

Original Article

ASSESSMENT OF AIR POLLUTION TOLERANCE INDEX OF PLANTS: A COMPARATIVE STUDY

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ABSTRACT

Objective: Air pollution is one of the major global tribulations in many developing cities around the world. Addressing this sort of pollution is more intricate than other ecological challenges. As pollution is an upcoming issue, we aimed at assessing the air pollution tolerant plants from roadside exposed to vehicular air pollution from two different locations in Thane city.

Methods: In the present study, commonly available ten roadside tree species selected from polluted and control area, and their air pollution tolerance index (APTI) determined in Thane city. The biochemical parameters viz. pH, ascorbic acid, total chlorophyll, relative water content (RWC) were considered to calculate APTI by using standard method.

Results: The study shows that the control site has more APTI than the polluted site. The APTI observed minimum in *Tectona grandis* 5.2±0.3247 and maximum in *Azadirachta indica* 13.5±0.4404. Reduction in APTI at polluted site shows that *Alstonia scholaris* (6.6%), *Tamarindus indica* (8.8%) and *Azadirachta indica* (10.3%) were the most tolerant tree species, while *Tectona grandis* (47.5%), *Acacia nilotica* (27.4%) and *Cassia fistula* (20.7%) were more sensitive tree species. The results showed the order of tolerance (% difference in APTI) as *Alstonia scholaris* (6.6%)>*Tamarindus indica* (8.8%)>*Azadirachta indica* (10.3%)>*Moringa pterygosperma* (11.9%)>*Mangifera indica* (13.9%)>*Bahunia variegata* (14.3%)>*Annona squamosa* (18.7%)>*Cassia fistula* (20.7%)>*Acacia nilotica* (27.4%)>*Tectona grandis* (47.5%).

Conclusion: Tolerant trees species can serve as a sink, and sensitive tree species can act as an indicator for air pollution mitigation. Thus, this study provides useful insights for selecting tolerant species for future planning and Greenbelt development in urban areas.

Keywords: Ascorbic acid, Chlorophyll, Relative water content, pH, Air pollution tolerance index, Greenbelt, Air pollution

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INTRODUCTION

Pollution is an upcoming issue, which alters metabolism in any organisms. The rapid growth of industries and vehicular density is the primary cause behind the rise in environmental air pollution in urban areas and is a major problem of cities [1]. The expanding cities in developing countries are at the receiving end as they face the wrath of air pollution. Vehicular exhaust and construction work are the primary reasons for air pollution in the city. Continuous increase in vehicles is adding further woes. Trees are playing a major role in improving air quality by exchanging gases as they act as a sink for the air pollutants. They remove particulate matter by acting as living filters to minimize the air pollution. Trees that exposed to environmental pollutants absorb, accumulate and integrate these pollutants into their systems, depending on their sensitivity level. Plants show visible damages, which would include alteration of the biochemical processes or accumulation of individual metabolites. These changes used for assessing the APTI of plants [2].

Many researchers have investigated air pollutants through plants when exposed to air pollution [3-6]. Most plant experiences physiological changes before exhibiting visible damage to leaves [7]. According to responses of plants towards air pollution, analysis of some biological parameters of each species helps in determining tolerance level. The impacts of air pollution on ascorbic acid content [8], chlorophyll content [9], and leaf extract pH [10] and RWC [11] has extensively studied. In the present study, four parameters (ascorbic acid, total chlorophyll content, relative water content and leaf extract pH) analyzed and expressed together in one formula to evaluate the sensitivity of plants to air pollutants [12]. APTI determines the plant's reaction to air pollution and the plant's ability to fight against air pollution [13].

There is no distinct barrier between industrial and residential areas due to rapid urbanization in developing countries. Due to this, deterioration of air quality is the major environmental problem in urban areas. Air pollution in urban areas is adversely affecting

human health, and it is affecting plant's life enormously, which is difficult to quantify. Each plant species tends to respond differently to different pollutants and climatic conditions. Therefore, the present study was carried out to understand the resistance and adaptability of plants towards air pollution.

In the current study, the susceptibility levels of commonly growing tree species on the roadside exposed to vehicular air pollution have been determined based on their air pollution tolerance indices. Biological monitoring of plant tolerance towards air pollution helps in selecting tolerant and sensitive plants as a bioindicator of air pollution. The plants with the minimum tolerance index value were sensitive to air pollution. While the plants with high tolerance index value were tolerant to air pollution. Tolerant species helps in mitigating air pollution while less tolerant species acts as an indicator. Greenbelt developers can employ results of the study in managing the urban air pollution.

MATERIALS AND METHODS

Chemicals and reagent used

All chemicals and reagents were of analytical grade. Acetone, magnesium carbonate, oxalic acid, distilled water, standard pH solution (buffer) were obtained from the department of botany, Institute of Science, Mumbai. Ethylenediaminetetraacetic acid (EDTA), metaphosphoric acid pellets, acetic acid, ammonium molybdate, sulphuric acid, standard L-ascorbic acid were purchased from Paras Chem India, (Mumbai).

Study area and sampling location

Thane city is located in Maharashtra State and is a part of the Mumbai metropolitan region. Thane city lies between 19° 12' N and 73° 02' E and spread over the area of 128.23 square km. The maximum temperature ranges from 35 °C to 40 °C during summer, and the minimum temperature is between 25 °C to 35 °C during the winter months of November-January. The average rainfall is about

2500 mm receives during the rainy season from June to the end of September. The climate of the region is coastal, hot and humid.

Sampling sites are located in Thane city. Chendani Koliwada area in Thane with high peak hour vehicular traffic volume selected as the polluted site (P). The area with a dense forest of Yeoor hills near the city chosen as the control site (C).

Collection of plant material

Fresh leaves from each plant were collected from both the sites (control and polluted). The present work was designed to assess the effects of air pollution on plants; hence, 10 commonly available plants exposed to vehicular emission along the roadside were selected for the study (viz., *Alstonia scholaris*, *Tamarindus indica*, *Azadirachta indica*, *Moringa pterygosperma*, *Mangifera indica*, *Bahunia variegata*, *Annona squamosa*, *Cassia fistula*, *Acacia nilotica*, *Tectona grandis*). All selected plants were identified with the help of available standard literature [14] and verified with the help of experts in the field of taxonomy. Three samples from healthy and fully matured leaves of each plant gathered through the random selection from the lowermost position of a canopy at the height of 1.8-2.1 m from ground level. The further analysis was carried out in the laboratory. All collected leaf samples were washed with the running tap water, rinsed with distilled water and then used for further analysis.

Estimation of total chlorophyll

1.0 g of the greenest leaves were selected and cleaned thoroughly with water and dried at room temperature for a while. Then samples were macerated in a pestle with mortar by adding 20–25 ml of 80% acetone. A pinch of magnesium carbonate was added to the material prior to extraction to prevent deterioration of chlorophyll. The leaf extract content was centrifuged at 2000 r. p. m. for 15 min in the cooling centrifuge. Transferred the extract to a volumetric flask and made to the volume of 50 ml using 80% acetone. The optical density of this green solution read at 645 nm (D645), and 663 nm (D663) using a spectrophotometer and the total chlorophyll calculated with the following formula by Arnon [15].

$$CT = 20.2 (D645) \pm 8.02 (D663)$$

Measuring leaf extract pH

pH is the measure of hydrogen ion activity and mostly depends on the relative amounts of the adsorbed hydrogen and metallic ions. It

is a good measure of the intensity of acidity and alkalinity of suspension. 5.0 g of fresh leaves were homogenized in 10 ml distilled water. Leaf extract filtered and the pH determined after calibrating pH meter with a buffer solution of pH 4, 7 and 9.

Relative water content (RWC)

Fresh weight obtained by weighing the fresh leaves. The leaves were then immersed overnight in water blotted, dry and then weighed to get the turgid weight. The leaves kept to dry overnight in an oven at 70 °C and reweighed to obtain the dry weight. RWC was determined and calculated by the following formula by Barr and Weatherly [16].

$$RWC (\%) = [(FW-DW)] / [(TW-DW)] \times 100$$

Where,

FW is Fresh weight,

DW is Dry weight, and

TW is turgid weight.

Ascorbic acid analysis

1.0 g of fresh foliage homogenized in 4.0 ml oxalic acid-EDTA extracting solution for the 30s. 0.5 ml of metaphosphoric acid-acetic acid and 1.0 ml of 5% v/v sulphuric acid followed by 2.0 ml of ammonium molybdate and dilute with distilled water. The solution was kept to stand for 15 min. The absorbance was read off with a digital spectrophotometer at 760 nm. The concentration of the ascorbic acid determined from a standard ascorbic acid regression curve by Bajaj and Kaur [17].

Air pollution tolerance index (APTI) determination

The air pollution tolerance indices often commonly available plants were determined by the following method by Singh and Rao [18].

$$APTI = [A \times (T \pm P) \pm R] / [10]$$

Where, A is Ascorbic acid (mg/g fr. wt),

T is Total chlorophyll (mg/g fr. wt),

P is Leaf extracts pH and

R is Relative water content (RWC) [(%) of the leaves].

The APTI values help to identify the tolerant and sensitive plant species.

Table 1: The APTI of selected plant species at the control and the polluted site

S. No.	Botanical name	Site	Total chlorophyll (mg/g)	pH of leaf extract	Relative water content (RWC) (%)	Ascorbic acid (mg/g)	APTI	Difference in APTI	% difference in APTI
1	<i>Moringa pterygosperma</i>	C	3.2±0.0237	5.4±0.0	69.2±0.1732	10.6±0.4	16±0.3363	3.4	11.9
		P	2.7±0.0105	5.9±0.0	55.4±0.05	6.1±0.557	12.6±0.2168		
2	<i>Tamarindus indica</i>	C	5.9±0.0265	3.1±0.0	70.4±1.015	4.5±0.3214	11.1±0.3139	1.8	8.8
		P	4.9±0.0311	2.9±0.0	65.3±0.1732	3.6±0.4	9.3±0.3054		
3	<i>Tectona grandis</i>	C	4.7±0.0194	5.3±0.0	44.1±4.063	10.2±0.7	14.6±0.3036	9.4	47.5
		P	3.5±0.0451	6.3±0.0	37.3±2.265	1.5±0.4582	5.2±0.3247		
4	<i>Annona squamosa</i>	C	1.8±0.0231	6.0±0.0	49.9±4.942	7.8±0.5568	11.1±0.1836	3.5	18.7
		P	1.6±0.0116	6.5±0.0	38.7±1.852	4.6±0.4582	7.6±0.2327		
5	<i>Azadirachta indica</i>	C	3.7±0.0208	6.3±0.0	74.2±5.568	9.1±0.3605	16.6±0.1819	3.1	10.3
		P	2.2±0.0529	5.9±0.0	67.5±1.179	8.2±0.3605	13.5±0.4404		
6	<i>Acacia nilotica</i>	C	7.8±0.0208	5.2±0.0	81.3±8.168	1.5±0.1732	10.0±0.6850	4.3	27.4
		P	5.1±0.0866	5.7±0.0	47.1±6.219	0.9±0.1	5.7±0.7050		
7	<i>Mangifera indica</i>	C	3.3±0.1	6.2±0.0	92.9±6.784	7.9±0.6557	16.8±0.2475	4.1	13.9
		P	2.5±0.138	6.2±0.0	73.3±2.858	6.1±0.557	12.7±0.2799		
8	<i>Cassia fistula</i>	C	5±0.0866	6.2±0.0	78.4±10.001	8.9±0.2645	17.8±0.9324	6.1	20.7
		P	4.1±0.1732	6.6±0.0	56.5±7.549	5.7±0.1732	11.7±0.9136		
9	<i>Alstonia scholaris</i>	C	4.4±0.1322	6.0±0.0	92.2±3.477	3.7±0.1	13±0.2566	1.6	6.6
		P	2.4±0.05	5.8±0.0	86.1±0.8544	3.4±0.1732	11.4±0.0897		
10	<i>Bahunia variegata</i>	C	3.4±0.1732	6.7±0.0	74.4±4.582	5.3±0.1	12.8±0.3480	3.2	14.3
		P	1.6±0.05	6.7±0.0	63.7±3.606	3.8±0.1732	9.6±0.2184		

Note: Mean±SEM for triplicates of plants showing the values for the biochemical parameters

Statistical analysis

The evaluation of plant material was done in triplicates. The correlation coefficient was determined between independent variables viz. total chlorophyll, pH, RWC, ascorbic acid and dependent variable such as APTI. To determine the degree of correlation between the variables Analysis ToolPack in Excel was used. Results were expressed as graphs representing mean±SEM (Standard error of mean)

RESULTS

The results of APTI presented in table 1.

Total chlorophyll

Results of total chlorophyll presented in table 1. Total chlorophyll found the maximum 5.1 ± 0.0866 mg/g in *Acacia nilotica* and the minimum 1.6 ± 0.0116 mg/g in *Annona squamosa*. The study revealed that total chlorophyll decreased significantly in plant leaves at the polluted area as compared to the control area. Reduction in chlorophyll content observed the minimum for *Annona squamosa* (5.9%), followed by *Moringa pterygosperma* (8.5%) and *Tamarindus indica* (9.3%). Reduction in chlorophyll content found the maximum for *Bahunia variegata* (36.0%), followed by *Alstonia scholaris* (29.4%) and *Azadirachta indica* (25.4%).

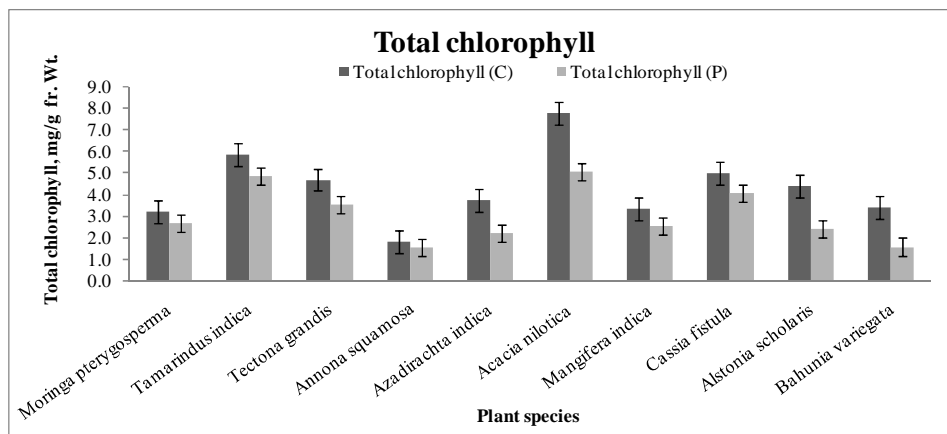


Fig. 1: Total chlorophyll content of plant species at the control and the polluted sites

Note Total chlorophyll (C)-Total chlorophyll at the control site, Total chlorophyll (P)-Total chlorophyll at the polluted site. Values are expressed as mean±SEM, and the analysis was done in triplicates

Ascorbic acid

Results of ascorbic acid presented in fig. 2. The ascorbic acid content found the maximum in *Azadirachta indica* 8.2 ± 0.3605 mg/g fr. wt. While the minimum in *Acacia nilotica* 0.9 ± 0.1 mg/g fr. wt. Plants were

maintaining high ascorbic acid under pollutant conditions considered as tolerant to air pollution. The study revealed that ascorbic acid decreased significantly in plant leaves at the polluted area as compared to the control area. Reduction in ascorbic acid content found the minimum for *Alstonia scholaris* (4.2%), followed by *Azadirachta indica* (5.2%) and *Tamarindus indica* (11.1%). Reduction in ascorbic acid content observed the maximum for *Tectona grandis* (74.4%), followed by *Annona squamosa* (25.8%) and *Acacia nilotica* (25.0%).

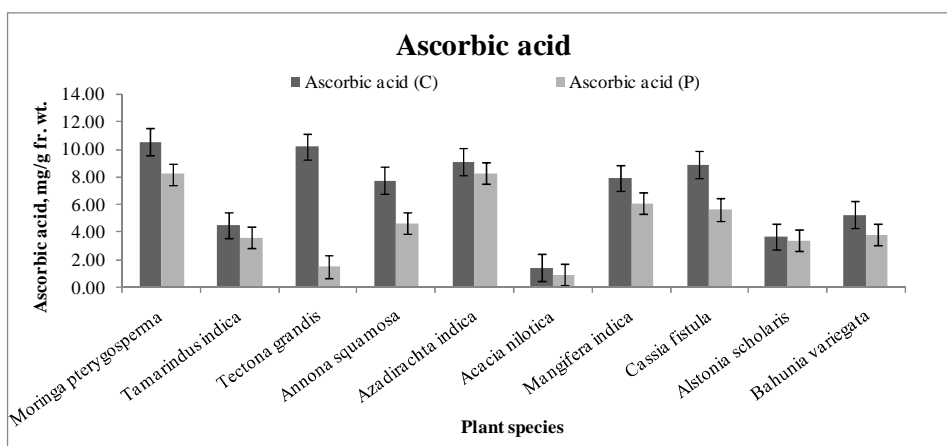


Fig. 2: Ascorbic acid content of plant species at the control and the polluted sites

Note Ascorbic acid (C)-Ascorbic acid at the control site, Ascorbic acid (P)-Ascorbic acid at the polluted site. Values are expressed as mean±SEM and the experiments were done in triplicates.

Leaf extract pH

The leaf extract pH found the maximum 6.7 ± 0.0 in *Bahunia variegata*, and the minimum in *Tamarindus indica* 2.9 ± 0.0 . The leaf

extract pH plays a major role in regulating the SO_2 sensitivity of plants. The change observed in leaf extract pH observed the minimum for *Bahunia variegata* (0.0%), followed by *Mangifera indica* (0.0%) and *Alstonia scholaris* (1.7%). The change observed in leaf extract pH found the maximum for *Tectona grandis* (8.6%), followed by *Moringa pterygosperma* (4.4%) and *Acacia nilotica* (4.6%). Results of leaf extract pH shown in fig. 3.

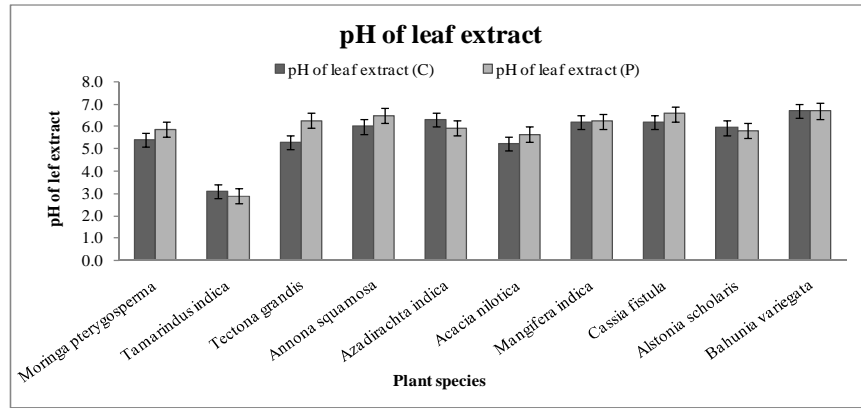


Fig. 3: pH of leaf extract for plant species at the control and the polluted sites

Note: pH of leaf extract (C)–pH of leaf extract at the control site, pH of leaf extract (P)–pH of leaf extract at the polluted site. Values are expressed as mean±SEM and the analysis was done in triplicates.

Relative water content (RWC)

The RWC found maximum 86.13±0.8544 % in *Alstonia scholaris* and minimum in *Tectona grandis* 37.27±2.265%. The study

revealed that RWC decreased in plant leaves at the polluted area as compared to the control area. Results of RWC shown in fig. 4.

Reduction in RWC observed the minimum for *Alstonia scholaris* (3.4%), followed by *Tamarindus indica* (3.8%) and *Azadirachta indica* (4.7%). Reduction in RWC found the maximum for *Acacia nilotica* (26.6%), followed by *Cassia fistula* (16.2%) and *Annona squamosa* (12.6%).

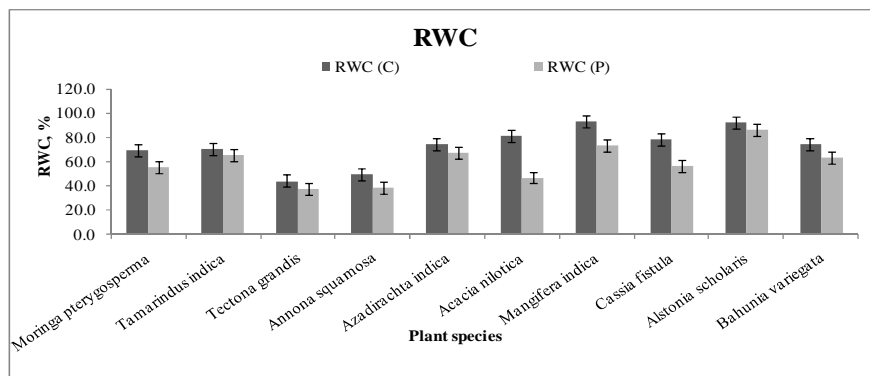


Fig. 4: Relative water content of plant species at the control and the polluted sites

Note: RWC-Relative water content, RWC(C)-Relative water content at the control site, RWC(P)-Relative water content at polluted site. Values are expressed as mean±SEM and the analysis was done in triplicates.

Air pollution tolerance indices (APTI)

APTI index shows the capability of a plant to fight against air pollution. The APTI found the minimum in *Tectona grandis*

5.2±0.3247 and the maximum in *Azadirachta indica* 13.5±0.4404. The study reveals that the control site has more APTI than the polluted site. Reduction in APTI observed the minimum for *Alstonia scholaris* (6.6%), followed by *Tamarindus indica* (8.8%) and *Azadirachta indica* (18.7%). Reduction in APTI found the maximum for *Tectona grandis* (47.5%), followed by *Acacia nilotica* (27.4%) and *Cassia fistula* (20.7%). Results of APTI as shown in fig. 5.

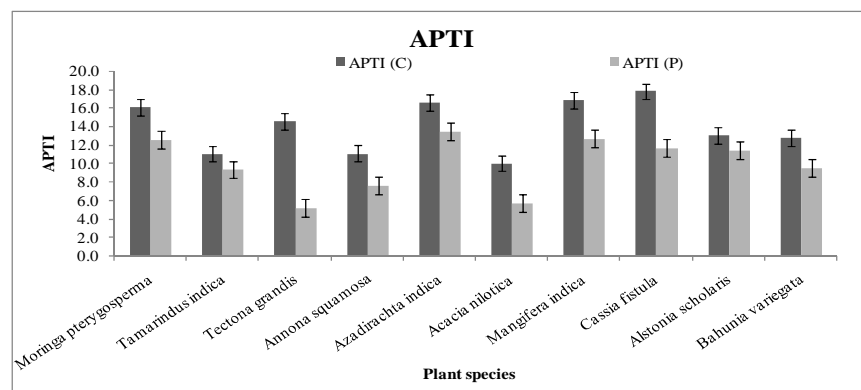


Fig. 5: APTI of plant species at the control and the polluted sites

Note: APTI–Air pollution tolerance index, APTI (C)–APTI at the control site, APTI (P)–APTI at the polluted site. Values are

expressed as mean±SEM, and the analysis was done in triplicates.

Table 2: Correlation between the APTI values and biochemical parameters estimated from the leaf samples of control site

	Total chlorophyll	pH	RWC	Ascorbic acid	APTI
Total chlorophyll	1				
pH	-0.515359752	1			
RWC	0.248590547	0.198766	1		
Ascorbic acid	-0.603916103	0.255081	-0.46014	1	
APTI	-0.33886687	0.443226	0.190119	0.749861324	1

Note: RWC–Relative water content, APTI–Air pollution tolerance index

Table 3: Correlation between the APTI values and biochemical parameters estimated from the leaf samples of the polluted site

	Total chlorophyll	pH	RWC	Ascorbic acid	APTI
Total chlorophyll	1				
pH	-0.569894403	1			
RWC	-0.192520359	-0.22355	1		
Ascorbic acid	-0.4498179	0.130612	0.30581	1	
APTI	-0.372470055	0.037882	0.710256	0.873806498	1

Note: RWC–Relative water content, APTI–Air pollution tolerance index

DISCUSSION

Developed cities have a remarkable pressure of air pollution, which is eventually causing injuries to the plants through various means, and thus the effects of these injuries found less intolerant plant species. These tolerant plant species showed great role as bioindicators of air pollution [19].

The results showed that total chlorophyll content values found less in all selected plant species of polluted sites. It ranged from maximum 5.1±0.0866 mg/g fr. wt. in *Acacia nilotica* and minimum 1.6±0.0116 mg/g fr. wt. in *Annona squamosa*. Photosynthetic process of plant mainly depends upon the chlorophyll content and development of biomass; it varies from plant to plant due to leaf age, biotic, abiotic conditions and pollution levels [20]. The disintegration of these pigments in urbanized plants may occur due to atmospheric pollutants [21]. There are certain pollutants that increase the total chlorophyll content and others decreases. The chloroplast is the primary site of the attack by air pollutants. As the air pollutant directly enter in the tissues through stomata, cause partial denaturation of the chloroplast, and decreases the pigment content in the cells of polluted leaves. Degradation of photosynthetic pigments has been widely used as an indicator of air pollution [21]. The decrease in chlorophyll content of leaves may be due to the alkaline condition created by the dissolution of chemical present in dust particles *i.e.* metals and polycyclic hydrocarbons in cell sap which block the stomatal spores for diffusion of air and thus put stress on plant metabolism resulting in chlorophyll degradation [22]. Moreover, it found that pollution generated through automobiles is one of the biggest reasons in decreasing chlorophyll content in plant growing along roadsides [23, 24]. Thus, the reduction in chlorophyll content of polluted site roadside plants attributes to high levels of vehicular air pollution.

Ascorbic acid content found less in all selected plant species of the polluted site. It ranged maximum in *Azadirachta indica* 8.24±0.3605 mg/g fr. wt. and minimum in *Acacia nilotica* 0.93±0.1 mg/g fr. wt. Ascorbic acid acts as an antioxidant and develops the mechanism of a plant to resist against the adverse atmospheric conditions [25]. Ascorbic acid plays a role in the cell wall synthesis, defence and cell division [26]. It is also a strong reducer and plays an important role in photosynthetic carbon fixation [27]. Moreover, its high level in plants indicated high tolerance level of plant species against pollutions and its lower values rank the plants in a sensitive category against air pollution [28, 29]. Thus, the decrease in the ascorbic acid content of plant species at polluted area may be due to vehicular emissions.

The RWC found higher in all selected plant species of the polluted site. It was the maximum 86.13±0.8544 % in *Alstonia scholaris* and

the minimum 37.3±2.265 % in *Tectona grandis*. Availability of water in plant cells associated with the protoplasmic permeability of cells and thus a loss in water content and nutrients from the cells resulted in senescence of leaf in very early stage of plant life [30, 31]. As one study indicated that plants with higher RWC would have greater drought resistance, so it can be concluded that high water content in plants may lead the tree species as tolerant one [32]. Thus, all the results of RWC of the polluted roadside area showed tolerance to vehicular air pollution.

Results revealed that some of the plant species of the polluted site showed a pH in acidic nature and some towards basic nature. The pH found maximum 6.70±0.0 in *Bahunia variegata* and minimum in *Tamarindus indica* 2.9±0.0 at polluted area roadside plants. The leaf extract pH plays a major role in regulating the SO₂ sensitivity of plants. Researchers have reported that in the presence of an acidic pollutant, the leaf pH lowered and the decline is greater in sensitive species [33, 34]. Low leaf pH extract showed good correlation with sensitivity to air pollution and reduced photosynthetic process in plants [35]. The plants with high sensitivity to SO₂ and NO₂ closed the stomata faster when they exposed to pollutants [36].

The result of this study reveals that different trees respond differently to air pollution, hence have different indices. The study shows that the control site has more APTI than the polluted site. The APTI observed minimum in *Tectona grandis* 5.2±0.3247 and maximum in *Azadirachta indica* 13.5±0.4404. Reduction in APTI found the minimum for *Alstonia scholaris* (6.6%), followed by *Tamarindus indica* (8.8%) and *Azadirachta indica* (10.3%). Reduction in APTI observed maximum for *Tectona grandis* (47.5%), followed by *Acacia nilotica* (27.4%) and *Cassia fistula* (20.7%). From the result obtained, it revealed that *Alstonia scholaris*, *Tamarindus indica*, and *Azadirachta indica* found most tolerant since they had the least percentage reduction in APTI values. While *Tectona grandis*, *Acacia nilotica*, and *Cassia fistula* found more sensitive as they had the higher percentage reduction in APTI values.

However, some of the researchers found higher APTI values in the polluted environment as compared to the controlled environment [37]. This could be due to different environmental conditions. Moreover, the sensitivity of a plant species varies from area to area as they behave different atmospheric conditions [38] could be a reason. The study supports the results which other researchers also found that *Azadirachta indica*, as an intermediately tolerant and *Tectona grandis* as sensitive species towards air pollution. [39, 40].

Between the ten plants species considered for experimental analysis, the order of plant species tolerant to air pollution with the percentage change in APTI values is as follows:

Alstonia scholaris (6.6%)>*Tamarindus indica* (8.8%)>*Azadirachta indica* (10.3%)>*Moringa pterygosperma* (11.9%)>*Mangifera indica* (13.9%)>*Bahunia variegata* (14.3%)>*Annona squamosa* (18.7%)>*Cassia fistula* (20.7%)>*Acacia nilotica* (27.4%)>*Tectona grandis* (45.5%)

Tolerant plant species can be used in Greenbelt development, as they tend to serve as barriers and act as a sink for air pollutants. These plant species can play a significant role along the city roadside, traffic islands as well as in industrial areas to control the level of air pollution, while sensitive plant species can act as bioindicators of air pollution. These particular plant species help to mitigate environmental air pollution.

Correlation matrix interpretation

The correlation coefficient values of biochemical parameters viz., total chlorophyll, ascorbic acid, relative water content, and leaf extract pH with air pollution tolerance index of selected plant species are presented in table 2, and 3. At control as well as polluted sites, APTI showed a positive correlation with pH, RWC, and Ascorbic acid but negative correlation with total chlorophyll. It is revealed from the study that ascorbic acid content and RWC are the most significant factors of the leaves, which determines the tolerance of same species at different locations.

CONCLUSION

The results of the present study provide information that the vehicular pollution of the Thane city is creating trouble not for all organisms but also for the plants. Plants in urban areas are continuously exposed to air pollutants, ensuing accumulation of pollutants and their integration into their system, resulting in changing the nature of leaf and its tolerance and sensitivity. This sensitivity is measured through various biochemical parameters and finally through APTI. Since this, determination of APTI is more appropriate than before. The plant that shows higher index value is tolerant to air pollution and can be used as a sink to control pollution. The plants with lower index value seemed to be sensitive and used as bioindicator to recognise levels of air pollution. Thus, trees can utilize as tolerant or sensitive towards air pollution.

Air pollution in the urban region is on the rise and augmented significantly due to increased vehicular pollution, urbanization and fast increase in small-scale industries. Existing quantity of air quality improvement due to pollution removal from urban trees is although insignificant, it can improve by improving urban tree canopy cover via Greenbelt development and urban forest development initiatives. Thus, this study provides useful insights for selecting tolerant and sensitive species for future planning and Greenbelt development in urban areas.

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AUTHOR CONTRIBUTION

These authors contributed equally to this work

CONFLICTS OF INTERESTS

All authors have none to declare

REFERENCES

1. Hamraz HA, Sadeghi-Niaraki, Omati M, Noori N. GIS-based air pollution monitoring using static stations and mobile sensor in Tehran/Iran. *Int J Sci Res Environ Sci* 2014;2:435-48.
2. Khureshi SGD. Air pollution tolerance indices (APTI) of some plants around Ponnur, Guntur (Dist.). *Int J Eng Res Tech* 2013;2:2366-75.
3. Feder WA. Plants as bioassay systems for monitoring atmospheric pollutants. *Environ Health Perspect* 1978;27:139-47.
4. Hasegawa YH, Uchida S, Asada T, Katsube, Oyabu T. Investigation of air pollution purification process by a bioelectrical potential analysis. *Proceedings Indoor Air Health Prospect* 2002;27:139-47.
5. Simon E, Simini M, DecoTeau DR. Using plants to monitor air pollution: Purdue Univ West Lafayette, Indiana; 2006. p. 47907.
6. Chauhan A. Photosynthetic pigment changes in some selected trees induced by automobile exhaust in Dehradun, Uttarakhand. *J New York Sci* 2010;3:45-51.
7. Dohmen GP, Loppers A, Langebartels C. Biochemical response of *Norway spruce* towards 14 mo exposure to ozone and acidmist, the effect on an amino acid, glutathione and polyamine titers. *Environ Pollut* 1990;64:375-83.
8. Hoque MA, Banu MNA, Oluma E. Exogenous proline and glycine betaine increase NaCl-induced ascorbate-glythione cycleenzyme activities and praline improves salt tolerances more than glycine betaine in tobacco bright yellow-2 suspension cultural cells. *J Plant Physiol* 2007;164:1457-68.
9. Flowers MD, Fiscus EL, Burkey KO. Photosynthesis, chlorophyll fluorescence and yield of snap bean (*Phaseolus vulgaris* L.) genotypes differing in sensitivity to ozone. *Environ Exp Bot* 2007;61:190-8.
10. Klumpp G, Furlan CM, Domingos M. Response of stress indicators and growth parameters of *Tibuchina Pulchra Cogn* exposed to air and soil pollution near the industrial complex of Cubatao, Brazil. *Sci Total Environ* 2000;246:79-91.
11. Rao DN. Plant as a pollution-monitoring device. *Fertilizer News* 1979;24:26-8.
12. Kotecha MK, Naik, Abraham L. Study of the air pollution tolerable index (APTI) and distribution pattern by using importance value index (IVI) of plants in the disturbed and undisturbed locality around Anand city (India). *Carpathian J Earth Environ Sci* 2014;9:163-9.
13. Vinita P, Tripathi BD, Mishra VK. Evaluation of anticipated performance index of some tree species for green belt development to mitigate traffic generated noise. *Urban Forestry Urban Greening* 2011;10:61-6.
14. Cooke T. The flora of the presidency of Bombay. Vol. 1, 2, 3. London: Taylor and Francis; 1908.
15. Arnon DI. Copper enzymes in isolated chloroplast polyphenol oxidase in *Beta vulgaris*. *Plant Physiol* 1949;24:1-15.
16. Barr HD, Weatherley PE. A re-examination of the relative turgidity technique for estimating water deficits in leaves. *Aust J Biol Sci* 1962;15:413-28.
17. Bajaj KL, Kaur G. Spectrophotometric determination of l-ascorbic acid in vegetables and fruits. *Analyst* 1981;106:117-20.
18. Singh SK, Rao DN. Evaluation of plants for their tolerance to air pollution. *Proceedings Int Symp on air pollution control IIT Delhi*; 1983. p. 218-24.
19. Seyyednjad SM. Air pollution tolerance indices of some plants around the industrial zone in the south of Iran. *Asian J Biol Sci* 2011;4:300-5.
20. Katiyar V, Dubey PS. Sulphur dioxide sensitivity on two stage of leaf development in few tropical tree species. *Indian J Environ Toxicol* 2001;11:78-81.
21. Ninave SY, Chaudhari PR, Gajghate DG, Tarar JL. Foliar biochemical features of the plant as indicators of air pollution. *Bull Environ Contam Toxicol* 2001;67:133-40.
22. Anthony P. Dust from walking tracks, impact on rainforest leaves on epiphylls. Co-operative Res Center for Tropical Rainforest Eco and Manage, Australia; 2001.
23. Tripathi AK, Gautam M. Biochemical parameters of plants as indicators of air pollution. *J Environ Biol* 2007;28:127-32.
24. Mir QA, Yazdani T, Kumar A, Narain K, Yunus M. Vehicular population and pigment content of certain avenue trees. *Pollut Res* 2008;27:59-63.
25. Keller T, Schwager H. Air pollution and ascorbic acid. *Eur J For Pathol* 1977;7:338-50.
26. Conklin PL. Recent advances in the role and biosynthesis of ascorbic acid in plants. *Plant Cell Environ* 2001;24:383-94.
27. Pasqualini S, Batini P, Ederli L. Effects of short-term ozone fumigation on tobacco plants: Response of the scavenging system and expression of the glutathione reductase. *Plant Cell Environ* 2001;24:245-52.
28. Chaudhary CS, Rao DN. Study of some factors in plants controlling their susceptibility to sulphur dioxide pollution. *Proceedings Indian Natl Sci Academy-Part B* 1977;46:236-41.

29. Varshney SRK, Varshney CK. Effects of sulphur dioxide on ascorbic acid in crop plants. *Environ Pollut* 1984;35:285-90.
 30. Masuch G, Kicinski HC, Kettrup A, Boss KS. Single and combined effects of continuous and discontinuous O₃ and SO₂ emission on *Norway spruce* needles. Historical and cytological changes. *Int J Environ Anal Chem* 1998;32:213-41.
 31. Agrawal S, Tiwari SL. Susceptibility level of few plants on the basis of air pollution tolerance Index. *Indian For* 1997;123:319-22.
 32. Dedio W. Water relations in wheat leaves as screening tests for drought resistance. *Canad J Pt Sci* 1975;55:369-78.
 33. Rao DN. Use of plants as indicators and monitors of SO₂ pollution. *Chem Age India* 1977;28:665-72.
 34. Scholz F, Reck S. Effects of acids on forest trees as measured by titration invitro inheritance of buffering capacity in *Picea-abies*. *Water, Air Soil Pollut* 1977;8:41-5.
 35. Yan Ju L, Hui D. Variation in air pollution tolerance index of the plant near a steel factory; Implication for landscape plant species selection for industrial areas. *WSEAS Trans Environ Dev* 2008;1:24-32.
 36. Thambavani S, Prathipa DV. Assessment of air quality through biomonitors of selected sites of dindigul town by air pollution tolerance index approach. *J Res Biol* 2012;2:193-9.
 37. Agbaire PO, Esiefarienrhe E. Air pollution tolerance indices (APTI) of some plants around otorogun gas plant in Delta state, Nigeria. *J Applied Sci Environ Manage* 2009;13:11-4.
 38. Raza SH, Murthy MSR, Ahmed A. Air pollution tolerance index of certain plants of Nacharam Industrial Area, Hyderabad. *Indian J Bot* 1988;11:91-5.
 39. Krishnaveni M, Durairaj S, Madhiyan P, Amsavalli L, Chandrasekar R. Impact of air pollution in plants near the thermal power plant, Mettur, Salem, Tamilnadu, India. *Int J Pharm Sci Rev Res* 2013;20:173-7.
 40. Krishnaveni M, Mangesh P. Air pollution tolerance index induced by biochemical components in plants. *Int J Pharm Pharm Sci* 2014;6:362-4.
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