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RESEARCH ARTICLE

ACTIVE BIOMONITORING OF AIR QUALITY USING STOMATAL CHARACTERISTICS AND PARTICULATE MATTER OF FICUS BENJAMINA L. LEAF IN A TROPICAL URBAN ENVIRONMENT

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ABSTRACT

Plants that are constantly exposed to environmental pollutants absorb, accumulate and integrate these pollutants into their systems. Particulate matter (PM) emissions, stomatal characteristics such as Stomatal density (SD), stomatal pore surface (SPS) and Stomatal resistance (RS) were investigated in Ficus benjamina exposed along main roads (MR) as well as in parks (P) as control in Abidjan. This study found a higher level of particulate matter (1,354.10-4 A), Stomatal density (4,26 108 number of stomata.mm-2) and stomatal resistance (45,050 s.m-1) in polluted area (Roads). The highest stomatal pore surface (269,479 µm2) is observed in parks (P). This study showed that particulate matter, stomatal density and stomatal resistance are more effective in stress conditions in Ficus benjamina and in tropical countries to estimate the atmospheric pollution, it's possible by using particulate matter, stomatal density and stomatal resistance plants.

Key words: Bioindicator, Air Pollution, Stomata, Leaf SIRM, Côte d'Ivoire.

INTRODUCTION

The growing industrialization and the intensification of human activities (transport, industry, waste, etc.) affected the urban air quality. Air pollution can also be transported over very long distances by wind. Plants play an important role in monitoring and capture the pollutant as carbon monoxide (CO), carbon dioxide (CO_2), hazardous air pollutions (HAPs), nitrogen oxides (NOx), sulphur dioxide (SO_2) and tropospheric ozone (O_3). Plants are more frequently used as biomonitor/ bioindicator than humans and animals because plants have abroad geographical distribution, are easy to gather and reflect better the local conditions, since they are more sensitive in terms of physiological reaction to the common air pollutants (Falla *et al*., 2000; Nali *et al*., 2007; Raz *et al*., 2011). The anatomical, morphological and physiological plant parameters, which have been proved to be sensitive to air pollution (Wen *et al*., 2004; Verma and Singh, 2006; Balasooriya *et al*., 2009; Wuytack *et al*., 2011). Among these methods, the biological method is known to be inexpensive for prolonged surveys of air quality due to integration of the effect of all the environmental factors (Yu-mei *et al*., 2005; Fernández *et al*., 2007).

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In this study, the air pollution effects on the stomatal characteristics and particulate matter were investigated in *Ficus benjamina* in Abidjan city. The present study was conducted on trees growing along national highway as well as Park area.

MATERIALS AND METHODS

Study area: The study was conducted in the city of Abidjan city, Côte d'Ivoire. Abidjan is the economic capital city with a human population of over 4 million on 422 km^2. The intensive development of industry and road traffic and the increasing number of automobiles in the city lead to a notable increase of air pollution. All transport vehicles (about 30,000 in 2010) have diesel engines (Barima *et al*., 2014). The city was subdivided into 2 land use classes: Parks (2 sites) and Roads (4 sites). It is suggested that the air pollution is an important problem which should be resolved. First of all, effective technology of monitoring air pollution is needed. At each site three sampling leaf were selected to determine the particulate matter and stomata characteristics. The city of Abidjan also contains several parks of which a national park, a botanical garden and a floristic center. In these green areas, the human influence is relatively weak and activities of pollution are most controlled relatively to the industrial areas and road traffic.

Sampling and measurements: We used *Ficus benjamina* plant species which was usually used as ornamental plant. This specie was obtained and grown in a garden of the city. This plant was grown in 30 cm diameter, 27 cm height plastic pots. The Medium was a mixture of compost and soil. The plant was grown for three months until reaching 140-180 cm. *Ficus benjamina* have more hairs in the adaxial leaf than abaxial leaf.

Leaf magnetic properties: Magnetic measurements were carried out at the Department of Bioscience Engineering of the University of Antwerp (Belgium). All six dried leaves of each sampling location were tightly packed together by cling film, avoiding the movement of any leaf parts, and pressed into a 10 cm^3 plastic tube. These tubes containing leaf samples were magnetised in a direct current (DC) field of 300 mT with a Molspin pulse magnetiser (Molspin Ltd, UK). Isothermal Remanent Magnetisation (IRM) of the samples ($A.m^2$) was measured using a Molspin Minispin magnetometer (MolspinLtd,UK) with high sensitivity, and was normalized by leaf area (m^2) (Kardel *et al*., 2011).

Stomatal characteristics: Stomatal imprints were made by applying a very thin coat of color less nail varnish on the abaxial leaf, thereby avoiding the midrib and the leaf margin, while the leaf remained attached to the plant. Subsequent to drying (15-20 minutes), the adhered nail varnish film was gently peeled off by using transparent tape and was subsequently fixed on a clean labelled microscopic slide. Stomatal density (SD, number of $stomata.mm^{-2}$), stomatal pore surface (SPS, μm^2) and Stomatal resistance (RS, $s.m^{-1}$) were determined with a light microscope as described by (Balasooriya *et al*., 2009; Kardel *et al*., 2010).

Statistical analysis: The mean leaf SIRM and stomatal characteristic were calculated and compared using ANOVA procedure for each land use class. We used STATISTICA 7.1 software, to make correlation between stomatal parameters and find linear regression.

RESULTS AND DISCUSSION

Leaf SIRM: *Ficus benjamina* presents the highest leaf SIRM ($1,354.10^{-4}$ A) at Roads and the lowest was observed at Park ($6,789.10^{-6}$ A) (Figure 1). The leaf SIRM was significantly ($p < 0.05$) between land use classes. The most polluted land use class was major roads. These results are in agreement with those obtained by [10] who found high levels of SIRM in urban (main roads and intersections) and industrial areas compared to parks and residential areas in the city of Abidjan (Cote d'Ivoire). Also, in the city of Gent (Belguim) (Kardel *et al*., 2012) have found high levels of SIRM in urban (tram lines, highways, main roads and intersections) and harbor-industrial areas compared to green and sub-urban areas. Our results indicate that the main sources of pollution determined with SIRM were car exhaust as described by (Bukowiecki *et al*., 2010; Kardel *et al*., 2012).

Stomatal characteristics: Figure 3 shows the results of stomatal density (SD), stomatal pore surface (SPS) and stomatal resistance (RS). The results revealed that SD and RS of *Ficus benjamina* significantly increased from main roads toward parks, while the reverse was observed for SPS. It means that the stomatal characteristics of *Ficus benjamina* allow clear distinction between the most polluted land use classes (Roads) and the less polluted land use classes (Park). This result can be explained by the adaptation mechanisms of plants to stressful habitats, due to e.g. air pollution stress (Kardel *et al*., 2012). Also, plants can reduce the uptake of pollutants by decreasing their stomatal density (Larcher *et al*., 2003). Thereby, when plants increase stomatal density and reduce stomatal size that leads to an optimal adjustment for control of gas exchange in general and the entrance of pollutants through stomata in particular (Alves *et al*., 2008). The reduction of stomatal densities and pore size may be important for controlling absorption of pollutants (Verma and Singh, 2006), but will limit photosynthesis at the same time.

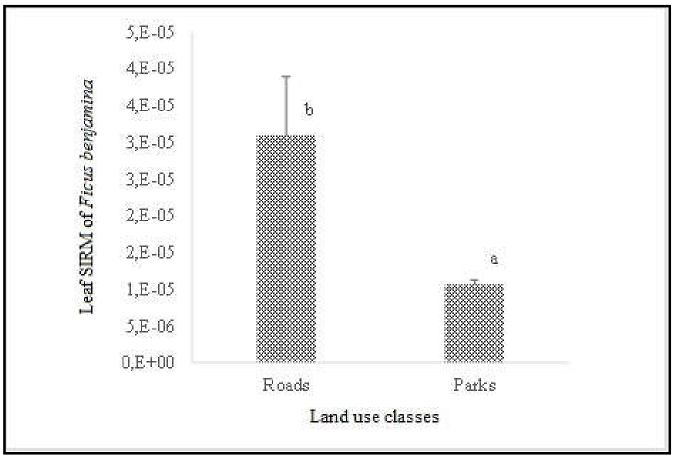


Figure 1. Leaf SIRM for *Ficus benjamina* in mean roads and parks. Small letters indicate significant differences between land use classes in *Ficus benjamina*. Error bars are standard deviation. Significant p < 0.05

Correlation between stomatal pore surface (SPS) and stomatal resistance (RS) in *Ficus benjamina:* The linear regression of stomatal pore surface (SPS) and stomatal resistance (RS) obtained starting from the slope of the models of regression (Figure 3) shows a negative but significant correlation ($R^2 = 0,5613$; $P \leq 0.05$). The result shows the influence of stomatal resistance on stomatal pore surface. Moreover, it is this RS which will influence the exchange of pollutants between the atmosphere and the interior of the leaf (Kardel *et al*., 2010). This significativity could suggest, that in polluted areas the plant reduces the surface of the pores and shows a stomatal resistance.

Correlation between stomatal density (SD) stomatal and resistance (RS) in *Ficus benjamina:* The linear regression of stomatal density (SD) stomatal resistance (RS) obtained from the slope of the models of regression (Figure 4) shows a negative but significant correlation ($R^2 = 0,227$; $p \leq 0,05$). Atmospheric pollutants can disturb stomatal control mechanisms (Robinson *et al*., 1998), since plants optimize their stomatal closure efficiency by increasing SD and decreasing SPS as a response to air pollution (Elagoz *et al*., 2006; Kardel *et al*., 2010). This observation, could be explained by a control of absorption of the pollutants (Verma and Singh, 2006) with an obstruction of the stomata by the particulate matters (Auclair, 1997) thus leading to the reduction of photosynthesis (Thompson, 1984) at roadsides. This observation could represent the limitation of the diffusion of gas by the stomata front of externe pollution (Verma and Singh, 2006; Balasooriya *et al*., 2009).

Correlation between Leaf SIRM, stomatal density and Stomatal pore surface: The positive correlation obtained between leaf SIRM and stomatal density (Figure 5A) shows

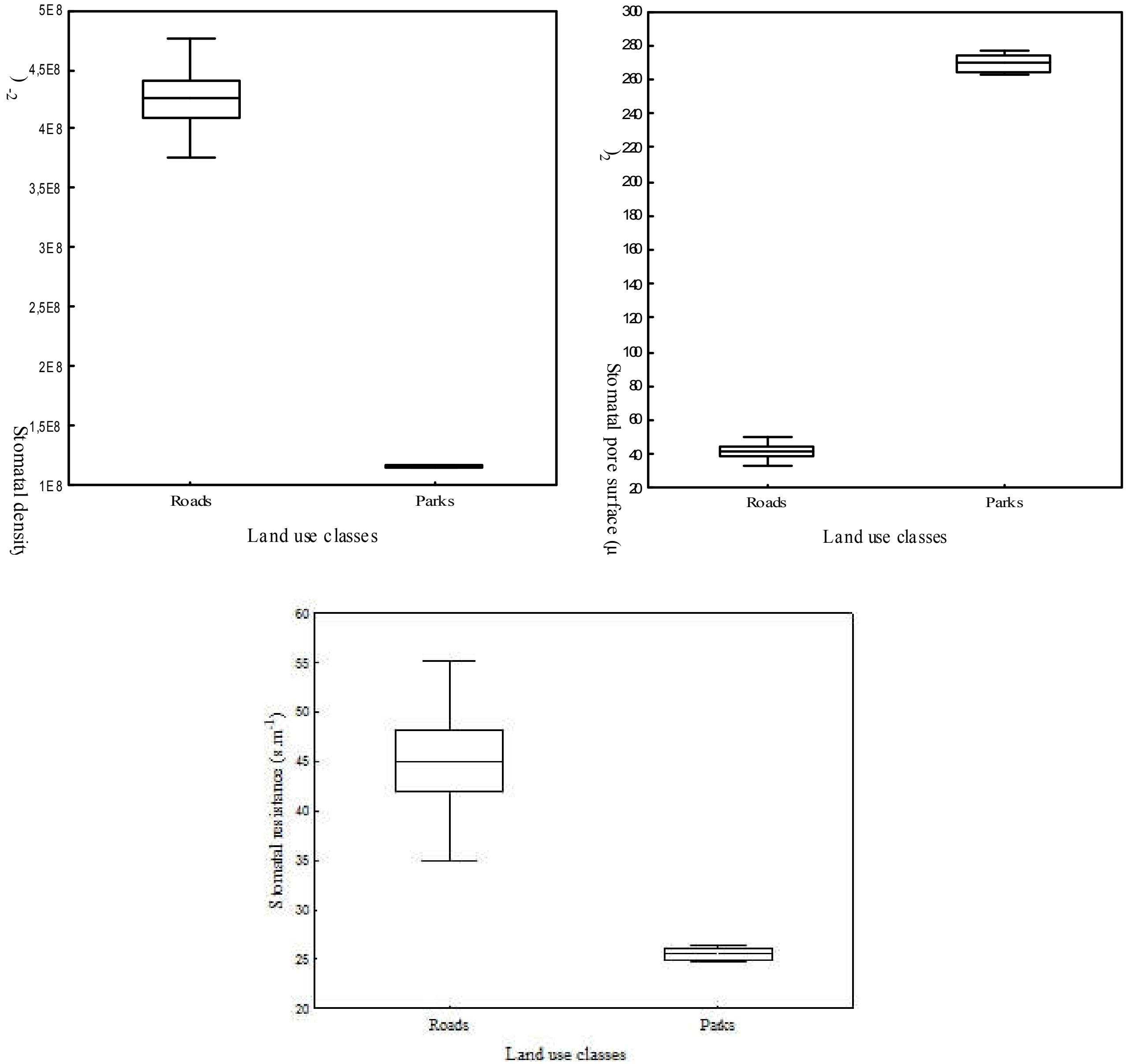


Figure 2. The stomatal characteristics of Ficus benjamina

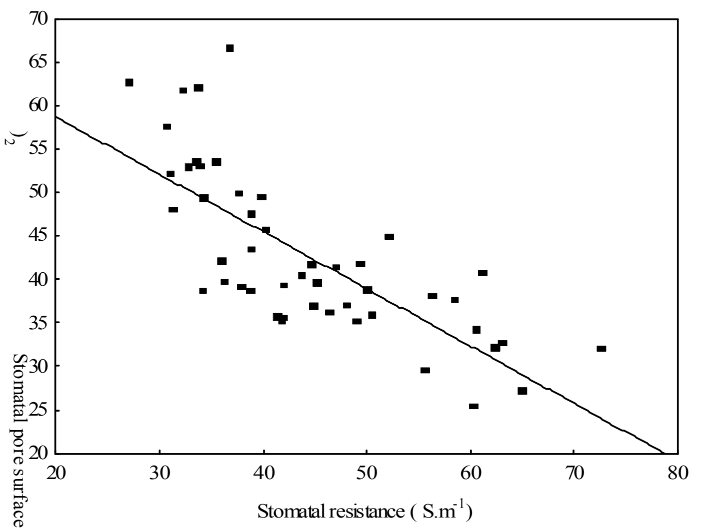


Figure 3. Correlation of stomatal pore surface (SPS) and stomatal resistance (RS) in *Ficus benjamina*

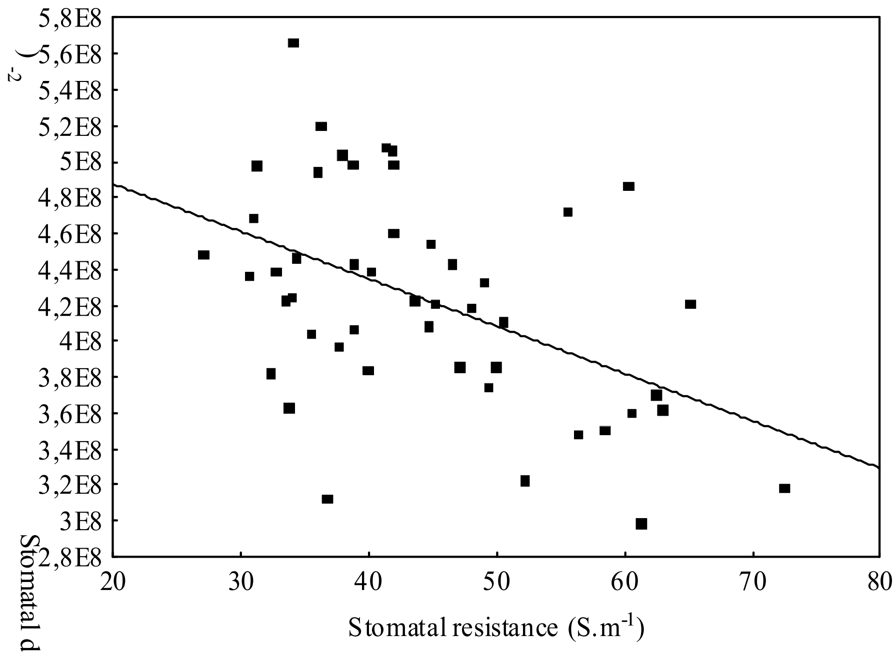
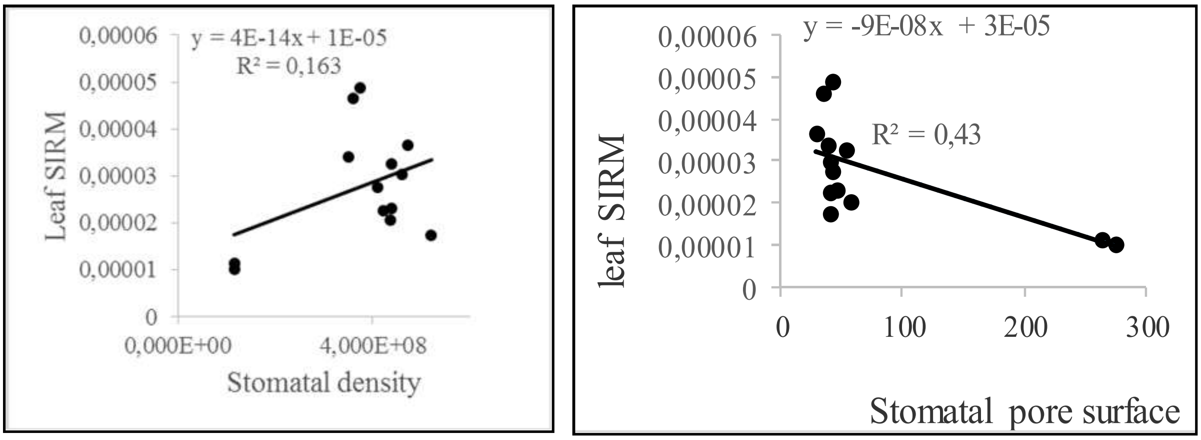


Figure 4. Correlation between stomatal density (SD) stomatal resistance (RS) in *Ficus benjamina*



A **B**

Figure 5. Correlation of Leaf SIRM, Stomatal density and Stomatal pore surface

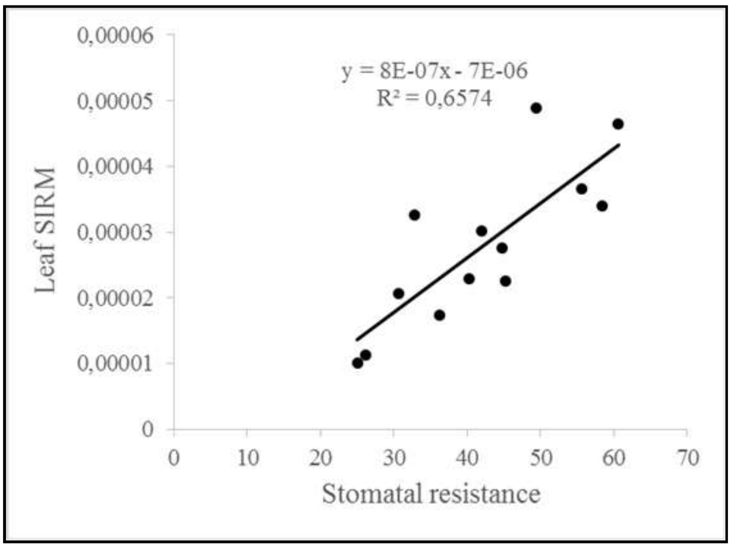


Figure 6. Correlation of Leaf SIRM and Stomatal resistance

that no significant correlation ($R^2 = 0,163$; $p \geq 0,05$). These results could be also explained due to this characteristic as an important bioindicator. The gases that penetrate into the plant's leaves through the ostiole can cause alterations in their physiology, metabolism, ultra structure, and/or cellular structures. And these observations indicated that the pollution levels in those localities were unfavorable to normal physiological development, and that the increase in the number of stomata is essential for effective gas exchange under adverse conditions. Also, the negative correlation obtained between leaf SIRM and stomatal pore surface (Figure 5B) show that significant correlation ($R^2 = 0,43$; $p \leq 0,05$). These results could be also explained by a reduction of stomata is also found in response air pollution. The highest level of pollution led to the reduction of stomatal pores from exchange air, thus causing stress on plant metabolism (Kapoor *et al*., 2013). The reduction in pore size may be important for controlling absorption of pollutants but would limit photosynthesis at the same time (Verma and Singh, 2006).

Correlation between Leaf SIRM and stomatal resistance: The positive correlation obtained between Leaf SIRM and Stomatal resistance (Figure 6) show that significant correlation ($R^2 = 0,231$; $p \leq 0,05$). Plants are constantly exposed to environmental pollutants that they absorb, integrate and accumulate in their systems. It is reported that, depending on their level of sensitivity, the plants show visible changes that would include biochemical and physiological modification (Agbaire, 2009).

Conclusion

This study favours the choice of *Ficus benjamina* as an active biomonitoring species of tropical urban habitat quality due to its wide cosmopolitan distribution. The present study allowed to estimate air quality of the city of Abidjan from leaf SIRM values, stomatal characteristics (stomatal density, stomatal pore surface and stomatal resistance) in *Ficus benjamina*. Moreover, the species is easy to sample, it has a suitable height for biomonitoring and its leaves are less delicate. This study showed that the higher level of leaf SIRM, stomatal density, stomatal resistance values were found at roadsides.

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