# EFFECTS OF AIR POLLUTION ON THE LEAF MORPHO - PHYSIOLOGICAL TRAITS OF SOME COMMON TREE SPECIES OF RAMNA PARK AND ITS ADJACENT ROADSIDE AREAS IN DHAKA CITY, BANGLADESH

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## Abstract

The present study examined the effects of air pollution on the leaf morphological and physiological properties of selected nine plant species *viz*, *Swietenia mahagoni*, *Polyalthia longifolia*, *Ficus benghalensis*, *Ficus religiosa*, *Syzygium cumini*, *Artocarpus heterophyllus*, *Terminalia arjuna*, *Mimusops elengi*, and *Terminalia catappa* grown in the Ramna park (non-polluted site) and its adjacent roadside areas (polluted site) of Dhaka city (Bangladesh). Leaf samples were collected and measured to determine the morphological variables such as length, breadth, area, perimeter, specific leaf area and petiole length and physiological traits such as leaf water content, relative water content, leaf dry matter content and chlorophyll content of these plants. Results of this study showed a significant difference in plant leaf morphology between polluted and non-polluted areas. *T. arjuna* showed minimum decrease in leaf length (7.00%), leaf area (29.42%) and leaf perimeter (7.09%) on the contrary, *P. longifolia* showed maximum decrease in leaf length (41.47%), leaf breadth (46.37%), leaf area (67.82%) and leaf perimeter (39.25%). Results also showed that minimum decrease in specific leaf area (4.84%) and petiole length (9.71%) was observed in *F. benghalensis* and *T. catappa* whereas, maximum decrease 29.31 and 42.74% for the same traits were found in *T. catappa* and *F. benghalensis*, respectively. Among the leaf physiological properties, chlorophyll content, relative water content and leaf dry matter content showed significant difference between two study sites. Among the nine tree species, seven showed the higher chlorophyll content in non-polluted Ramna park site than the polluted road sites. The findings of this study demonstrate the severity of air pollution and its potential effects on plant functional traits that are associated with environmental cycles. Results thus suggest the importance of improving air quality for better urban planning.

## Resumen

El presente estudio examinó los efectos de la contaminación del aire en las características morfológicas y fisiológicas de las hojas de nueve especies de plantas seleccionadas, *Swietenia mahagoni, Polyalthia longifolia, Ficus benghalensis, Ficus religiosa, Syzygium cumini,* *Artocarpus heterophyllus*, *Terminalia arjuna*, *Mimusops elengi* y *Terminalia catappa* cultivadas en el parque Ramna (sitio no contaminado) y sus áreas al borde de la carretera adyacentes (sitio contaminado) de la ciudad de Dhaka (Bangladesh). Se recolectaron y midieron muestras de hojas para determinar las variables morfológicas como largo, ancho, área, perímetro, área foliar específica y longitud del pecíolo y rasgos fisiológicos como contenido de agua de la hoja, contenido de agua relativo, contenido de materia seca de la hoja y contenido de clorofila de estas plantas. Los resultados de este estudio mostraron una diferencia significativa en la morfología de las hojas de las plantas entre áreas contaminadas y no contaminadas. *T. arjuna* mostró una mínima disminución en la longitud de la hoja (7,00 %), área foliar (29,42 %) y perímetro de la hoja (7,09 %), por el contrario, *P. longifolia* mostró una máxima disminución en la longitud de la hoja (41,47 %), el ancho de la hoja (46,37 %), área foliar (67,82%) y perímetro foliar (39,25%). Los resultados también mostraron una disminución mínima en el área foliar específica (4,84 %) y en la longitud del pecíolo (9,71 %) en *F. benghalensis* y *T. catappa*, mientras que se encontró una disminución máxima de 29,31 y 42,74 % para las mismas características en *T. catappa* y *F. benghalensis*, respectivamente. Entre las propiedades fisiológicas de la hoja, el contenido de clorofila, el contenido relativo de agua y el contenido de materia seca de la hoja mostraron una diferencia significativa entre los dos sitios de estudio. Entre las nueve especies de árboles, siete mostraron un mayor contenido de clorofila en el sitio del parque Ramna no contaminado que en los sitios de caminos contaminados. Los resultados de este estudio demuestran la gravedad de la contaminación del aire y sus efectos potenciales sobre características funcionales de las plantas que están asociados con los ciclos ambientales. Por lo tanto, los resultados sugieren la importancia de mejorar la calidad del aire para una mejor planificación urbana.

## Introduction

Air pollution is a major environmental issue and has a negative impact on trees in urban areas. The leaf is the most vulnerable portion of the plant to contaminants in the air resulting in the photosynthesis inhibition and plant growth reduction in affected plants. Even before symptoms appeared, air contaminants have both direct and indirect impact on the metabolism of roadside plants (Aribal et al. 2016, Saadullah et al. 2013, Viskari et al. 2000). In urban environments, trees and urban forests can improve air quality by filtering and absorbing pollutants and particulates (Beckett et al. 2000) and some plants usually show phenotypic differences in response to changes in the environment (Ivancich et al. 2012, Warren et al. 2005).

Ramna Park is a plain forested park that lies in the centre of Dhaka city with a moderate number of flora and fauna. It now protects an area of 68.50 acres having 151 distinct types of plant species where 71 species of flowering trees, shrubs, and herbs, 41 species of forestry, 33 species of medicinal plants and other species (Pasha et al. 2021, Murshed 2012). As Dhaka is the largest urban area in Bangladesh and the population and vehicles are increasing by the day, so the air quality in Dhaka is unhealthy and has even reached dangerous levels recently. The plant biodiversity of urban roads acts as an ecologically sustainable filter for air pollution. The leaf surface of urban road side plants serves as a sink for deposition of particulate material and, as a result, they exhibit specific morphological, physiological and biochemical responses, which are now being studied as a part of comprehensive science of air pollution. The objective of this study was to know the impact of air pollution on leaf morphology and physiology of common tree plant species available in this park and its nearby roadsides area.

## Materials and Methods

*Study sites description*

Two sites in Ramna park (23° 44' 18.90" N 90° 24' 1.47" E) and adjacent roadside areas (23° 44' 15.53" N 90° 23' 44.92" E) under the district of Dhaka, Bangladesh were selected for the collection of plant samples (figure 1). Ramna park was selected as control site and the streets with heaviest volume of vehicles per day adjacent of Ramna park selected as polluted site. Temperature of the study areas ranged from 14 to 34°C while the average rainfall is 124.4 mm/year (www.timeanddate.com/weather).

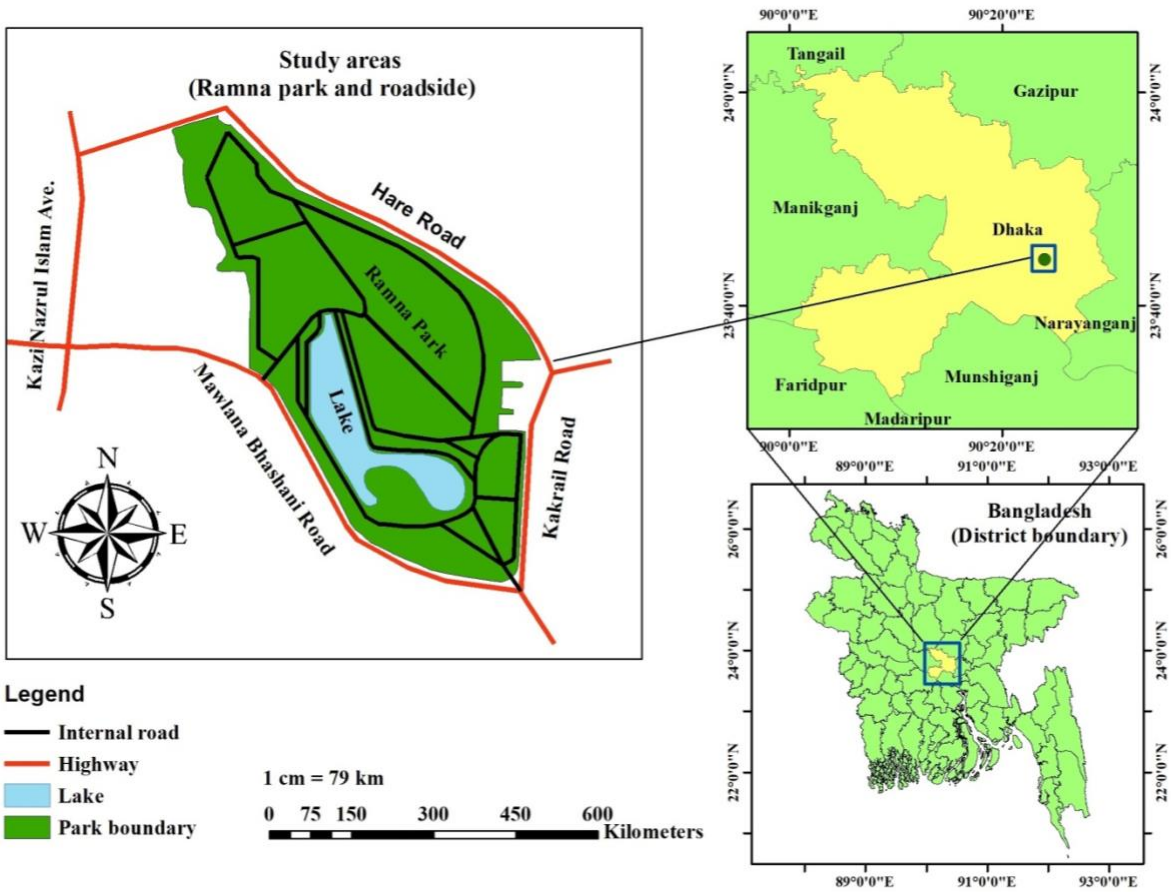


Figure 1. Map of the study sites.

*Collection of leaf samples*

Leaf samples of nine different plant species *viz. S. mahagoni*, *P. longifolia*, *F. benghalensis*, *F. religiosa*, *S. cumini*, *A. heterophyllus*, *T. arjuna*, *T. catappa* and *M. elengi* were collected from both sites (figure 2), centre of Ramna park with at least 50 m distance and adjoining road sides of it. Due to their prevalence and presence in both the polluted and non-polluted sites, these plant species were chosen. Three replicates of each plant species were done from each site to collect fully expanded leaf samples. Collected leaf samples then were kept in a polythene bag. Immediately after collection from the study areas, samples were brought to the Ecology and Environment Laboratory at the Department of Botany, University of Dhaka. Leaf morpho-physiological properties such as leaf fresh weight, leaf dry weight, leaf turgid weight, leaf length, leaf breadth, leaf area, specific leaf area, leaf water content, relative water content, leaf dry matter content and chlorophyll were determined from collected leaf samples.


Figure 2. Photograph showing the vegetation of study sites of Ramna park (a-b) and the vegetation of its adjacent road sites (c-d).

*Analysis of leaf morphological traits*

For the analysis of leaf traits, six fresh leaves were selected randomly from the samples collected from each species of each replicate. Then, morphological and physiological traits of leaf measurements were done for all these six leaves and then the average value of each variable was obtained. Measurement of leaf length was done using software named ImageJ Ver: k 1.45. For this, leaves were spread over a plain paper sheet along a ruler. Image of the leaves was captured using a camera (Canon EOS 1500D). By this way, single image of each six leaves for each sample was captured separately. Then, from each image leaf length was measured using the software ImageJ. Captured image was open by ImageJ. After that from the scale bar scale was set by width tool in centimeters from analyze menu. Then the color image was converted with gray scale (8 bit) from image menu. Image was adjusted in threshold to get red leaf image. The red leaf image was selected by wand tool and selected image data was added in ROI manager window from analyze menu. Then result was analyzed by click on Measure box. Petiole length, leaf breadth, perimeter and leaf area were analyzed by same way. Dry leaf weight was measured after drying the leaf in oven at 60ºC for 24 h. Specific leaf area ($cm^2$ $g^{-1}$) was calculated as leaf area of the sampled leaves divided by the dry weight of the leaf.

*Analysis of leaf physiological traits*

Leaf chlorophyll content was determined by using a chlorophyll meter (SPAD-502Plus, Minolta, Japan). Leaf water content per unit area (g $cm^{-2}$) was determined as leaf fresh mass minus dry mass, divided by leaf area. Leaf dry matter content (g $g^{-1}$) was calculated as leaf dry mass divided by leaf fresh mass. Relative water content was calculated by dividing fresh weight minus dry weight by turgid weight minus dry weight.

*Statistical analysis*

To determine the difference in morpho-physiological traits among nine plant species from both sites, ANOVA was performed. Tukey's HSD was done to test the level of significance among the means. For data analysis JMP 4.0 software (SAS Institute, Carry, NC, USA) was used.

## Results and Discussion

*Leaf morphological traits*

Results presented in figure 3 revealed that the overall average leaf length of all species except *F. religiosa* was recorded higher at Ramna park than road side areas. Minimum leaf length at polluted and non-polluted site (11.15 and 12.92 cm) was found in *M. elengi* and *F. religiosa*, while maximum (21.64 and 27.40 cm) was recorded in *T. catappa*, respectively. Statistical t-test indicated that there was highly significant ($p<0.0001$) variation in the values of leaf length between two sites. The overall average decreasing % of leaf length at polluted site with respect to non-polluted site was found in the range of 7.00-41.47% lowest to highest in the leaf of *T. arjuna* and *P. longifolia* , respectively, while *F. religiosa* showed increasing in leaf length among the studied tree plant species (table 1). Aribal et al. 2016 showed that significant reduction in leaf length between polluted and non-polluted areas. Bhatti and Iqbal (1988) found significant decline in leaf length of *Ficus benghalensis* at the polluted sites. The slow increase in the proportion of leaf length at polluted sites compared to unpolluted sites may be caused by the impact of air pollution at such sites, which reduces the exchange of gases for photosynthesis and leaf productivity. Shafiq and Iqbal (2005) also reported that plants growing adjacent to roadsides exhibited considerable damage in response to automobile exhaust emission.

Among the selected plants of polluted and non-polluted areas, there were reductions in the leaf breadth in all plants except *F. religiosa* in polluted sites. Figure 3 showed that minimum leaf breadth at polluted and non-polluted site (2.51 and 4.68 cm) was found in *P. longifolia*, while maximum (10.34 and 14.23 cm) was recorded in *T. catappa*. Statistical t-test also indicated that there was highly significant ($p<0.0001$) difference in the leaf breadth of all the plant species of both sites. In polluted plants *P. longifolia* (46.37%) showed the highest reduction in leaf width followed by *S. mahagoni* (34.72%) and *T. catappa* (27.38%) while in *F. religiosa* 3.09% increased (table 1). Shafiq et al. (2009) found that the leaves from the polluted sites showed decrease in length, breadth and area. Preeti (2000) also observed that leaves of *Thevetia nerifolia* and *Cassia siamea* growing in the polluted environment showed significant reduction in their growth.

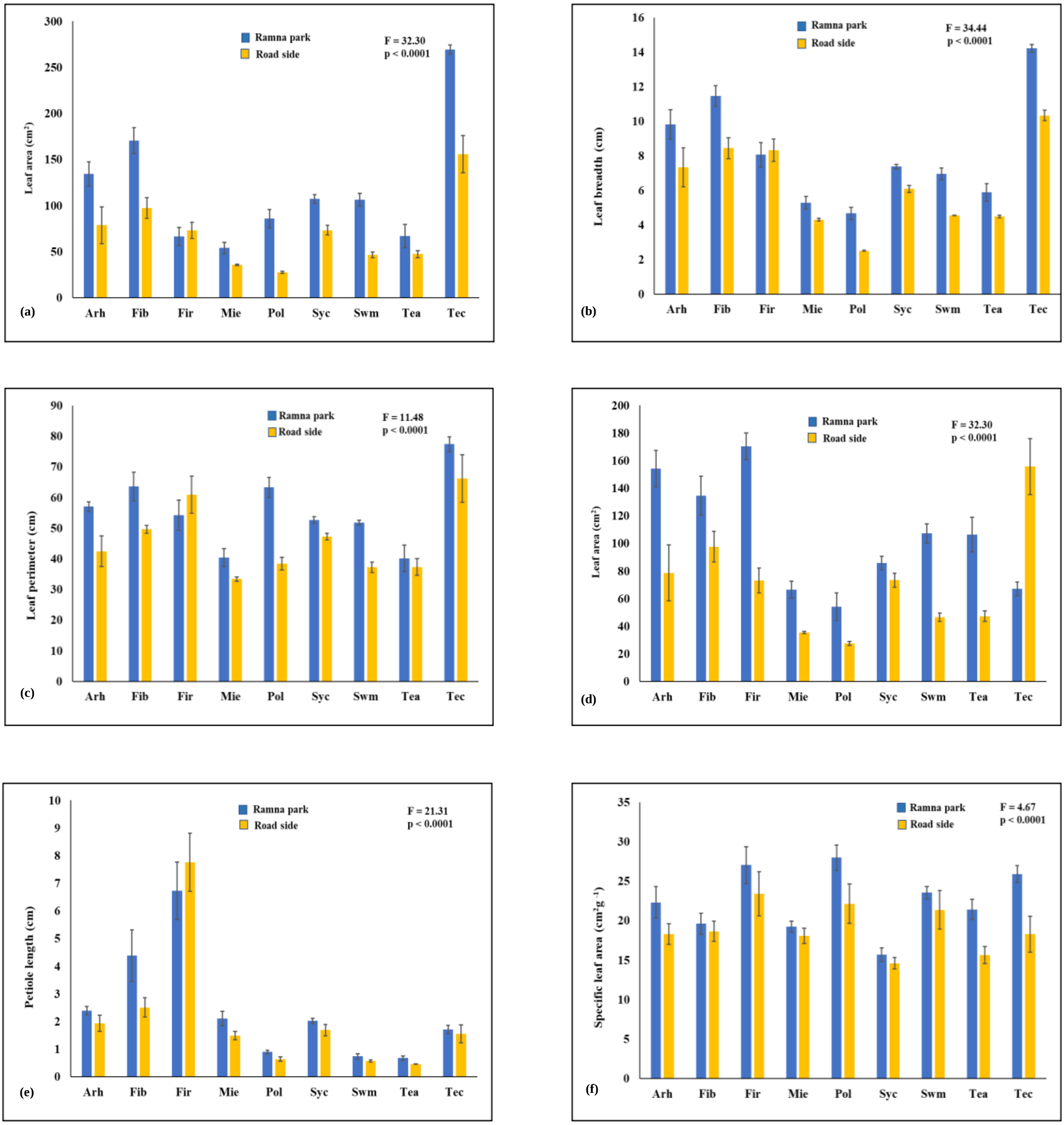


Figure 3. Mean values of the leaf morphological traits of selected tree species of Ramna park and its adjoining road sites. Graph shows leaf length (a), leaf breadth (b), leaf perimeter (c), leaf area (d), petiole length (e), Specific leaf area (f). Arh = *Artocarpus heterophyllus*, Fib = *Ficus benghalensis*, Fir = *Ficus religiosa*, Mie = *Mimusops elengi*, Pol = *Polyalthia longifolia*, Syc = *Syzygium cumini*, Swm = *Swietenia mahagoni*, Tea = *Terminalia arjuna*, Tec = *Terminalia catappa*.

With the exception of *F. religiosa*, all of the selected plants in polluted and non-polluted locations showed declines in leaf perimeter. Figure 3 showed that minimum leaf perimeter at polluted and non-polluted site (33.38 and 40.17 cm) was found in *M. elengi and T. arjuna*, while maximum (66.21 and 77.41 cm) was recorded in *T. catappa*, respectively. There was highly significant ($p<0.0001$) difference in the leaf perimeter of all the plant species of both sites. In polluted plants *P. longifolia* (39.25%) showed the highest reduction in leaf width followed by *S. mahagoni* (28.11%) and *A. heterophyllus* (25.53%) while in *F. religiosa* 12.41% increase in perimeter (table 1).

Average leaf area of all species was found higher at Ramna park than road side areas (figure 3). Minimum leaf area at polluted and non-polluted site (27.62 and 54.2 $cm^2$) was found in *P. longifolia* and *M. elengi*, while maximum (155.73 and 269.26 $cm^2$) was recorded in *T. catappa*, respectively. Statistical t-test indicated that there was highly significant ($p<0.0001$) variation in the values of leaf area between two studied sites. Observations shown recorded in Table 1 revealed that the Polluted plants *P. longifolia* (67.82%) showed the highest reduction in leaf area followed by *S. mahagoni* (56.26%), *F. benghalensis* (42.74) and *T. catappa* (42.16%) while *T. arjuna* showed the lowest reduction (29.42%). Similar reduction in leaf area growing in the polluted areas was also observed in many other plant species by Bhatti and Iqbal (1988). Species in polluted areas typically have shorter leaves than those in unpolluted areas. This is due to abiotic stresses dominantly caused by air pollution. Syyenejad et al. (2009) suggested that reducing leaf area can help balance the water content of tissues, hence increasing tolerance in contrast to stress. Several authors concluded that the reduced leaf area is the most common observation by studying the interaction between plants and pollution (Myers 2015, Ekpemerechi et al. 2014 and Neverova et al. 2013).

Table 1. Change (increasing or decreasing %) in morphological traits of leaf of different plant species at Ramna park and its adjacent roadside of Dhaka city due to air pollution.

| **Plants name** | **Leaf Length (%)** | **Leaf breadth (%)** | **Leaf perimeter (%)** | **Leaf area (%)** | **Petiole length (%)** | **Specific leaf area (%)** |
|---|---|---|---|---|---|---|
| *Artocarpus heterophyllus* | 28.28 | 25.21 | 25.53 | 41.46 | 19.31 | 17.93 |
| *Ficus benghalensis* | 25.06 | 26.39 | 21.98 | 42.74 | 42.74 | 4.84 |
| *Ficus religiosa* | +6.27 | +3.09 | +12.41 | +10.15 | +15.31 | 13.46 |
| *Mimusops elengi* | 21.44 | 18.51 | 17.49 | 34.33 | 28.96 | 6.00 |
| *Polyalthia longifolia* | 41.47 | 46.37 | 39.25 | 67.82 | 28.52 | 20.88 |
| *Syzygium cumini* | 19.15 | 17.42 | 10.35 | 31.62 | 16.61 | 6.95 |
| *Swietenia mahagoni* | 30.07 | 34.72 | 28.11 | 56.26 | 23.66 | 9.29 |
| *Terminalia arjuna* | 7.00 | 23.64 | 7.09 | 29.42 | 31.37 | 27.09 |
| *Terminalia catappa* | 21.02 | 27.38 | 14.46 | 42.16 | 9.71 | 29.31 |

'+' indicates increasing in amount in respective parameters of studied tree species at polluted sites

The leaves which were collected from polluted areas showed reduction in petiole length in all studied tree species except *F. religiosa*. Minimum petiole length at polluted and non-polluted site (0.47 and 0.68 cm) was found in *T. arjuna*, while maximum (2.51 and 4.38 cm) was recorded in *F. benghalensis*. ANOVA results showed that there was highly significant ($p<0.0001$) variation in the values of petiole length of polluted and non-polluted sites in all the plant species except *F. religiosa* (figure 3). The overall average decreasing % of petiole length at polluted site with respect to non-polluted site was 9.7-42.73% in *T. catappa*. and *F. benghalensis*, respectively. While *F. religiosa* showed 15.3% increase in petiole length (table 1). Aribal et al. 2016 showed that the *Swietenia macrophylla* in polluted area has shorter petiole length compared to non-polluted areas. Similar observations were also reported in the leaves of *Ricinus communis* and *Guaiacum officinale* which showed significant reduction in petiole length (Suwal et al. 2019, Bhatti and Iqbal 1988). Jahan and Iqbal (1992) in their study showed changes in leaf blade and petiole size of *Platanus acerifolia* of polluted site.

Specific leaf area of all species was found higher at Ramna park than road side areas (figure 3). Minimum specific leaf area at polluted and non-polluted site (14.60 and 15.69 $cm^2/g$) was found in *S. cumini*, while maximum (23.40 and 27.99 $cm^2/g$) was recorded in *F. religiosa* and *P. longifolia*, respectively. Statistical t-test indicated that there was highly significant ($p<0.0001$) variation in the values of specific leaf area between two studied locations. As shown in Table 1 the Polluted plants *T. catappa* (29.31%) showed the highest reduction in specific leaf area while *F. benghalensis* showed the lowest reduction (4.84%). However, other remaining plant species showed reduction in the range of 6.0-27.09% low to high, respectively. Similar reduction in leaf area growing in the vicinity of heavy pollutants was also observed in many other plant species by Bhatti and Iqbal (1988). Therefore, it has been proved from the above results that the leaf surface were badly affected by air pollutant, as its area remain small at polluted site with respect to non-polluted site.

*Leaf physiological traits*

Three of the nine tree species showed increased leaf water content (LWC) in polluted road side areas, compared to other six species in non- polluted site but there was no significant difference (Fig. 4). Minimum LWC at polluted and non-polluted site (0.06 and 0.05 g $cm^{-2}$) was found in *M. elengi and S. mahagoni*, while Maximum 0.13 g $cm^{-2}$ was recorded in *F. benghalensis*. Table 2 showed that the Polluted plant *T. catappa* (29.41%) showed the highest reduction in LWC while *S. cumini* showed the lowest (16.21%). *A. heterophyllus*, *F. benghalensis*, and *S. mahagoni* had higher leaf water content at the polluted sites than at the non-polluted sites.

All tree species of non-polluted site showed the higher relative water (RWC) content of leaf samples. Maximum RWC at polluted and non-polluted site (0.95 and 0.98 g $g^{-1}$) was found in *S. cumini and P. longifolia*, while Minimum 0.84 and 0.91 g $g^{-1}$ was recorded in both *T. arjuna* and *A. heterophyllus*. ANOVA results showed that there was highly significant ($p<0.0003$) variation in the values of RWC at polluted and non-polluted sites in all the plant species (figure 1). Table 2 also revealed that the polluted plants *T. arjuna* (13.31%) showed the highest reduction in RWC while *A. heterophyllus* showed the lowest (0.37%) (table 1). According to Dedio (1975), high relative water content favors drought resistance in plants. In the present study, *A. heterophyllus*, *S. mahagoni* and *S. cumini* had higher relative water content at the road sites indicating that this species has improved drought tolerant ability among all the studied plants. Uka et al. (2019) also reported that some tree species showed the higher relative water content at polluted site than non-polluted site.

Four among the nine tree species of polluted sites showed the higher leaf dry matter content (LDMC) of leaf samples whereas non-polluted sites showed higher in five plants. Maximum LDMC at polluted and non-polluted site (0.48 and 0.43 g $g^{-1}$) was found in *M. elengi and S. mahagoni*, while Minimum 0.27 and 0.28 g $g^{-1}$ was recorded in *T. catappa* and *F. relegiosa* at both sites. ANOVA results showed that there was significant ($p<0.0079$) difference in the values of LDMC at polluted and non-polluted sites in all the plant species (figure 1). Table 2 revealed that the polluted plants *A. heterophyllus* (10.75%) showed the highest reduction in LDMC while *S. mahagoni* showed the lowest (4.17%). *F. religiosa*, *M. elengi*, *T. arjuna* and *S. cumini* had higher leaf dry matter content at the road sites plants than at the non-polluted site. Suwal et al. 2019 also reported that *Ricinus communis* showed the higher leaf dry matter content at polluted site than non-polluted site. Bhatti and Iqbal (1988) found that the air pollution significantly reduced the leaf dry matter content of *Guaiacum officinale*, *Ficus benghalensis* and *Eucalyptus* sp. at polluted sites.

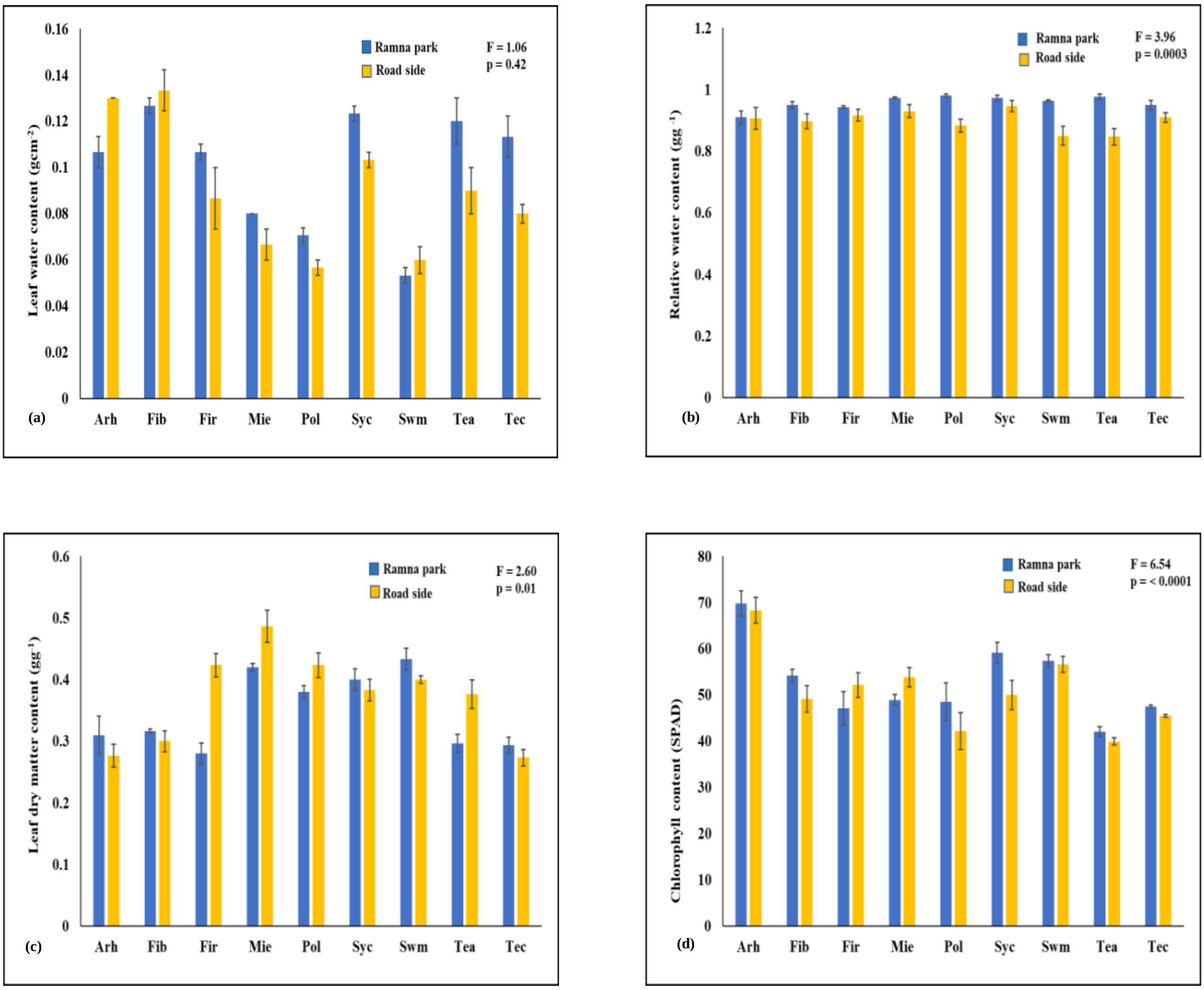


Figure 4. Mean values of the leaf physiological traits of common plants of Ramna park and its adjoining roadside. Graph shows leaf water content (a), relative water content (b), leaf dry matter content (c) and chlorophyll content (d). Arh = *Artocarpus heterophyllus*, Fib = *Ficus benghalensis*, Fir = *Ficus religiosa*, Mie = *Mimusops elengi*, Pol = *Polyalthia longifolia*, Syc = *Syzygium cumini*, Swm = *Swietenia mahagoni*, Tea = *Terminalia arjuna*, Tec = *Terminalia catappa*.

Statistical t-test also indicated that there was highly significant ($p<0.0001$) difference in the leaf chlorophyll content of all the plant species of both sites (figure 4). Seven of the nine tree species showed decreased leaf chlorophyll content in polluted areas. Minimum leaf chlorophyll content at polluted and non-polluted site (39.93 and 42.03) was found in *T. arjuna*, while Maximum 68.33 and 69.83 was recorded in *A. heterophyllus*. Table 2 also showed that the Polluted plants *S. cumini* showed the highest reduction (15.49%) in leaf chlorophyll content while *S. mahagoni* showed the lowest reduction (1.39%). However, other remaining plant species showed reduction in the range of 2.15-13.11% low to high, respectively, may be due to the tolerance nature of these studied trees. Jyothi and Jaya (2010) also observed that less degradation of total chlorophyll content found in *Ficus auriculata* and *Cinnamomum camphora*. In the present study, the total chlorophyll content of *A. heterophyllus*, *F. benghalensis*, *P. longifolia*, *S. mahagoni*, *T. arjuna*, *T. catappa* and *S. cumini* was found comparatively higher at non-polluted site and lower at polluted site due to air pollution which liable to reduce chlorophyll content of plant leaves in the polluted areas. Similar results also found in other studies, they suggested that higher traffic exposures reduce chlorophyll content of plant leaves around the polluted areas (Patel and Kumar 2018, Ikbal et al. 2015).

Table 2. Change (increasing or decreasing %) in physiological traits of leaf of different plant species at Ramna park and its adjacent roadside of Dhaka city due to air pollution.

| **Plants name** | **Leaf water content (%)** | **Relative water content (%)** | **Leaf dry matter content (%)** | **Chlorophyll content (%)** |
|---|---|---|---|---|
| *Artocarpus heterophyllus* | +21.87 | 0.37 | 10.75 | 2.15 |
| *Ficus benghalensis* | +5.26 | 5.61 | 5.26 | 5.29 |
| *Ficus religiosa* | 18.75 | 2.83 | +51.19 | +10.67 |
| *Mimusops elengi* | 16.67 | 4.45 | +15.87 | +9.87 |
| *Polyalthia longifolia* | 19.81 | 9.86 | +11.4 | 13.12 |
| *Syzygium cumini* | 16.22 | 2.74 | 4.17 | 15.49 |
| *Swietenia mahagoni* | +12.5 | 11.76 | 7.69 | 1.39 |
| *Terminalia arjuna* | 25 | 13.31 | +26.97 | 5.0 |
| *Terminalia catappa* | 29.41 | 4.21 | 6.82 | 4.21 |

'+' indicates increasing in amount in respective parameters of studied tree species at polluted sites

Results of the present study revealed that most of the leaf morpho-physiological traits showed difference between species and between polluted and non-polluted sites which might be related with air pollution. Air pollution is considered as a component of climate change. Air pollution and climate change are caused mostly by anthropogenic and biogenic emissions in the atmosphere. The functions of urban vegetation such as C-sequestration, photosynthesis and transpiration rates are altered by air pollution and climate change simultaneously which in turn changes the environmental processes. Thus knowledge regarding effects of air pollution on functional traits of plants is relevant for prediction consequences of climate change on environmental processes. Data of this study also suggest the importance of controlling air pollution for healthy and better environment of Dhaka city.

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