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VARIATION IN THE MACRO-MORPHOLOGICAL TRAITS OF LEAVES IN RESPONSE TO AUTOMOBILE POLLUTION IN SELECTED URBAN TREE SPECIES IN THE CITY OF DHAKA

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ABSTRACT

The present study was carried out at National Botanical Garden, Dhaka, considered as control site and Motijheel-Sayedabad roadside areas as polluted site to compare the impact of automobile pollution on leaves macro-morphological traits of selected ten plants growing in the polluted areas with those growing in control sites. Leaf morphological characteristics including leaf abnormalities of both young and mature leaves were assessed. Variations in leaf color such as light green, dark green, browning, yellowing and change in the leaf's shape either normal or deformed were also assessed for both the sites. All the selected plant species showed highly significant ($p<0.0001$) reduction at polluted site in their all leaf macro-morphological traits (leaf length, leaf breadth, leaf area, leaf perimeter, specific leaf area and petiole length) when compared with control site. The findings of this study revealed that the automobile pollution stress influenced tree morphological features in the Dhaka city. This study also indicated that plants go through adaptive processes in order to survive in automobile polluted environments.

Keywords: Air pollution, leaf characteristics, urban areas

Introduction

Automobile pollution refers to the emissions from cars and other vehicular traffic, which mostly include carbon monoxide, nitrogen oxides, carbon dioxide, sulfur oxides, hydro carbon, particulate matter and heavy metals. These harmful gaseous and particle pollutants affects negatively on roadside trees (Joshi and Swami 2009). Due to the stress of car exhaust pollution and high traffic intensity in urban roadside areas, leaf length, leaf breadth, petiole length, leaf area, and specific leaf area are some among the most prominent macro-morphological parameters of leaf have been observed to be significantly altered in plant species (Rodríguez-Alarcón *et al.* 2022, Montes-Pulido 2014, Rai and Mishra 2013). In order to preserve balance and ecological flexibility, plants have a variety of features. In particular, leaf macro- and micro-morphology plays a significant role in the ecosystem benefits which the plant species bring to urban environmental dynamics (Hanisch *et al.* 2020, Matasov *et al.* 2020). Trees are essential to preserving the natural balance in metropolitan areas, and their importance cannot be ignored. Through the absorption of pollutants, the capture of particulate matter, and the release of oxygen, urban trees also help to reduce air pollution levels (Escobedo *et al.* 2006)

The use of motor vehicles is growing fast globally at large and with a far faster rate in developing nations including Bangladesh. In Bangladesh, Dhaka is one of the largest urban areas where the population and vehicles are increasing day by day. The air quality in Dhaka is unhealthy and recently, it has even reached at dangerous levels (Kashem *et al.* 2022) due to our automobiles emit a high level of air polluting gases for their old age, poor performance, and lack of maintenance. Moreover, the situation is made worse by narrow roads, poor geometry, and regular traffic jams. The significant growth in vehicle density in the Dhaka city causes negative consequences on the vegetation growing closest to busy roads. Depending on the pollutant and the species' tolerance, the nature of the negative effects can vary to some extent (Seyyednezhad *et al.* 2013). Therefore, the present work was designed to analyze the effects of automobile exhaust gases on the leaves macro- morphology of different plant species that growing at the road sides in the Dhaka city.

Materials and Methods

Study sites: As control site, the study was conducted at the National Botanical Garden at Dhaka in Bangladesh with an area of around 204 acres. It is located at 23.81660° North and 90.34875° East and divided into 57 sections based on predominant flora and is managed by Forest Department under the Ministry of Environment and Forests, Government of Bangladesh (Al-Kaium *et al.* 2022). It is one of the largest botanical gardens of Bangladesh and a center of knowledge for nature lovers and botanists and a tourist destination. On the other hand, huge amount of petrol driven three wheelers vehicles with diesel driven four stroke engines vehicles are mostly found on the road at Motijheel-Sayedabad areas. These areas were selected as polluted site due to the heavy traffic congestion and emission of significant amounts of pollutants and dangerous substances such as small particles and lead (Kashem *et al.* 2022).

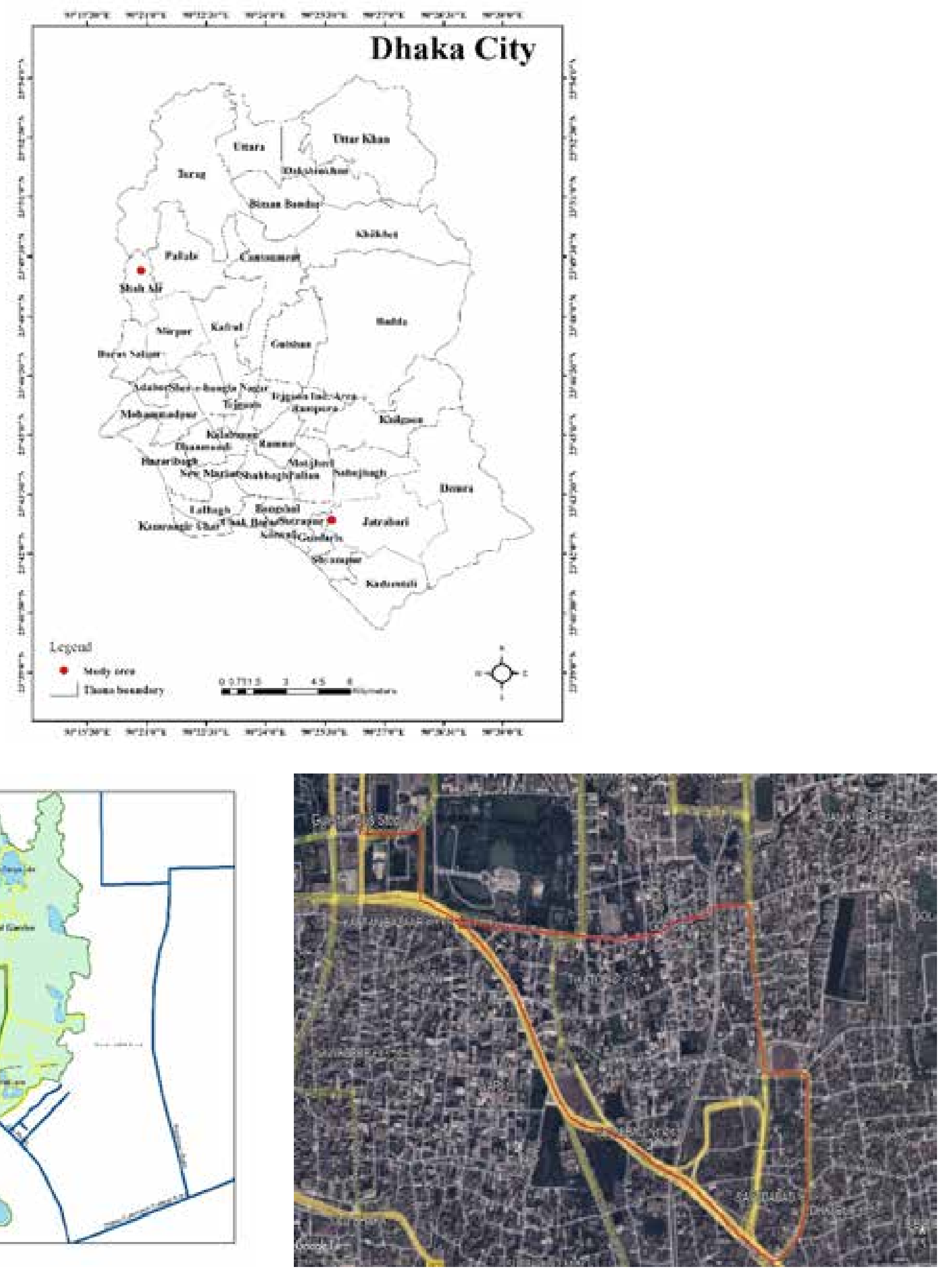

Figure 1: Map showing the control (left side) and polluted site (red marked at the right side) of the study areas in Dhaka city.

Plants material collection: The most frequently common species were considered for both sites and the study was conducted in october 2022. Fresh samples of leaves of jackfruit tree (*Artocarpus heterophyllus*), banyan tree *(Ficus benghalensis*), sacred fig tree *(Ficus religiosa),* spanish cherry (*Mimusops elengi*), false ashoka *(Polyalthia longifolia),* black plum tree (*Syzygium cumini*), mahogany (*Swietenia mahagoni*), arjun tree (*Terminalia arjuna*), indian almond (*Terminalia catappa*) and mango tree (*Mangifera indica*) were collected and then they were brought to the Ecology and Environment Laboratory at the Department of Botany, University of Dhaka. The diameter at breast height (DBH) of selected species varied largely across polluted and control locations, ranging from 18.26 to 189.45 cm, demonstrating variation in growth from site to site. Ten fully expanded youngest leaves were taken from each of the ten tree species where three individuals were selected per species. Thus, a total of 300 young leaves per sampling site were collected for the analysis of color, shape and macro-morphological traits of leaf. Mature leaves were also collected from both sites for the identification of color and shape.

Analysis of macro-morphological traits: Ten leaf attributes were studied to determine the effects of traffic on macro-morphological traits. Table 1 lists these parameters as well as their abbreviations. Six leaves from each tree were taken to examine macro-morphological traits. The macro-morphological parameters such as leaf length, leaf breadth, leaf perimeter, leaf area, specific leaf area and petiole length were measured using photography and ImageJ software (Kashem *et al.* 2022). Specific leaf area (cm^2g^{-1}) was obtained by dividing the leaf area of the sampled leaves by the leaf's dry weight (Jake *et al.* 2020). Changes in color (chlorosis, browning, yellowing, spotting, or change in the leaf's normal pigment) and shape (normal shape or deformed/modified) were also observed on plants from both control site and polluted site. The percentage increase or decrease of leaf traits was calculated using the technique developed by Syed and Iqbal (2008).

Table 1. Macro-morphological traits studied for leaves of selected tree species

Macro-morphological traits	Scale	Abbreviation
Leaf length	Cm	LL
Leaf breadth	Cm	LB
Petiole length	Cm	PL
Leaf area	cm^2	LA
Leaf perimeter	Cm	LP
Specific leaf area	cm^2g^{-1}	SLA

Statistical analysis: ANOVA was used to compare the macro-morphological features of ten plant species from both polluted and control sites. Turkey's HSD was applied to determine the level of significance among the means. JMP 4.0 software (SAS Institute, Carry, NC, USA) was used to analyze the data.

Results and Discussion

The macro-morphological characteristics of *A. heterophyllus, F. benghalensis, F. religiosa, M.elengi, P. longifolia, S. cumini, S. mahagoni, T. arjuna, T. catappa* and *M. indica* leaves were observed and measured in both control and polluted environments. Trees serving as bio-contaminant absorbents can filter poisonous and hazardous compounds through the surface of their leaves and roots, resulting in variations in leaf size during this process (Squires 2016). The leaves sampled from polluted areas exhibited highly significant ($p<0.0001$) reductions in all parameters (length, breadth, area, perimeter, petiole length and specific leaf area) when compared to control site (Table 2). These results were found in the studied polluted site due to different pollutants such as ozone, sulfur dioxide, nitrogen dioxide, and peroxyacetyl nitrate can induce leaf damage and plant harm. Pollution related particulate matter also can cause reduced leaf size, chlorotic and necrotic leaf patches, and decreased chlorophyll concentration. Furthermore, environmental contamination can cause a decline in growth as well as a drop in stomatal frequency and size in leaves. These findings imply that plants are stressed by automobile pollution and have developed adaptive systems to deal with the consequences and these results are also similar to other works (Seyyednezhad *et al.* 2013, Rai and Mishra 2013, Ianovici*et al.* 2011, Laghari and Zaidi 2013).

Table 2. Leaf macro-morphological traits of selected plants in polluted and control sites

Species	Sites	LL	LB	LA	LP	PL	SLA
A. heterophyllus	Polluted	12.23±0.57	6.26±0.38	58.77±2.53	40.19±1.15	1.64±0.06	15.91±0.74
	Control	15.16±0.97	7.05±0.58	79.13±11.36	51.27±7.45	1.68±0.17	25.39±1.92
F. benghalensis	Polluted	14.76±0.39	8.73±0.68	101.13±8.76	54.28±2.07	2.94±0.087	17.39±1.55
	Control	15.38±0.16	9.14±0.66	112.46±8.05	56.21±6.95	4.16±0.09	19.18±2.72
F. religiosa	Polluted	12.34±0.9	7.23±0.85	59.24±13.82	52.49±7.51	5.63±0.97	24.1±0.16
	Control	15.18±0.57	10.2±0.75	91.45±8.66	67.06±1.63	8.45±0.67	32.03±3.68
M. elengi	Polluted	10.81±1.11	4.86±0.35	40.07±6.57	33.09±2.96	1.32±0.31	19.58±1.23
	Control	12.88±1.65	4.96±0.23	46.11±7.52	35.94±5.03	1.48±0.096	20.65±0.46
P. longifolia	Polluted	14.1±0.95	2.48±0.11	26.33±2.85	34.97±1.76	0.61±0.075	17.85±7.44
	Control	25.67±2.58	4.85±0.79	89.7±20.95	70.01±12.6	0.94±0.09	31.59±3.03
S. cumini	Polluted	15.5±0.89	5.19±0.53	59.97±9.43	44.17±2.35	1.07±0.1	12.27±0.18
	Control	18.4±0.29	5.73±0.05	73.94±0.92	50.91±1.01	1.69±0.087	15.46±2.09
S. mahagoni	Polluted	13.54±0.31	4.38±0.02	44.28±1.6	35.64±0.96	0.44±0.023	14.34±1.91
	Control	22.55±1.85	7.28±0.53	115.68±15.3	58.08±5.22	0.8±0.04	22.24±0.6
T. arjuna	Polluted	10.13±0.64	3.84±0.37	32.2±1.58	30.05±2.89	0.42±0.017	16.18±0.63
	Control	11.96±0.98	3.89±0.05	36.55±6.47	30.85±3.03	0.46±0.07	19.18±1.15
T. catappa	Polluted	19.04±2.25	9.32±1.23	131.97±30.5	59.05±6.4	1.52±0.08	15.16±2.58
	Control	20.15±1.3	12.57±0.94	214.36±27.5	71.25±4.73	2.18±0.72	25.08±0.76
M. indica	Polluted	17.25±0.64	4.08±0.31	51.98±4.95	56.08±4.29	2.61±0.17	15.53±1.1
	Control	21.73±2.16	8.35±0.94	98.1±13.34	86.47±8.54	4.66±0.9	16.4±1.7
F ratio		33.58	50.66	38.85	24.79	62.57	5.47
P value		<.0001	<.0001	<.0001	<.0001	<.0001	<.0001

The statistical t-test revealed that there was highly significant (p<0.0001) difference in leaf length data in both two studied sites. *T. arjuna* had the shortest leaf length (11.96±0.98 and 10.13±0.64 cm) at the control and polluted sites, while *P. longifolia* and *T. catappa* had the longest (25.67±2.58 and 19.04±2.25 cm). Figure 2 showed that, the overall average decreasing percentage of leaf length at polluted site compared to control site was found to be in the range of 4.03-45.07%, lowest to highest, in the leaves of *F. benghalensis* and *P. longifolia,* respectively. Kashem *et al*. (2022) found in their study that the overall average leaf length of all studied species except *F. religiosa*was recorded higher at Ramna park site than its adjacent polluted roadside areas. The slow increase in the percentage of leaf length at polluted sites compared to non-polluted sites could be attributed to the effect of air pollution at that site, which affects gas exchange for photosynthesis and leaf productivity. Aribal*et al.* 2016, Keskin and Ili (2012), Makbul *et al*. (2006), and Gielwanowska *et al*. (2005), all made observations that supported these points of view. They discovered that plants growing along the city's major

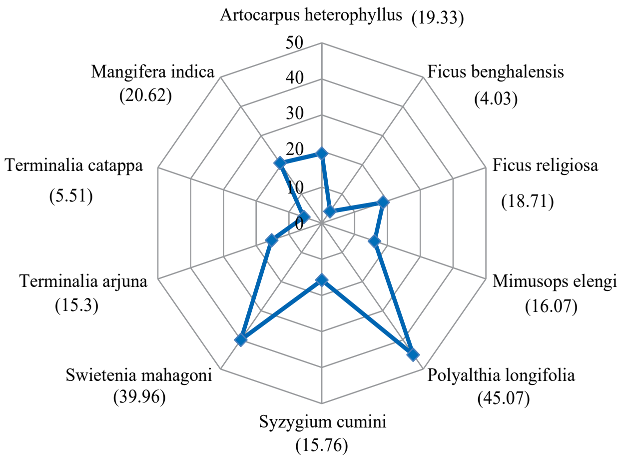

Figure 2. Average decreasing (%) of the leaf length of different plant species at the polluted site compared with the control site.

road are substantially influenced by auto-emission. The presence of hazardous substance in auto-emission causes the inhibitory effects on plant growth.

There were reductions in leaf breadth in all plants among the selected plants in polluted areas from the control site. Table 2 showed that *P. longifolia* and *T. arjuna* had the smallest leaf breadth at polluted and control sites (2.48±0.11 and 3.89±0.05 cm, respectively), while *T. catappa* had the largest (9.32±1.23 and 12.57±0.94 cm). The statistical t-test also revealed a highly significant ($p<0.0001$) difference in the leaf breadth of all plant species between the two sites. *P. longifolia* (48.87%) reduced leaf breadth the most in all selected plant species at polluted site, followed by *S. mahagoni* (39.84%), *M. indica* (35.75%), and *F. religiosa* (29.12%) (Figure 3). Similarly, there were reduction in the breadth of leaf in the polluted plants where *Tabernaemontana divricata* showed the highest reduction in leaf breadth followed by *Nerium olender*, *Azadirachata indica* and *Catharanthus roseus* (Madhumonisa and Saradha 2021). In addition, except *F. religiosa,* leaf breadth was recorded higher in all studied tree species at Ramna park site than its adjacent polluted roadside areas (Kashem *et al*. 2022). Squires (2016) also found that *F. rotundifolia* and *M. alba* showed a significant decrease in the size of leaf length and leaf breadth. These findings also support the study results of Rodríguez-Santamaría *et al.* (2022), Seyyednezhad *et al.* (2013), Laghari and Zaidi (2013) and Ianovici *et al.* (2011), who demonstrated that air pollution can inhibit the growth of leaf size specially leaf length and breadth.

Leaf of all ten plant species used in the study showed a significant difference ($p<0.0001$) in leaf area between two studied sites. The average leaf area of all selected species was found to be greater at the control site than at the polluted location (Table 2). *T. arjuna* and *P. longifolia* had the smallest leaf area at the control and polluted sites (36.55±6.47 and 26.33±2.85 cm^2), whereas *T. catappa* had the largest (214.36±27.5 and 131.97±30.5 cm^2). Polluted plants *P. longifolia* (70.65%) showed the biggest reduction in leaf area, followed by *S. mahagoni* (61.72%), *M. indica* (42.74), and *T. catappa* (38.44%), where *F. benghalensis* showed the lowest reduction (10.07%) (Figure 4). This finding was consistent with the results of Myers (2015) and Ekpemerechi *et al.* (2014), who found that reduced leaf area is the most common observation when assessing the interaction of plants and pollutants. In general, the findings of this study are consistent with the outcomes of previous studies on changes in leaf area in *Acer saccharum*, *Ginkgo biloba* (Sianping *et al.* 2009), *Albizia lebbeck* and *Callistemon citrinus* (Seyyednejad *et al*. 2009a, Seyyednejad *et al.* 2009b) and *Tilia begonifolia* (Yousefzadeh *et al.* 2011).

The ANOVA results demonstrated a highly significant ($p<0.0001$) change in the values of petiole length between control and polluted areas in all plant species (Table 2). The leaves collected from polluted areas showed decrease in petiole length in all selected plant species. The total average decrease in petiole length at the polluted

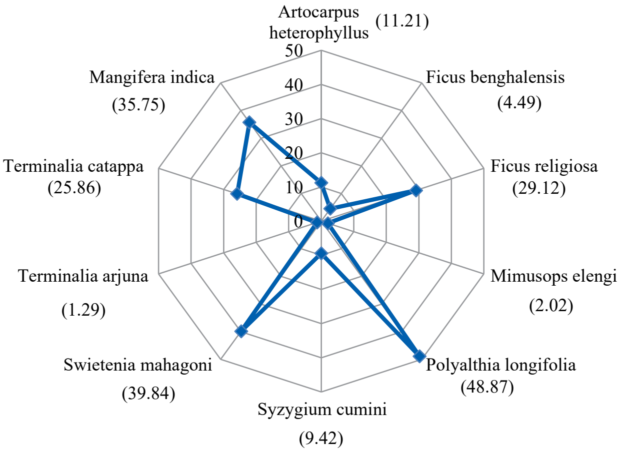

Figure 3. Average decreasing (%) of the leaf breadth of different plant species at the polluted site compared with the control site.

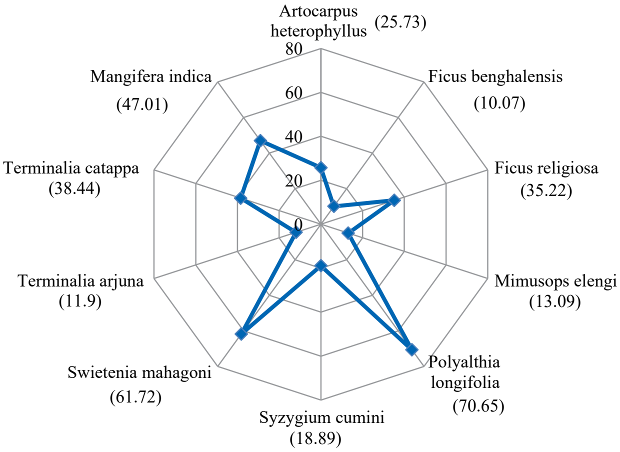

Figure 4. Average decreasing percentage (%) of the leaf area of different plant species at the polluted site compared with the control site.

site compared to the control site was 2.38-45% in *A. heterophyllus* and *S. mahagoni*, respectively. Minimum petiole length at control and polluted site (0.42±0.017 and 0.46±0.07 cm) was found in *T. arjuna*, while maximum (5.63±0.97 and 8.45±0.67 cm) was recorded in *F. religiosa*. The findings of the other study showed similar type of results where petiole length in *Parrotia persica*, *Celtis australis* and *Tilia begonifolia* lower in polluted sites compared to the control sites (Yousefzadeh *et al.* 2009, Zarafshar *et al.* 2010, Akhondnezhad *et al.* 2010). The pollution of the city resulted in significant effects on petiole length of *C. siamea* and *P. pterocarpum* compared to control areas (Zaidi and Leghari, 2004, Shafiq *et al.* 2009).

The statistical t-test revealed a highly significant ($p<0.0001$) variance in the values of specific leaf area between the two selected locations. As indicated in Figure 6, the polluted plants *P. longifolia* (43.49% decrease) had the highest loss in specific leaf area, whereas *M. elengi* (5.18% decrease) had the least reduction. Other remaining plant species, on the other hand, showed reductions ranging from 5.3-39.55% low to high. The specific leaf area of all species was greater at the control site than at the polluted site (Table 2). *S. cumini* had the lowest specific leaf area at the control and contaminated sites (15.46±2.09 and 12.27±0.18 cm^2/g, respectively), whereas *F. religiosa* had the highest (32.03±3.68 and 24.1±0.16 cm^2/g). This finding corresponded with the findings of others, who noticed an identical decrease in leaf area in several other plant species growing in roadside areas or close proximity to heavy pollutants (Rodríguez-Santamaría *et al.* 2022, Kashem *et al.* 2022, Yousefzadeh *et al.* 2011, Akhondnezhad *et al.* 2010). As a result of the above findings, it is clear that air pollutants have had a negative impact on the leaf surface, as its area remains small at polluted sites compared to control sites.

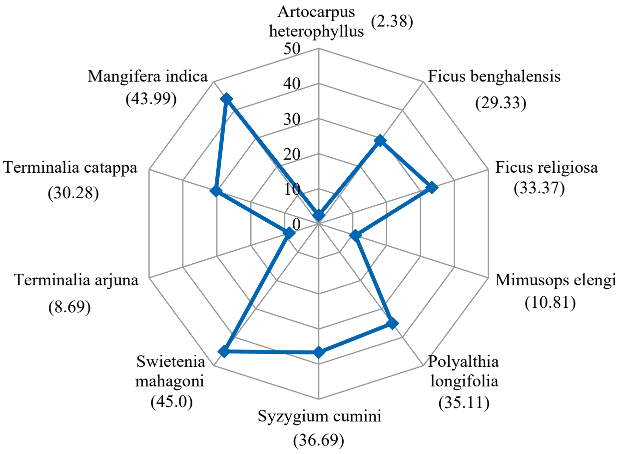

Figure 5. Average decreasing percentage (%) of the petiole length of different plant species at the polluted site compared with the control site.

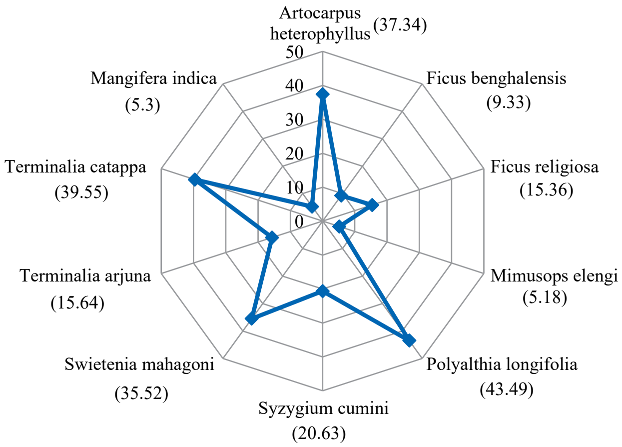

Figure 6. Average decreasing percentage (%) of the specific leaf area of different plant species at the polluted site compared with the control site.

ANOVA results showed that there was highly significant ($p<0.0001$) variation in the values of leaf perimeter of polluted and control site in all the plant species (Table 2). The overall average decreasing % of leaf perimeter at polluted site with respect to control site was 2.59-50.05% in *T. arjuna* and *P. longifolia*, respectively (Figure 7). The leaves collected from polluted areas showed reduction in leaf perimeter in all studied tree species. Minimum perimeter at control and polluted site (30.85±3.03 and 30.05±2.89 cm) was found in *T. arjuna*, while maximum (71.25±4.73 and 59.05±6.4cm) was recorded in *T. catappa*. Kashem *et al.* (2022) also found in their study that all of the selected plants at the adjoining roadside areas of Ramna park showed decrease in perimeter of leaf with the exception of *F. religiosa*.

Table 3 shows the leaf shape and color of the species under study in both polluted and non-polluted area. Species in polluted area showed significant difference compared to species found in the non-polluted area. The color of leaves vary from light green in polluted site to generally dark green in control site at young and mature growth stage for

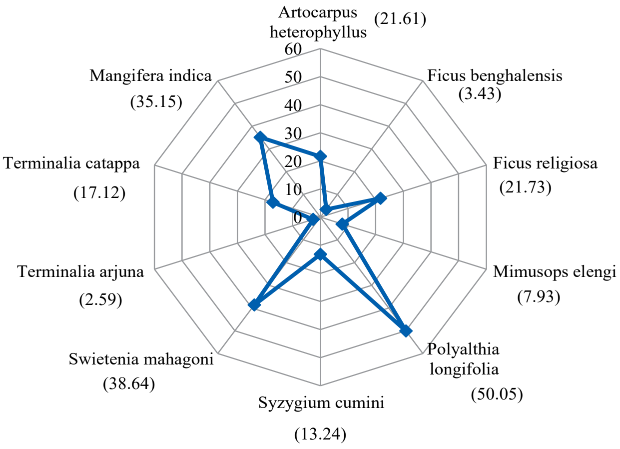

Figure 7. Average decreasing percentage (%) of the leaf perimeter of different plant species at the polluted site compared with the control site.

F. benghalensis and *F. religiosa* while most of the leaves of other species at young stage in polluted area were light green and at mature stage were dark green but in control site the leaves of all species were generally dark green. Moreover, majority of the leaves of *F. benghalensis, F. religiosa, P. longifolia, S. cumini* , *T. arjuna* and *T. catappa* were deformed at young and mature stage in polluted site while those found in control site exhibited typical leaf shape. For both sites, *A. heterophyllus, M. elengi, S. mahagoni* and *M. indica* at young growth stage had typical leaf shape for both sites, but those found in polluted areas at mature stage were deformed (Table 3). Leaf colors of a plant could be used to identify stress level due to its adaptation to environmental change. Leaves of most the species under study in control site at both young and mature stages were dark green, while the species found in polluted area are relatively lighter. This implies that the chlorophyll pigment on leaves in polluted area might be affected by automobile pollution. According to Giri *et al.* (2013), the photosynthetic pigments are the most likely to be damaged by air pollution and further explained that under stress they may underwent reduction in size and changes in color and shape. Laghari and Zaidi (2013) found in their study that the consequences

Table 3: Leaf morphological changes of selected plant species and growth stages growing in polluted and control sites

Plants name	Family	Growth stage	Color		Shape	
			Polluted site	Control site	Polluted site	Control site
A. heterophyllus	Moraceae	Young	Lg	Dg	T	T
		Mature	Dg	Dg	D	T
F. benghalensis	Moraceae	Young	Lg	Dg	D	T
		Mature	Lg	Dg	D	T
F. religiosa	Moraceae	Young	Lg	Dg	D	T
		Mature	Lg	Dg	D	T
M. elengi	Sapotaceae	Young	Dg	Dg	T	T
		Mature	Dg	Dg	D	T
P. longifolia	Annonaceae	Young	Lg	Lg	D	T
		Mature	Dg	Dg	D	T
S. cumini	Myrtaceae	Young	Lg	Dg	D	T
		Mature	Dg	Dg	D	T
S. mahagoni	Meliaceae	Young	Lg	Lg	T	T
		Mature	Dg	Dg	D	T
T. arjuna	Combretaceae	Young	Lg	Lg	D	T
		Mature	Dg	Dg	D	T
T. catappa	Combretaceae	Young	Lg	Lg	D	T
		Mature	Dg	Dg	D	T
M. indica	Anacardiaceae	Young	Lg	Lg	T	T
		Mature	Dg	Dg	D	T

Lg: Light green; Dg: Dark green; T: Typical; D: Deformed of macro-morphological features found in the studied species at polluted site were as a significant reduction in the size of leaves and the leaves turned into pale green. Moreover, Plants from polluted areas exhibit significant morphological alterations, particularly in terms of their colors, forms, leaf length, width, area, and petiole length (Seyyednezhad *et al.* 2013, Madhumonisa and Saradha 2021, Hanisch *et al.* 2020, Kashem *et al.* 2020). Overall, the study found that auto-emission has a negative impact on all plant species flourishing in the city's polluted environment.

Conclusion

Urban trees provide a variety of environmental advantages, including improved air quality due to the retention of atmospheric particulate matter on their leaves. In this study, all the selected tree species showed highly significant reduction at polluted site in all macro-morphological traits of leaf when compared with the control site. The findings imply that reducing automobile pollutant emissions is the best technique to maintain air quality and health of tree species in urban contexts. However, constant population increase, urbanization, and consumer demand make this impractical. To ensure the reduction of roadside pollution that affects plants, Bangladesh needs a reliable monitoring system and stronger environmental protection laws.

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