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AIR POLLUTION TOLERANCE INDEX OF *Mangifera indica* PLANT SPECIES GROWING IN THE GREATER DHAKA REGION, BANGADESH

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Abstract

Air pollution tolerance index (APTI) of the mango (*Mangifera indica*) leaves growing in the greater Dhaka region, Bangladesh was studied. Leaf samples were collected in winter season from both roadsides and residential locations of different parts of greater Dhaka region. The APTI values of the leaves were calculated from the total chlorophyll content (TCC), ascorbic acid concentration, relative water content (RWC), and pH of the leaf extract. Determined APTI values were compared with Particulate Matter ($PM_{2.5}$) values in each sampling location. TCC and ascorbic acid concentration were determined with a UV-Visible spectrophotometer. TCC values varied between 0.25 and 1.10 mg/g with an average of 0.66 mg/g. The average concentration of ascorbic acid was 2.21 mg/g (values ranging from 0.33 to 3.24 mg/g) and the RWC varied from 81.5% to 97.4%. Moreover, pH values of the leaf extracts were found acidic (4.48-5.78). The average APTI values varied depending on the locations with a total average of 10.1. However, the average APTI value in the residential area (10.5) was slightly higher compared to roadsides (9.70) indicating the existence of high-level pollutions at the roadsides. The highest APTI value was observed in Dhaka city sampling location (10.6) where the lowest value was found in Narayangonj (9.70). APTI values showed a strong correlation with particulate matter concentrations ($PM_{2.5}$). These results suggest that *Mangifera indica* is very sensitive to the air pollutants.

***Key words*:** Urban air pollution; Air pollution tolerance index; Ascorbic acid; Chlorophyll; Relative water content.

INTRODUCTION

Air pollution has a significant impact on human health, climate change and on ecosystem as a whole. Ecosystem itself is a natural process or system of interaction between abiotic and biotic factors in an area of the biosphere. All living organisms including plants, animals, microbes and other ecological complexes are the parts of an ecosystem. These are the factual components of an ecosystem in both the rural and urban areas. When one of the interacting factors gets interrupted, the whole ecosystem is affected. Plants are the most important determinant of the survival of life on earth. Plants can reduce air pollution through absorption and accumulation of pollutants on the enormous surface of leaves (Joshi and Swami 2009, Rawat and Banerjee 1996). So, plants are the initial receptors of air pollution and serve as collectors of many air-bone particulates and pollutants (Liu and Ding 2008). It can also cause injury in leaf, stomatal damage, the decrease of photosynthetic process, distract membrane permeability, growth reduction and yield of sensitive plants (Tiwari *et al*. 2006). However, sulfur dioxide, oxides of nitrogen, carbon dioxide and suspended particulate matters are absorbed on the leaves and may cause a reduction in the concentration of photosynthetic pigments, e.g. chlorophyll and carotenoids and directly affect plant productivity (Joshi and Swami 2007). Gradual decrease of chlorophyll and associated yellowing of leaves is one of the most common consequences of pollution (Joshi and Swami 2007). These changes in plant morphology and physiology are location specific depending on the nature of pollutions.

Air pollution tolerance index (APTI) is very important to understand the impact of air quality in plants. It is the inherent quality of plants which counters air pollution affects. Some biochemical parameters, such as total chlorophyll concentration (TCC), ascorbic acid concentration, relative water content (RWC) and pH of the leaf extracts are measured to determine the APTI value of a plant species using the formula $APTI = \frac{([A(T+P)]+R)}{10}$ (Singh and Rao 1983). Different plant parameters were used in many previous studies for APTI calculation (e.g., Singh 1989, Joshi and Swami 2007) as one parameter may not be enough for the evaluation. Therefore, ascorbic acid, water content, TCC, pH along with visible foliar injury, leaf conductance, and membrane permeability of the leaf extract were determined for understanding the impact of air pollution and its mechanism in plants (Singh, 1989). The mechanism between the pollutants and these parameters has not been fully understood yet. However, Sing and Rao (1983) used the formula to determine APTI value which we used in our study. Singh and Rao (1991) reported that the pH dependent reducing power of ascorbic acid protected chloroplast from SO_2 induced pollution and the enzymes of the CO_2 fixation cycle and chlorophyll from inactivation. Thus, the part of the above equation, [A(T+P)] represents the SO_2 sensitivity and R term indicates the capacity of cell membrane to maintain its permeability under polluted environment. Plants with low indices are generally sensitive to air pollution and vice versa. On the basis of these indices, evergreen plants of *M. indica* are classified into three groups as sensitive (less than 12), intermediate (13-16), moderately tolerant (16-20) and tolerant (greater than 20) according to the value of APTI (Singh and Rao 1991).

Plants can also be used as bio indicator depending on the resistance of the plants to air pollutants (Lakshmi *et al*. 2009). Babu *et al*. (2013) determined the air pollution tolerance index (APTI) of seven plants at both polluted and background locations. All the plants were found to be sensitive to the air pollutants (APTI values ranging from 7.38 to 10.1 in the polluted site, and 6.44 to 9.60 in background site). Kuddus *et al*. (2011) estimated APTI values of seven economically important plant species growing in the urban-industrial region of Allahabad, India. They reported that *M. indica* (APTI value of 18.5) can be considered as a tolerant species and the *Artocarpus* species (APTI value 8.75) was the most sensitive to air pollutants. Rafiq and Kumawat (2016) studied the effect of dust from cement industries on various parts of the apricot tree growing at different distances from the cement industrial belt Khrew, Kashmir, India. The chlorophyll and carotenoid content, pH of leaf wash, pH of leaf extract, and length of leaf were reduced due to the dust exposure. Tsega and Prasad (2014) worked on APTI and anticipated performance index (API) of five roadsides plant species using biological parameters.

Air pollution is a serious problem in the large cities of Bangladesh. Rapid industrialization and economic growth are continuously introducing new pollutants to the atmosphere. Coal burning in the brick kilns, rice mills and power plants, fossil fuel burning, traffic, industrial and residential emissions is contributing to the ambient particulate matters in Dhaka and other major cities in Bangladesh. Peoples are using cow dung, woods, dry leaves, rice husk and straw, jute stick, bagasse, bamboo, etc. at their cooking stoves in most of the rural areas of Bangladesh. These diverse air pollutions have a serious impact on plants. Regarding the impact of air pollution on plants in Bangladesh, there is no such study. Therefore, it stands essential to study the sensitivity of plants to air pollutions to avoid their extinction. To understand the impact of the air pollution on the species of *M. indica*, we envisaged to determine the air pollution tolerance index (APTI) based on ascorbic acid concentration, TCC, RWC and pH of leaf extract.

MATERIAL AND METHODS

Sample collection

The fresh matured leaf samples of *Mangifera indica* were collected between January and February 2015 from roadsides and residential locations in the urban Dhaka region (Dhaka City Centre, Gazipur, Narayangonj, Narsingdi and Savar) in Bangladesh (Fig. 1).

The leaves were collected manually from the bottom of the tree crown, about 8-10 feet above from the soil. The matured leaf samples were collected from nearby branches of tree in winter season. Winter is assumed to be the season of comparatively higher air pollution. Thus, we aimed to work in this season. The collected leaves were neither too young nor too old. They were free from any types of

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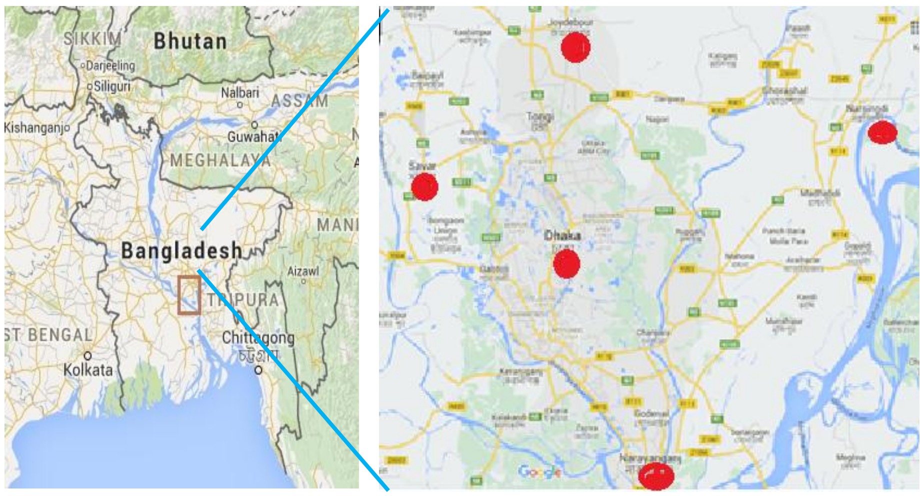
visible diseases of leaf and fungal attack. All the plants had almost the same ecological condition with respect to light, water, soil, pollutant exposure. They were collected fresh and analyzed as early as possible to avoid dryness. The leaf samples were extracted with standard solvents and measured the TCC, ascorbic acid concentration, RWC, and pH. Air pollution tolerance index (APTI) was calculated to study the sensitivity of the plant.



a **b**

Fig. 1 **a.** Map of Bangladesh; **b.** Red circles are the exact sampling locations in urban Dhaka, Bangladesh (Dhaka city Centre, Gazipur, Narayangonj, Narsingdi and Savar).

The major sources of pollutants on these areas were automobile exhaust and domestic heating for cooking. The roadside areas are bus stoppage and busy market sides. Residential sites consisted of concrete buildings and some are made of bamboo. The overall description of the sampling sites is given below (Table 1).

Table 1. Characteristics of the locations studied in greater Dhaka region.

Sampling site	Location Characteristics
Dhaka	23.8105° N, 90.3372° E Hub of all activities. There are educational institutes, offices, residential buildings, parks, few industries, busy traffic roads, vehicles mostly driven by CNG or petrol.
Gazipur	24.0958° N, 90.4125° E Along with remote rural areas, there are many garment factories, pharmaceuticals, railway station.
Narayangonj	23.7147° N, 90.5636° E Industrial area and highway roads connecting to the capital. Oil factories, chemical industries, cement and waving factories are very common there.
Savar	23.8820° N, 90.2808° E Very near from the capital. Along with university, it is familiar for many footwear, plastic, chemical industries.
Narsingdi	24.1344° N, 90.7860° E Plastic and polymer industries, Jute industries, textile, chemical industries are very common with its remote rural area.

Meteorology of Bangladesh

The climate in Bangladesh is characterized by high temperatures, excessive humidity, and distinct seasonal variations in precipitation. The seasons of Bangladesh include pre-monsoon (March-May), monsoon (June-September), post-monsoon (October-November), and winter (December-February). The average winter temperature varies from 4°C to 25°C, and the average summer temperature varies from 24°C to 36°C. The highest relative humidity occurs in July (99%), and the lowest in December (36%). Moderately higher temperatures were generally observed during the afternoon. Light precipitation occurs during March and April. The average meteorological conditions in the greater Dhaka have been given by Salam *et al*. (2003). The average temperature during hot, humid summer is 30ºC to 40ºC, in a cool rainy season is 28ºC to 35ºC and during cool, dry winter is 10ºC to 18ºC. Wind direction in Dhaka city is mainly from west and south-west direction at pre-monsoon and north and north-west at winter.

Total chlorophyll content determination (TCC)

Chlorophyll content was determined by using the method of Singh et al. (1991). This method was also used by Kuddus *et al.* (2011), Veni *et al*. (2014) and Nwadinigwe (2014) for chlorophyll content determination. Five hundred mg of leaf samples was ground with a mortar and pestle in small quantity (10.0 ml) of 80% acetone. The absorbance of the filtered extract was measured with a UV-Visible spectrophotometer (Model UV-1800, Shimadzu, Japan) at 645 nm and 663 nm. The following equation was used for the TCC determination.

$$Total\ chlorophyll\ content\ \left(\frac{mg}{g}\right) = (20.2 \times A645 + 8.02 \times A663) \times \frac{V}{1000 \times W} \quad \text{......(1)}$$

Where, A645 = Absorbance at 645 nm,
A663 = Absorbance at 663nm,
V = Total volume of the extract,
W = Weight of leaf materials in gram.

Ascorbic acid determination

Ascorbic acid was determined by using the method of Keller and Schwager (1977). Five hundred mg of fresh mango leaf samples were homogenized with 20 ml of extracting solution preparing 500 mg oxalic acid and 75 mg EDTA in 100 ml of distilled water. 2,6-dichlorophenol indophenol (DCPIP) (3 mg in 100 ml distilled water) was added to one ml of the above filtrate solution. The absorbance of the mixture was recorded at 520 nm (Es). After measuring the absorbance of the mixture, few drops of ascorbic acid was added to the mixture to bleach the pink color. After bleaching, the absorbance was recorded again at the same wavelength (Et). The absorbance of DCPIP solution was also recorded at 520 nm (Eo). The concentrations of the ascorbic acid in *Mangifera indica* leaf samples were calculated using the following equation.

$$Ascorbic\ acid\ \left(\frac{mg}{g}\right) = \frac{[E0 - (Es - Et)] \times V}{W \times V1 \times 1000} \quad \text{....................(2)}$$

Where, W = Weight of the fresh leaf taken (g),
V_1 = Volume of the supernatant solution (ml),
V = Total volume of the solution (ml).

The value of [Eo – (Es – Et)] was determined from following calibration curve. The calibration curve was prepared by using different known concentration of ascorbic acid solutions following the above method (Fig. 2).

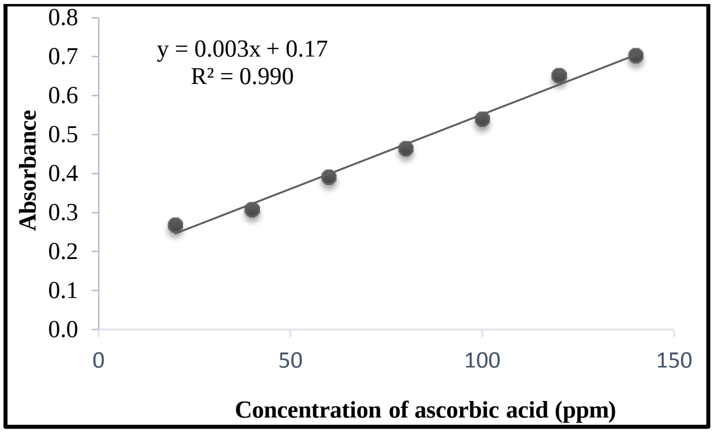


Fig. 2 Calibration curve for the determination of ascorbic acid concentration in leaf extracts.

Relative water content (RWC) determination

RWC was determined by using the method of Sivakumaran and Hall (1978). Individual leaf of *Mangifera indica* was excised and weighed immediately (initial weight) with an analytical balance (Model XB 120A, Precisa Gravimetric AG, Dietikon, Switzerland). Leaves were dipped into water in a beaker for about six hours. The leaves were then blotted and weighed (saturated weight). Then the leaves were dried at 80ºC for 16.0 hours and the dry weight was again recorded. The RWC was calculated by using the following equation.

$$RWC(\%) = \frac{Initial\ weight - Dry\ weight}{Saturated\ weight - Dry\ weight} \qquad \text{………………..……..(3)}$$

pH determination

The pH of the leaf extract was determined by homogenizing about one g sample with 10 ml of deionized water. The pH of the suspension was measured with a digital pH meter (Model pH 211, Hanna Instrument, Germany).

Air pollution tolerance index (APTI) determination

The APTI of *Mangifera indica* leaf was calculated by using following equation, which was developed by Singh and Rao (1983). The equation has been given as follows:

$$APTI = \frac{[A(T + P)] + R}{10} \qquad \text{………………..……………..……(4)}$$

Where, A is the ascorbic acid content in the leaf in mg/g dry weight, T is total chlorophyll content of leaf in mg/g dry weight, P is the pH of the leaf extract, and R is the percentage (%) RWC of the leaf.

$PM_{2.5}$ concentration measurement in sampling sites

The particulate matter ($PM_{2.5}$) concentration in the air of the sampling sites was measured by Aerocet (531S) with a flow rate of 2.83 L/min, a battery operated, handheld mass monitor or particle counter and completely portable unit. This unit provides particle counts or mass PM measurements as stored data-logged values, real-time networked data, or printed results.

RESULTS AND DISCUSSION

Air pollution impacts on tree of different parts of greater Dhaka region were studied. A low APTI value has observed in greater Dhaka region due to the high air pollution. The detail of results has given in Table 2.

Table 2. Summary of the measured parameters of *Mangifera indica* leaves at different roadsides and residential locations in urban Dhaka, Bangladesh with APTI values.

Locations	Types	Water content (%)	pH	Chlorophyll content (mg/g)	Ascorbic acid (mg/g)	APTI value	Average APTI
Narayangonj	Residential	88.02	5.78	0.25	2.94	10.57	**9.70**
	Roadside	86.35	5.48	0.41	0.33	8.83	
Narsingdi	Residential	94.00	5.48	0.88	1.12	10.11	**10.10**
	Roadside	90.96	4.48	0.40	2.15	10.09	
Dhaka	Residential	97.41	5.55	1.10	2.31	11.28	**10.52**
	Roadside	87.09	5.01	0.76	1.82	9.76	
Savar	Residential	83.51	5.42	0.70	2.80	10.06	
	Roadside	81.52	5.12	0.64	2.54	9.62	**9.84**
Gazipur	Residential	84.85	5.52	0.96	2.80	10.30	**10.25**
	Roadside	82.79	5.46	0.48	3.24	10.20	
	Average	**87.65**	**5.33**	**0.66**	**2.21**	**10.1**	

Total Chlorophyll Content (TCC)

The total average chlorophyll content in *Mangifera indica* leaves was 0.66 mg/g. Average chlorophyll content of the leaves in the residential area (0.78 mg/g) was 1.5 times higher than the roadsides (0.54 mg/g). Narayangonj, the high polluted location, had the lowest amount of TCC, whereas Dhaka had the highest value of TCC. The variation of the TCC between the roadsides and residential areas at different sampling locations in the greater Dhaka has been given in Fig. 3.

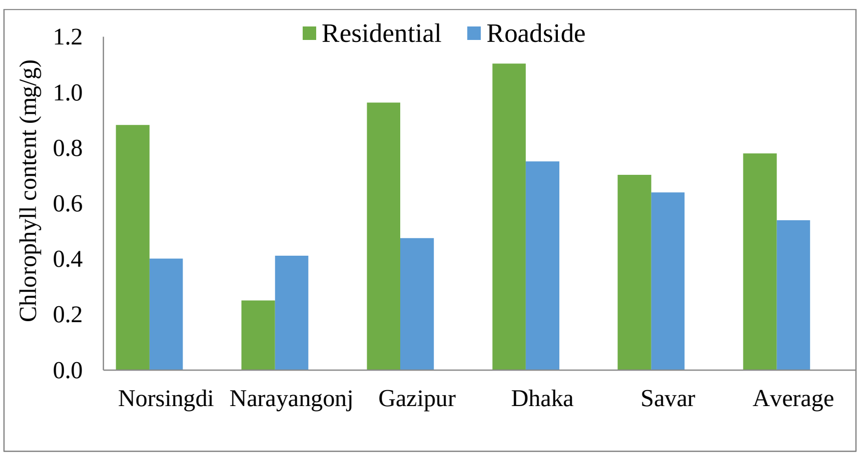


Fig. 3. Total chlorophyll content (mg/g) in *Mangifera indica* leaf samples at the different roadsides and residential locations in urban Dhaka, Bangladesh.

Ascorbic acid content

Total average of the ascorbic acid content was found to be 2.21 mg/g in mango leaves in the greater Dhaka region. The amount of ascorbic acid was the highest in the samples of Gazipur, whereas the lowest value was in Narayangonj. Narsingdi and Narayangonj showed an almost similar value of the ascorbic acid content. Moreover, ascorbic acid concentrations were higher in the residential areas (2.39 mg/g) than the roadsides (2.02 mg/g). The variation of the ascorbic acid content between the roadsides and residential areas at different sampling locations in the greater Dhaka has been given in Fig. 4.

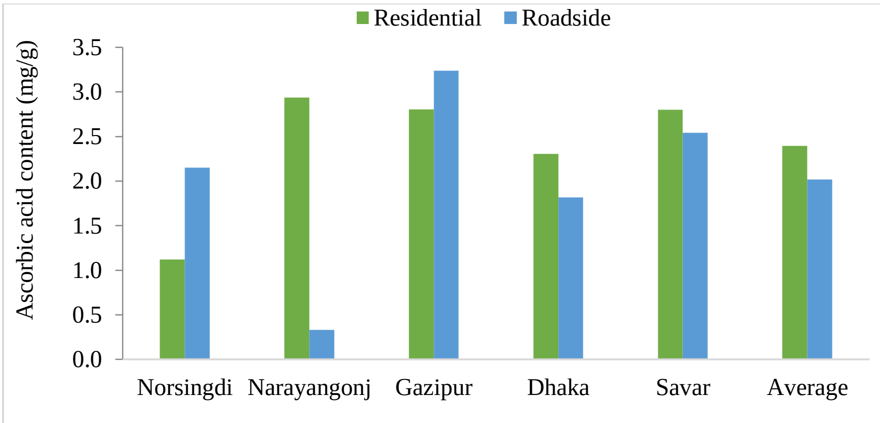


Fig. 4. Ascorbic acid content (mg/g) in *Mangifera indica* leaf samples at the different roadsides and residential locations in urban Dhaka, Bangladesh.

Relative water content (RWC)

The RWC in mango leaves was found to be 87.7% (on average) in greater Dhaka. However, RWC value was higher in residential areas (89.6%) than the roadsides (85.8%). The samples collected from Dhaka city and Narsingdi have the highest water content and lowest in Savar among these five sampling locations. The variation of the RWC between different roadsides and residential locations in the greater Dhaka region has been given in Fig. 5.

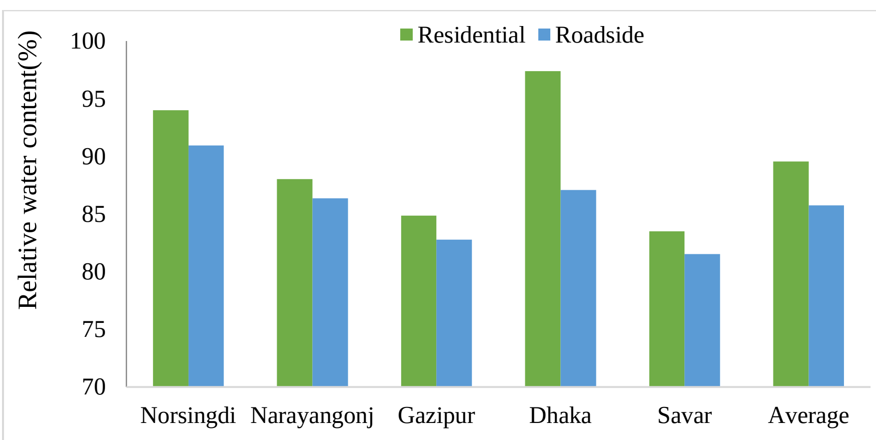


Fig. 5. Relative water content (%) in *Mangifera indica* leaf samples at the different roadsides and residential locations in urban Dhaka, Bangladesh.

pH

The pH values of mango leaf extracts were almost similar (on average 5.33) at these five sampling locations in Dhaka region. All the pH values were acidic. A slightly higher pH value was observed in the residential area (5.55) than the roadsides (5.11). The variation of the pH values has been given in Fig. 6.

The amount of TCC was decreasing with the increase of air pollution. Deposition of suspended particulate matters on the leaf surface might be responsible for the decrease in concentration of chlorophyll. Oxy radicals produced from reactions with SO_2, NO_2, and O_3 damaged chlorophyll and the membrane of the leaf (Shakaki *et al*. 1983). SO_2 also act as a potential bleaching and strong reducing agent. It is soluble in water and produces sulfurous acid. This acid ionizes to form H^+ and removes Mg^{2+} from chlorophyll a converting it to phaeophytin a. Thus, the chlorophyll content decreases due to the destruction of the structure in more polluted areas.

$$H_2SO_3 \rightarrow HSO_3^- + H^+$$
$$HSO_3^- \rightarrow SO_4^{2-} + H^+$$
$$\text{Chlorophyll} + 2H^+ \rightarrow \text{Phaeophytin} + Mg^{2+}$$

Nwadinigwe (2014) reported slightly higher chlorophyll content (about 0.78 mg/g) in Nigeria. Veni *et al*. (2014) found about 0.20 mg/g chlorophyll content in the leaves of mangoes in India. Kuddus *et al*. (2011) found a relatively higher value (12.3 mg/g) than all the values listed in Table 3. Pollutant resistivity of the plants increases with the amount of ascorbic acid concentration (Lima *et al*. 2000). Cytotoxic radicals are generated, when oxidative pollutants penetrate into the leaves. Ascorbic acid is consumed during the removal process (Pandey and Agrawal 1994). In the current study, the ascorbic acid concentration in the roadside leaves was lower than residential (up to 15.0%) presumably due to the high pollution stress. This decrease in ascorbic acid concentration deteriorates the plant's defense system. The ascorbic acid content in leaves was about 2.19 times higher in India (Kuddus *et al*. 2011) and 27.6 times lower in Nigeria (Nwadinigwe 2014) compared to Dhaka, Bangladesh (Table 3).

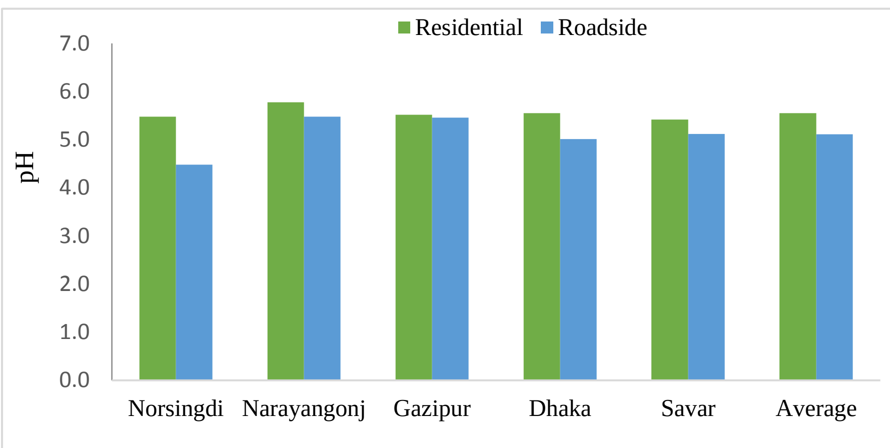


Fig. 6. pH values in *Mangifera indica* leaf samples at the different roadsides and residential locations in urban Dhaka, Bangladesh.

The plants with high RWC are tolerant to the polluted environments. The transpiration rate is lower with the lower water content under stressed condition. Air pollutants increase cell permeability and cause loss of water and dissolved nutrients from plant tissue. Early senescence of leaf occurs due to the increasing pollution. Dhaka city and Narsingdi were relatively less dry and less polluted than the other three sampling loscations in greater Dhaka. Mango leaves in Savar showed low water content due to the high pollutions from the garments and manufacturing industries. The RWC value in India (89.86%) (Kuddus *et al*. 2011) was slightly higher than the current study. Nwadinigwe (2014) found very low water content in Nigeria (3.72%).

Acidic pH (on average 5.33) indicates the presence of SOx and NOx in the ambient air (Swami *et al*. 2004). Diffusion of SO_2 through stomata, gaseous SO_2 dissolves in water to form sulfites, bisulfate and other ionic species with the generation of protons, have a great impact on the plant cellular pH. The pH change towards acidic range observed in most plant species is due to the entry of SO_2 into leaf mesophyll tissue. The plants with lower pH are more susceptible and pH around 7.0 is tolerant (Singh and Verma 2007). Hence, mango leaves are very sensitive to pollutants in both the roadsides and residential areas in greater Dhaka. The slightly higher pH value (5.70) was observed in Nigeria (Nwadinigwe 2014) than that of Dhaka. Neutral or slightly basic pH was found by Veni *et al*. (2014) (8.50) and Kuddus *et al*. (2011) (7.40) in India (Table 3).

Table 3. Comparison of different environmental parameters affecting *Mangifera indica* in the present study with previous studies in Nigeria and India.

	Current study (2015)	**Nwadinigwe (2014)**	**Veni *et al*. (2014)**	**Kuddus *et al*. (2011)**
	Bangladesh	Nigeria	India	India
[a]TCC (mg/g)	0.66	0.78	0.20	12.28
[b]AAC(mg/g)	2.21	0.08	1.33	4.84
pH	5.33	5.70	8.50	7.40
[c]RWC (%)	87.65	3.72	46.00	89.86
[d]APTI	10.10	3.92	5.50	18.51

Overall results for APTI have been given in the following Fig. 7 and Fig. 8. The mango leaves in roadsides areas showed lower APTI than the residential locations. Dhaka city had the highest APTI value (10.52) among all the sampling locations in the current study indicating a lower level of pollutions. A lower APTI value (9.70) was observed in Narayangonj, which indicates the sensitivity of the mango leaves towards the air pollution in this area. Irrespective of the variation in the APTI values and sampling locations, *Mangifera indica* is showing sensitivity towards the air pollutants in greater Dhaka.

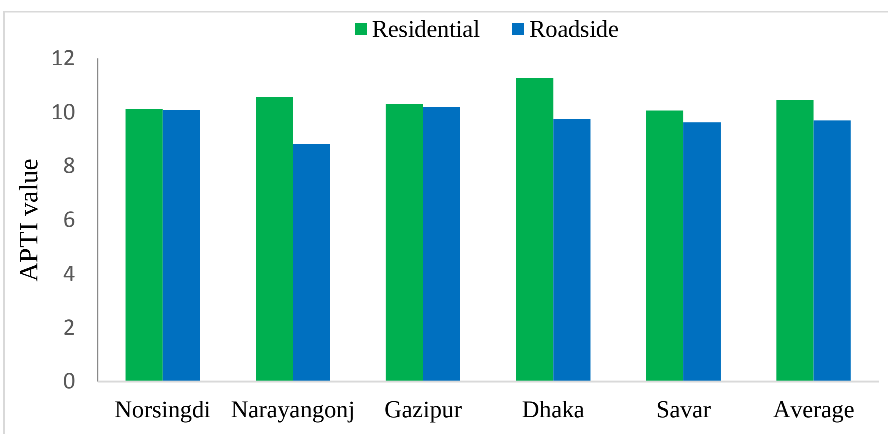


Fig. 7. APTI values in *Mangifera indica* leaf samples at the different roadsides and residential locations in urban Dhaka, Bangladesh.

The APTI values have a strong correlation (r^2=0.9506) with $PM_{2.5}$ in all the sampling locations. Most polluted areas with high $PM_{2.5}$ values have low APTI values and vice versa (Fig. 8). Brick kiln emission and long-range transport along with traffic and construction activities may have a significant contribution to the elevated concentrations of atmospheric particulate matters in Dhaka city as well as nearby locations. The emissions from brick kilns are also expected to be contributed to the high-level pollution during this winter sampling period as brick kilns are operating only during winter.

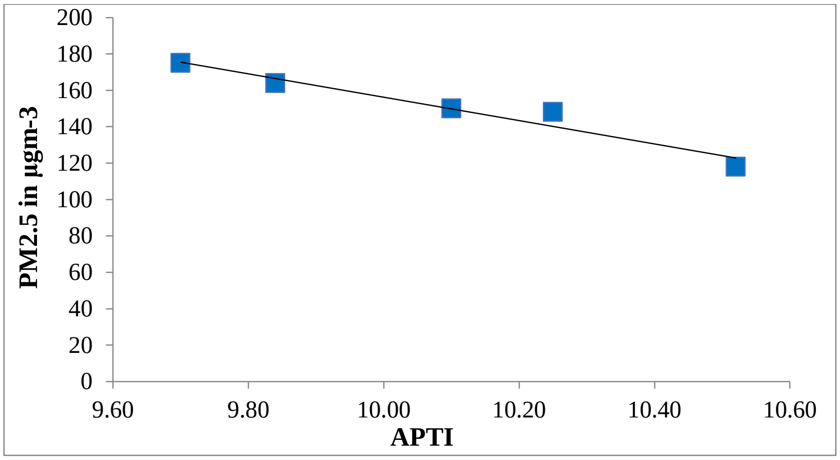


Fig. 8. The correlation between air pollution tolerance index (APTI) and $PM_{2.5}$ in five sampling locations in greater Dhaka region.

However, plants are continuously exposed to the air pollution leading to an accumulation of pollutants in their system. It alters the nature of the leaves and makes them more sensitive to the pollutants. The APTI values of the *M. indica* leaves collected from different roadsides and residential locations in greater Dhaka were found to be low. It shows the sensitivity of the mango leaves to the pollution irrespective of the sampling locations in greater Dhaka region. The APTI values of *M. indica* leaves were in the range of 9.70-10.52. The total average chlorophyll content in plant species was 30.0%, and the ascorbic acid concentrations were 15.0% higher in the residential locations than that of the roadsides. The pH of the leaf extracts (5.33) was acidic, and the RWC was 87.7%. There were no significant differences between roadsides and residential values of the determined parameters as well as APTI values. These results suggest that *Mangifera indica* is very sensitive to the air pollutants. The concerned authorities should take measures for saving mango tree from air pollution and be concerned about choosing the tree species for afforestation.

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