plant protein expression is still unknown. It is highly important to understand the expression profile of plant leaf proteins related to plant photosynthesis, productivity, and health status under different aerosol and atmospheric particle pollution conditions over a long-term period. In this work, we attempt to combine Geographic Information System (GIS) and proteomic approaches to investigate specific protein changes in plant leaves that are facilitated by aerosols and atmospheric particles. We tracked and continuously measured the atmosphere particles with diameters of 0.1–1.0 μm (PM_1) during the last 6 years (2007–2012). Meanwhile, AOD data were obtained by means of MODIS AOD products and remote sensing inversion. On the basis of these data, we selected two regions that have strong or weak diffuse solar radiation for further analyzing the expression patterns and changes in plant leaf proteins. Our results provide new insights into the biochemical mechanisms by which aerosols and atmospheric particles influence plant growth and health.

Table 1
Sampling time.

Years	PM_1
2007	May–June
2008	July–August
	December–January
2009	June–July
	December–January
2010	May–June
	December
2011	June–July
	December–January
2012	June 20–June 27
	June–July

2. Materials and methods

2.1. Study area and plant materials

This study was conducted in the city of Beijing, the capital city of China, where atmospheric particles present a significant problem (Wang and Xie, 2009). Beijing lies at east longitude 39.92°, north latitude 116.46° and covers an area of 16507.5 km^2. It is located at the northern edge of the North China Plain at the junction of Inner Mongolia Plateau, Loess Plateau, and North China Plain.

Euonymus japonica is native to China, Korea, and Japan. It is an evergreen shrub or small tree, which grows to 2–8 m tall, with opposite, oval leaves that are 3–7-cm long with finely serrated margins. The flowers are inconspicuous, greenish-white, and 5 mm in diameter. It is a popular ornamental plant for parks and gardens, both in its native area and also in North America and Europe. *E. japonica* is one of the main plant species planted near roads Beijing City Council, and was used as the experimental plant.

Mature leaves from 1-m high *E. japonica* were collected from different locations to ensure that the collected leaves had consistent growth time and received solar radiation under similar conditions. These leaves were stored in zip-lock bags and placed in an ice box