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Original article

Biodiversity of roadside plants and their response to air pollution in an Indo-Burma hotspot region: implications for urban ecosystem restoration

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ABSTRACT

In recent Anthropocene, biodiversity of urban roadside plants is now increasingly being realized as an eco-sustainable tool for monitoring and mitigation of air pollution. The present study aimed to investigate the impact of particulate matter (PM) pollutants on leaf morphology (stomata), biochemical (heavy metals, protein, and sugars) parameters and enzyme activity (peroxidase and catalase) of 12 common roadside plant species, growing at two different sites of Aizawl City, i.e. the Ramrikawn (RKN-Med; polluted peri-urban) site and the Mizoram University (MZU-Low; less polluted rural) site. The highest dust deposition was noted for the RKN-Med site on *Ficus benghalensis* and the lowest in *Bauhinia variegate*. The plant species growing at the RKN-Med site showed significant decreases in stomatal size and stomatal index ($p < 0.05$). Further, increased concentration of heavy metals (Fe, Cu, and Zn) was recorded at the RKN-Med site. Moreover, tolerant roadside plants find their suitability for plantation in ecologically sensitive regions, having implications for urban ecosystem restoration.

Introduction

Biodiversity of urban roadside plants acts as an eco-sustainable filter for air pollution. Air pollution originating from rapid industrialization, urbanization, population growth, and economic development has perturbed the pristine environment of urban ecosystems. Unfortunately, urban ecosystems of ecologically sensitive and biodiversity rich regions like the Indo-Burma hotspot are under severe air pollution stress (Panda and Rai 2015; Rai 2012a; Rai and Chutia 2014; Rai and Panda 2014, 2015a,b; Rai et al 2014b).

Air pollutants comprised of both particulate matter (PM) and gaseous pollutants may cause adverse health effects in humans, affect plant life, and impact the global environment by changing the atmosphere of the earth (Raabe 1999; Rai 2013, 2015b; Rai and Panda 2014; Rai et al 2013, 2014b). Air pollution emanating from PM is particularly deleterious as it leads to various cardiopulmonary diseases through oxidative stress (Rai 2013, 2015b).

In quest of an alternative eco-friendly technology pertaining to urban ecosystem restoration, impacts of air pollutants on morphological, physiological, and biochemical parameters of plants of an urban forest are now being investigated as an integral part of air pollution science. Instead of the existing plethora of policies as well as instrumentation technologies with high cost issues and other limitations (Rai 2013), urban roadside plants are inextricably linked with eco-sustainability (Panda and Rai 2015, Rai 2013; Rai et al 2014a).

Foliar surface of urban roadside plants acts as a sink for PM deposition and through their deposition they show specific morphological, physiological, and biochemical responses. Deposition of PM pollutants on a leaf surface induces structural and functional changes (Panda and Rai 2015).

Although plants are very important to maintain urban ecosystem health, they may, however, be severely affected by PM pollution (Agbaire 2009; Panda and Rai 2015; Rai 2013; Rai and Panda 2014a, 2015a,b; Rai et al 2013, 2014a,b; Randhi and Reddy 2012; Shweta 2012; Steubing et al 1989).

Further, effects of PM pollutants occur at various scales in the plant system, beginning at the biochemical level and progressing up to the landscape level (Panda and Rai 2015). Also, urban roadside plants demonstrate a wide array of responses when

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exposed to pollutants in the form of photosynthesis, respiration, enzymatic reactions, stomatal behavior, membrane disruption, senescence, and ultimately death (Panda and Rai 2015; Rai and Panda 2014b, 2015a,b; Rai et al 2014a; Shweta 2012; Thakar and Mishra 2010).

The foliar injury (foliar effect) along with the significant changes in plant anatomy, physiology, and biochemistry indicates polluted urban environment (Panda and Rai 2015; Rai and Panda 2015a). Therefore, urban roadside plants should be considered as an integral part of any comprehensive plan aimed at improving overall urban air quality and concomitantly they assist in following an eco-sustainable approach (Abida et al 2009; Panda and Rai 2015; Rai 2013; Rai et al 2014b).

The impacts of PM on the morphological, biochemical, and physiological features of urban roadside plants (species) have been recorded by several researchers (Hirano and Aiga 1995; Joshi and Bora 2011; Joshi and Swami 2009; Kulshreshtha et al 2009; Malhotra and Khan 1984; Panda and Rai 2015; Pandey and Agrawal 1992; Rai 2013; Rai and Panda 2014a, 2015a,b; Rai et al 2013, 2014a; Shweta 2012; Thambavani and Sabitha 2011). Concomitantly, the aforesaid researches assist in screening of tolerant plants. By analyzing morphological, physiological, and biochemical parameters, an early diagnosis of urban air quality may be evaluated and eco-sustainable mitigation approaches or options may be investigated (Panda and Rai 2015).

Several studies have been performed on the impacts of air pollution with selected plants only in urban polluted regions (Hirano and Aiga 1995; Joshi and Bora 2011; Joshi and Swami 2009; Malhotra and Khan 1984; Pandey and Agrawal 1992; Shweta 2012; Rai 2013; Rai and Panda 2015b, Thambavani and Sabitha 2011), however, no systematic study has been done in an urban portion of ecologically sensitive hilly regions like Aizawl, Mizoram, North-East India, which is also an integral part of the extremely diverse Indo-Burma hotspot region of Myers (Rai 2009a, 2012b; Rai and Chutia 2014). Further, a plant's response may alter under varying pollution stress; however, until now, no study has been done in ecologically sensitive hilly regions of the Indo-Burma hotspot region to study the impacts of PM pollution on urban roadside plants with their possible phyto-technological innovation.

In the light of abovementioned discussion, the present study deals with the quantification of air pollutants in the ambient air, and assesses the impacts of air pollutants with special reference to PM on morphological, physiological, biochemical changes, and enzymatic activities of some common urban roadside plant species in an Indo-Burma hotspot region.

Material and methods

The study area

The present study was conducted in Aizawl, the capital of Mizoram state (North East India), (21°58'–21°85' North and 90°30'–90°60' East), at 1132 m above sea level (Figure 1). The altitude in Aizawl district varies from 800 m to 1200 m. The climate of the area is monsoonal. The annual average rainfall amounts to ~2350 mm. The area experiences distinct seasons. The ambient air temperature normally ranges from 20°C to 35°C in summer and from 9°C to 21°C in winter. It is well known that meteorological data may also affect the air pollutants including dust or PM, therefore the monthly average minimum and maximum temperatures of the study area are recorded during the study period, i.e. from November 2011 to February 2012. The average minimum temperature during the study period was 13.82°C while the maximum was recorded as 25.52°C (Rai 2015a).

Sampling site

Two sampling sites were selected within Aizawl to assess the impact of air pollution on morphological and biochemical plant parameters. These sampling sites include Mizoram University (MZU) campus (an institutional/rural area) and Ramrikawn (residential and commercial/peri-urban area). Ramrikawn is a very densely constructed commercial area with markets, bus and taxi stands, and the Food Corporation of India (FCI). The FCI provides space for food storage for the whole of Mizoram state. Due to existence of the FCI in the Ramrikawn area, there are frequently heavy duty vehicles coming from all parts of India through the National highway of Pushpak (NH-54). As there is a public bus and taxi stand, vehicular movement is usually high in the Ramrikawn area. Stone quarrying activity is also found in this area, which leads to emission of dust or PM particles (Panda and Rai 2015). Biomass burning through shifting cultivation is very common in this region (Panda and Rai 2015; Rai 2009a, 2012; Rai and Chutia 2014) and may also be a source of suspended PM pollution. In view of these pollution sources, we selected Ramrikawn as the polluted area for investigation. Twelve selected urban roadside plants were sampled from the roadside of the Ramrikawn site over a 7 km stretch of road.

MZU campus is an institutional area. University buses, taxis, trucks, or trollies coming with construction materials are the main sources of pollution in MZU campus. However, the load of vehicles is comparatively low. Therefore, we selected MZU as reference or control site in order to compare with the results recorded from the Ramrikawn site. Twelve selected plants were sampled from the roadside of the MZU site over the stretch of 5 km. We confined our quest on impact of air pollution to two sites, as both covered the range of 12 km. Thus, the present study was carried out for comparative assessment of two differentially polluted sites (in peri-urban and rural locations) in relation to morphological and biochemical parameters of 12 common roadside plant species during the winter season (November 2011–February 2012).

Dust or PM tends to concentrate during the winter season through atmospheric inversion (Panda and Rai 2015; Verma and Singh 2006) particularly during the morning hours. Further, in our recent research (Rai and Panda 2014b) we recorded maximum dust deposition during winter seasons for the 12 plants used for the present study. Moreover, since the leaves were formed well before the air quality sampling, the morphology is more likely related to air qualities prior to the beginning of the air sampling period, therefore, there might be an argument that the prior growth season has an impact on the extent of dust deposition as well. The aforesaid fact cannot be totally overlooked. However, to address this issue, we started the air and plant sampling immediately after rainy season cessation, as rain tends to wash off the dust particles from the leaf surface and therefore we assume that air pollutant impact on leaf morphology and physiology is negligible. Moreover, we point out that average rainfall recorded during the winter season in our study period is zero; therefore, there is no net removal of dust particles through rain during the winter season.

Air quality analysis

Ambient air quality in terms of common air pollutants such as SO_2, NO_2, and suspended PM was analyzed for the selected sites (Table 1). Sampling was conducted over 24 hours, and twice in a week during the winter season of the study period. A high volume air sampler (Envirotech model, APM-460NL; Envirotech Instruments Pvt. Ltd., India) with a gaseous attachment (Envirotech model, APM-411TE; Envirotech Instruments Pvt. Ltd., New Delhi)