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A comparative study for air pollution tolerance index of some terrestrial plant species

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ABSTRACT: Although water and land pollution are very dangerous, air pollution has its own peculiarities due to its transboundary dispersion of pollutants over the entire world. In any well planned urban set up, industrial pollution takes a back seat and vehicular emissions take precedence as the major cause of urban air pollution. In the present study, Air pollution tolerance index was calculated for various plant species growing at two sites Nagal village at Sahastradhara Road and the Clock Tower (the experimental site) of Dehradun city, India. The leaf samples were collected from 7 commonly present tree species. The results showed significant effects of various air pollutants on the vegetation in terms of four biochemical parameters analysed. Four physiological and biochemical parameters, which are leaf relative water content, Ascorbic acid content, total leaf chlorophyll content and leaf extract pH were used to compute the air pollution tolerance index values. Statistically significant difference was observed between control and experimental group for Ascorbic acid, $t(6)=-4.848, p=.003$. Paired t test for air pollution tolerance index between the two groups showed a statistically significant difference, $t(6) = -4.548$, $p=.004$. On the basis of air pollution tolerance index values for above mentioned seven tree species, *Eucalyptus globus* exhibited the highest degree of tolerance at all the sites followed by *Ficus religiosa* > *Mangifera indica* > *Polyalthia longifolia* > *Phyllanthus emblica* > *Citrus limon* > *Lantana camara*.

Keywords: *Air pollution tolerance index (APTI); Ascorbic acid content (AAC); Leaf extract pH; Relative water content (RWC); Total leaf chlorophyll content (TLC)*

INTRODUCTION

Pollution is mainly caused due to human activities like dumping of waste products, incomplete combustion of fossil fuels, burning of firewood or other harmful secondary products which are harmful to living organisms. Air is the most important resource for sustenance of life and all organisms need clean air for their healthy growth and development. But today this air has become highly polluted due to industrialization and urbanisation. A major contributor to the air pollution problem is the transport sector which contributes through the vehicular emission. Air pollution can be defined as introduction of foreign particles into the atmosphere in the form of chemicals, particulate matter or biological materials that cause harm or discomfort to humans, or other living organisms or damage the environment (Anonymous, 2008). Various studies on air pollution have been done (Khanna *et al.*, 2013; Khanna *et al.*, 2014). Plants are an integral basis for all ecosystems and also most likely to be affected by air borne pollution which are identified as the organisms with most potential to receive impacts from ambient air pollution. Since plants are stationary and continuously exposed to chemical pollutants from the surrounding atmosphere, air pollution injury to plants is proportional to the intensity of the pollution. Also, the effects are most often apparent on the leaves which are usually the most abundant and most obvious primary receptors

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of large number of air pollutants. Bio-monitoring of plants is an important tool to evaluate the impact of air pollution. Hence, in latest years, urban vegetation became increasingly important not only for social reasons but mostly for affecting local and regional air quality. Sensitivity and response of plants to air pollutants is variable. The plant species which are more sensitive act as biological indicators of air pollution (Lakshmi *et al.*, 2009).The response of plants to air pollution at physiological and biochemical levels can be understood by analyzing Air pollution tolerance index (APTI). It is a species dependent plant attribute which expresses the inherent ability of plant to encounter stress arising from pollution. The APTI determination provides a reliable method for screening large number of plants with respect to their susceptibility to air pollutants. APTI is calculated by using four biochemical parameters ascorbic acid, chlorophyll, leaf extract pH and relative water content in leaf samples. Species having higher APTI value are more tolerant to air pollution than those having lower APTI value. Species having lower APTI value may act as bio-indicators of pollution. The present study has been undertaken to determine the effects of ambient particulate and gaseous pollutants on relative humidity, pH, total chlorophyll, ascorbic acid and to make a comparative study of air pollution tolerance of some common terrestrial plant species of Dehradun area in and around Clock Tower (experimental site) and Nagal village (control site), Dehradun.

This study has been performed in Dehradun District is situated in north west of Uttarakhand State of India in during the period of 2014.

MATERIALS AND METHODS

Area of Study

Dehradun District is situated in NW corner of Uttarakhand state and extends from N Latitude 29^0 58’ to 31^0 02’ 30" and E Longitude 77^0 34’ 45" to 78^0 18’ 30". It falls in Survey of India Topo sheets Nos. 53E, F, G, J and K. The district is bounded by Uttarkashi district on the north, Tehri Garhwal and Pauri Garhwal districts on the east and Saharanpur district (UP) on the south. Its western boundary adjoins Sirmour district of Himachal Pradesh separated by Rivers Tons and Yamuna. Doon Valley is bounded by the Lesser Himalayan foot hills to the north-east, the Shiwalik Hills to the south-west, the Yamuna River to the north-west and the Ganga to the south-east. The saucer shaped Doon valley covers an area of approximately 1500 Km along with an average annual rainfall of about 2200 mm per year. The total area of Dehradun district is 3088 km ^{2} with an average altitude of 640 m above MSL. The present study was conducted during the period January’14 to April’14.

Sampling sites

Two sites were taken into account for the study of APTI (Fig. 1).

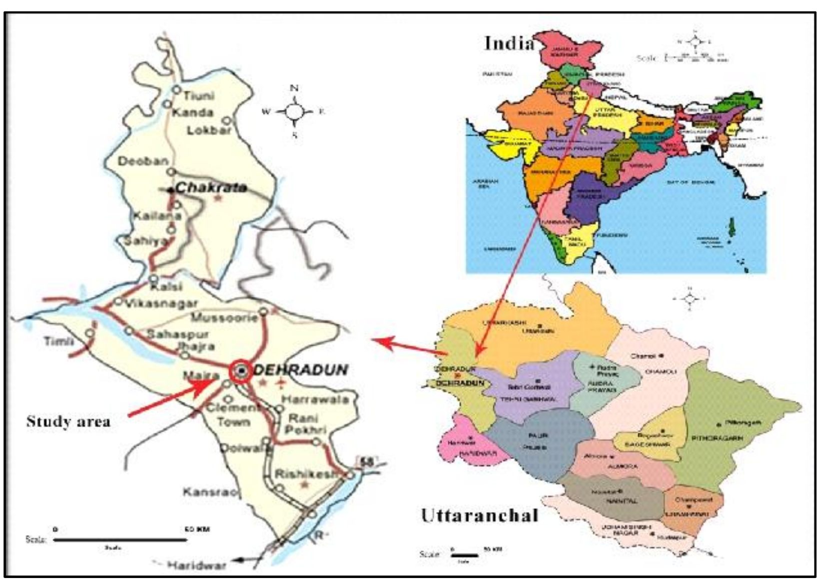

Fig. 1: Map showing the study area selected for APTI evaluation

Site-1 (Clock Tower): It is situated in the heart of the city which we have taken as experimental site.

Site- 2 (Nagal Village): It is our control site which is located on Sahastradhara Road, Dehradun, about 11 Kms away from experimental site (Clock Tower) where pollution level is almost very low and possesses very dense forest and vegetation.

Sampling Procedures

For experimental purpose, a total of seven dominant tree species i.e. *Ficus religosa*, *Eucalyptus* sp. (L.), *Phyllanthus emblica* L., *Mangifera indica*, *Polyalthia longifolia*, *Citrus limon* L. (Citrus) and *Lantana camera* L. were selected because of their presence at both the control and experimental sites. For investigation, leaves from top, middle and base canopy of plants were collected in forenoon between 07: 00 A.M and 10: 00 A.M. around 1-2 Kms of the area of the experimental site and the control site. Replicates of fully mature leaf samples of the plants were collected, put in polyethene bags and marked with masking tapes. These were immediately taken to the laboratory for analysis. Composite samples of eight leaves for each species were used for analysis. Care was taken to ensure all plants undergoing investigation had isoecological conditions with respect to light water, soil and pollutant exposure.

Methodology

The following physiological and biochemical parameters were analyzed: leaf RWC, ascorbic acid content (AAC), total leaf chlorophyll content (TLC) and pH of leaf extract. These were used to compute the APTI values for both the experimental and control site.

RWC was calculated using the formula as described by Singh (1977) below:

$$RWC = \frac{Fresh\ Weight(FW) - Dry\ Weight(DW)}{Turgid\ weight\ (TW) - Dry\ Weight\ (DW)} X\ 100$$

The fresh plants were immediately taken to the laboratory for determination of the leaf fresh weight in order to minimize water loss. Leaf samples were weighed immediately on a weighing balance to obtain the fresh weight (FW). The leaves were then immersed in water for 24 h (overnight), blotted dry with Whatman filter paper and weighed to obtain the turgid weight (TW). The leaves were finally dried in an oven for 48 h at 70°C and reweighed on the weighing balance to obtain the dry weight (DW).

TLC was obtained by weighing 1.0 g of each leaf sample and soaked in 20 ml of 50% acetone, then left for five days. 25 ml aliquot of extract was added to 50 ml diethyl ether in a separating funnel. For optical density, absorbance was taken at 645 nm on spectrophotometer (ELICO-1305) using ether as a reference. TLC was calculated thus:

Total chlorophyll in ether solution (mg/L) =
(7.12 x optical density at 660 nm + 16.8 x optical density at 645 nm) ÷ 10

The leaf extract pH was obtained by homogenizing 10 g of the fresh leaves in 20 ml of deionized water. This was filtered and the pH of leaf extract determined using a pH meter (ELICO-112) after allowing it to stabilize for 15 min and calibrated with buffer solution of pH 3 and 9.

AAC was measured using the indophenol acetic acid method. 1 g of the leaf sample was crushed and made up to 50 ml using distilled water and 10 ml of acetic acid. A solution of 0.01% indophenol was made and then titrated with the sample.

APTI was calculated using the following standard method (Singh and Rao, 1983).

$$APTI = \frac{A(T + P) + R}{10}$$

(Where A is the ascorbic acid in mg/g, T is the total chlorophyll in mg/g, P is pH of leaf sample and R is relative water content in mg/g).

RESULTS AND DISCUSSION

The mean values of all the four biochemical parameters for seven tree species at both the sites are given in Table 1. Percentage increment in relative water content, pH, total chlorophyll, ascorbic acid and APTI for all the tree species at both sites are shown in Table 2.

Relative Water Content

RWC of a leaf is the water present in it relative to its full turgidity. High water content within plant body helps to maintain its physiological balance under stress conditions such as exposure to air pollution when the transpiration rates are usually high. It also serves as

Table 1: Average values for biochemical parameters in leaves of different tree species

Tree species	Relative Water Content (%)		pH		Total chlorophyll (mg/g)		Ascorbic acid (mg/100 g)		Air Pollution Tolerant Index	
	Control	Experimental	Control	Experimental	Control	Experimental	Control	Experimental	Control	Experimental
Ficus religiosa	84.07 ± 0.43	84.60 ± 0.74	7.11 ± 0.00	5.72 ± 0.05	11.98 ± 0.11	13.17 ± 0.32	22.21 ± 0.52	22.68 ± 0.55	82.36 ± 61.43	85.45 ± 73.13
Mangifera indica	65.1 ± 0.39	70.10 ± 0.39	7.42 ± 0.00	4.32 ± 0.00	11.73 ± 0.58	14.11 ± 0.31	21.08 ± 0.28	21.95 ± 0.12	70.59 ± 45.94	80.52 ± 69.73
Polyalthia longifolia	67.17 ± 0.27	75.10 ± 0.39	7.41± 0.01	4.64 ± 0.05	12.00 ± 0.11	13.42 ± 0.18	20.07 ± 0.29	21.00 ± 0.18	68.17 ± 45.18	79.01 ± 69.65
Eucalyptus globus	94.97 ± 0.38	96.17 ± 0.27	8.10 ± 0.08	8.43 ± 0.14	14.02 ± 0.58	14.16 ± 0.53	23.09 ± 0.27	23.53 ± 0.25	88.85 ± 76.5	95.20 ± 83.0
Phyllanthus emblica	71.17 ± 0.27	72.35 ± 0.50	6.76 ± 0.02	6.85 ± 0.04	11.12 ± 0.25	11.39 ± 0.21	14.29 ± 0.29	15.38 ± 0.23	51.31 ± 40.93	57.88 ± 44.92
Lantana camara	39.25 ± 0.59	42.35 ± 0.50	4.53 ± 0.06	4.68 ± 0.02	16.08 ± 0.27	16.18 ± 0.28	3.96 ± 0.06	4.04 ± 0.03	16.30 ± 10.95	18.14 ± 10.89
Citrus limon	78.75 ± 0.42	77.9 ± 0.46	4.96 ± 0.01	4.88 ± 0.19	10.04 ± 0.08	10.14 ± 0.07	14.47 ± 0.30	15.05 ± 0.23	40.32 ± 25.80	43.57 ± 26.28

an indicator of drought resistance in plants. Due to the air pollution, there is reduction in transpiration rate and damage to the leaf engine that pulls water up from the roots (1-2 % of the total). Consequently, the plants neither bring minerals nor cool the leaf. Reduction in relative water content plant species is due to impact of pollutants on transpiration rate in leaves (Swami *et al.,* 2004). The highest value of average relative water content was noticed for *Eucalyptus globus* to be 94.97±0.38 at the control site and 96.17±0.27 at the experimental site while the least water content was observed for *Lantana camara i.e* 39.25±0.59 for the control site and 42.35 ± 0.50 for the experimental site. The most significant change in relative moisture content of the tree leaves from the experimental site and the control site was found in *Polyalthia longifolia* i.e. from 67.17% to 75.1% (Table 1). An increase of about 11.80% of relative water content in *Polyalthia longifolia* was observed during course of study (Table 2). Least change was found in *Ficus religiosa* i.e. from 84.07% to 84.60% (Table 1) where a reduction of about 0.63% was observed (Fig. 2). Bhattacharya *et al.* (2013) found higher Relative water content in the monsoon season. Das and Prasad (2010) observed high leaf RWC during rainy season, low in winter and least in summer season. Plants with high relative water content under polluted condition may be tolerant to pollutants.

Leaf extract pH

There are so many factors controlling tolerance in plants. Plants with lower pH are more susceptible, while those with pH around 7 are more tolerant. But in overall observation, most plants showed alkaline pH (Table 1). The most significant change in leaf extract pH of the tree leaves from the control site and the experimental site was found in *Mangifera indica* i.e from 7.42 to 4.32 respectively (Table 1). A reduction of about 41.77 % of pH was observed in *Mangifera indica* during course of study (Table 2). Least change was found in *Phyllanthus emblica* i.e. from 6.76 to 6.85 where a decrease of about 1.33 % was observed (Fig. 3). In monsoon, due to washing of leaves there was least dust accumulation whereas, in winter and summer dust accumulation is more which can cause dust particle dissolution in cell sap and increasing the pH (Katiyar, and Dubey, 2001). Plants with lower pH are more susceptible while those with pH around 7 are tolerant (Singh and Verma, 2007; Kumar and Nandini, 2013). The change in leaf extract might influence the stomatal

Table 2: Percentage increase decrease in values for biochemical parameters studies

Tree species	Relative Water Content (%)	pH	Total chlorophyll (mg/g)	Ascorbic acid (mg/100 g)	Air Pollution Tolerant Index
Ficus religiosa	0.63	19.5	9.93	2.11	3.75
Mangifera indica	7.68	41.77	20.28	4.12	14.06
Polyalthia longifolia	11.80	37.38	11.83	4.63	15.90
Eucalyptus globus	1.26	4.07	0.99	1.90	7.14
Phyllanthus emblica	1.65	1.33	2.42	7.62	12.80
Lantana camara	7.89	3.31	0.62	2.02	11.28
Citrus limon	1.07	1.61	0.99	4.00	8.06

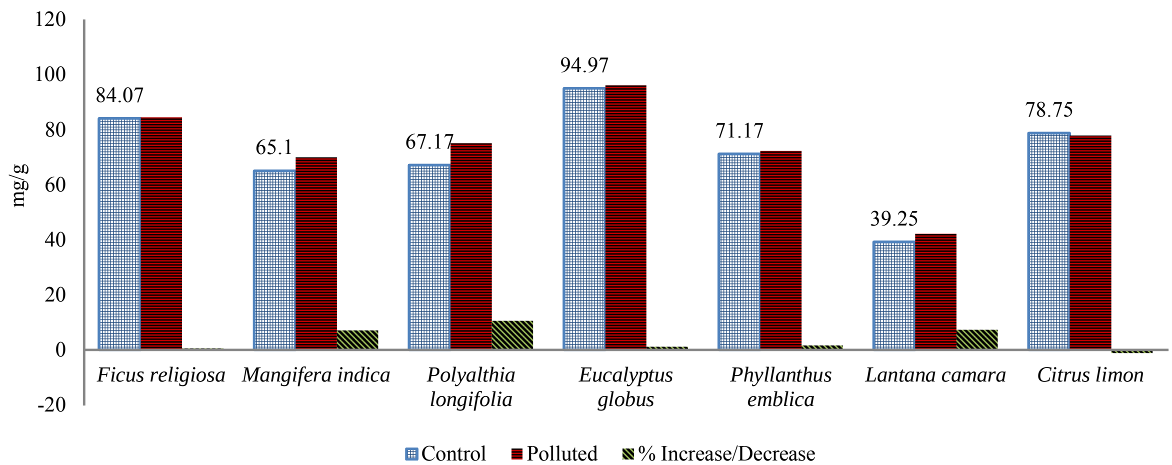

Fig. 2: Relative water content in different tree species at control and polluted site

sensitivity due to air pollution. Some species sampled exhibited a pH towards acidic side, which may be due to the presence of SO_2 and NO_x in the ambient air causing a change in pH of the leaf sap towards acidic site.

Total Chlorophyll

Chlorophyll is an index of productivity of plant (Raza and Murthy, 1988). Chlorophyll content of plants signifies its photosynthetic activity as well as the growth and development of biomass. It is well evident that chlorophyll content of plants varies from species to species; age of leaf and also with the pollution level as well as with other biotic and abiotic conditions (Abida, and Harikrishna, 2010). Whereas certain pollutants increase the total chlorophyll content other decrease it (Allen *et al.,* 1987).The most significant change in total chlorophyll content in the tree leaves from experimental site and control site was found in *Mangifera indica* i.e. from 11.73 mg/g to 14.11 mg/g (Table 1). An increase of about 20.28 % of total chlorophyll was observed in *Mangifera indica* during course of study (Table 2). Least change was found in *Lantana camara* from 16.08 mg/g to 16.18 mg/g where an increase of about 0.62 % was observed (Table 2 and Fig. 4). Higher levels of total chlorophyll observed may be due to its tolerance nature. Beg *et al.* (1990); Mir *et al.* (2008); Jyothi and Jaya (2010) also suggested that high levels of automobile pollution decreases chlorophyll content in higher plants near roadsides.

Ascorbic acid

Ascorbic acid is a strong reductant and it activates many physiological and defence mechanisms in plants. Its reducing power is directly proportional to its concentration (Raza and Murthy, 1988; Agbaire and Esiefarienrhe, 2009). However, its reducing activity is pH dependent, being more at higher pH levels because high pH may increase the efficiency of conversion of hexose sugar to ascorbic acid and is related to the tolerance to pollution (Liu and Ding, 2008). The result of the study revealed that *Eucalyptus globus* has the highest ascorbic acid

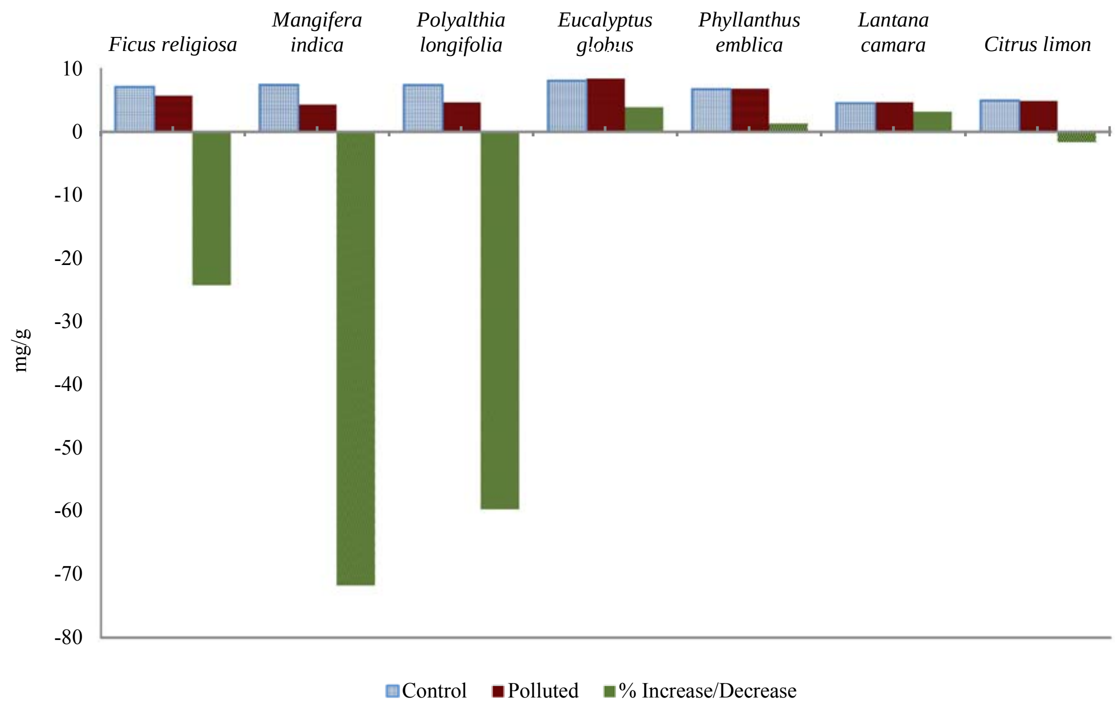

Fig. 3: pH of leaf extract in different tree species at control and polluted site

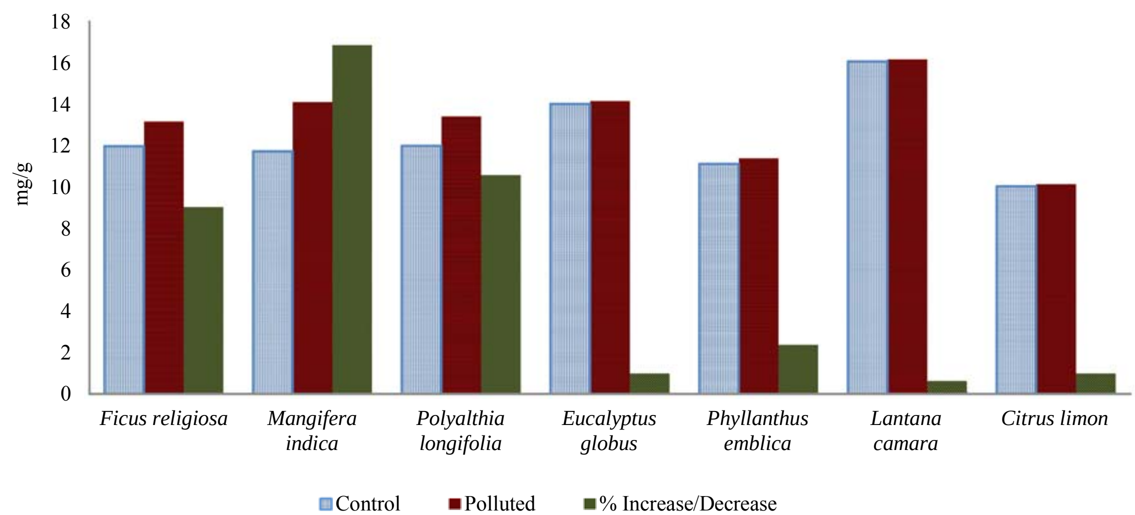

Fig. 4: Total chlorophyll content in different tree species at control and polluted site

content i.e. 23.09±0.27 at the control site and 23.53±.25 at the experimental site, while the least value of average ascorbic acid at both the sites was shown by *Lantana camara i.e. 3.96*±0.06 and 4.04±0.03. The most significant change in ascorbic acid content in the tree leaves from the experimental site and the control site was found in *Phyllanthus emblica* i.e. from 14.29 mg/100 g to 15.38 mg/100 g. An increase of about 7.62 % was observed during course of study (Table 2). Least change was found in *Eucalyptus globus* i.e. from 23.09 mg/100 g to 23.53 mg/100 g with an increase of about 1.90% (Table 2

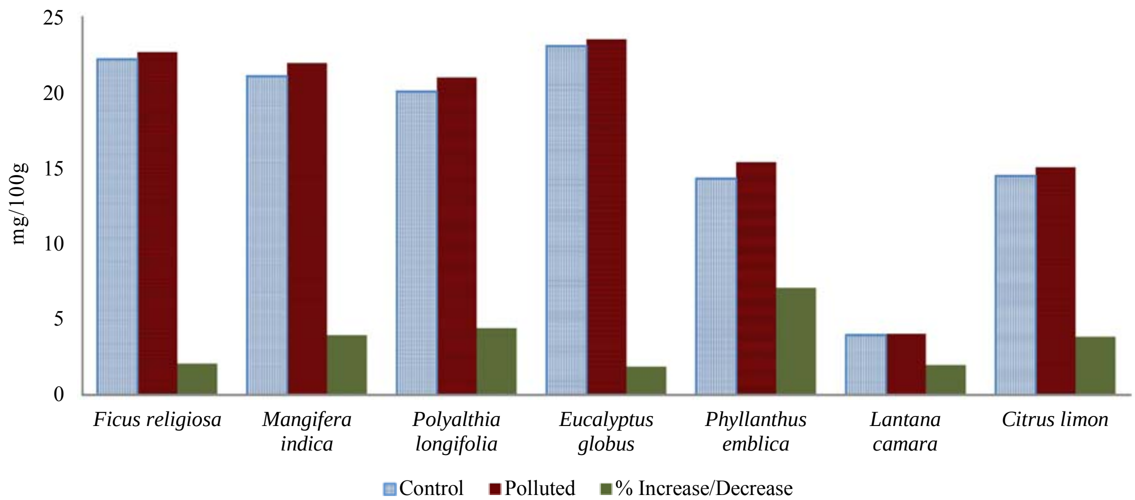

Fig. 5: Ascorbic acid content in different tree species at control and polluted site

Table 3: Various categories of tree species based on APTI

Tree species	APTI (mean value)	Tolerance
Eucalyptus globus	95.20	30-100 (Tolerant)
Ficus religiosa	85.45	30-100 (Tolerant)
Mangifera indica	80.52	30-100 (Tolerant)
Polyalthia longifolia	79.01	30-100 (Tolerant)
Phyllanthus emblica	57.88	30-100 (Tolerant)
Citrus limon	43.57	30-100 (Tolerant)
Lantana camara	18.14	17-29 (Intermediate)

Table 4: Air Pollution Tolerance Index (APTI)

Range of APTI	Tolerance
30-100	Tolerant
17-29	Intermediate
1-16	Sensitive
<1	Very Sensitive

and Fig. 5). Similar observations were made by Rao and Dubey (1991) who noticed ten plants susceptible to air pollution in Ujjain city. Similar results are found by Mishra and Pandey, (2011) at Tiruchirappalli city and Sirajuddin *et al*. (2012) at Ghaziabad. It was reported that plants like *Ficus religiosa, Ficus glomerata, Phyllanthus Embilca* and *Eucalyptus* with relatively low index value are generally sensitive to air pollutants and vice versa Singh *et al*. (1991) The long term, low-concentration exposures of air pollution produces harmful impacts on plant leaves without visible injury Joshi *et al*. (2009). Previous studies also showed the impact of air pollution on ascorbic acid, chlorophyll, leaf extract pH, and relative water content. Klump *et al*. (2000), Hoque *et al*. (2007) and Flowers *et al*. (2007).

In the present study, out of 7 species, 6 species showed APTI values ranging from 43.57 to 95.25 and found falls between the classification ranges of 30 to 100 and hence, were kept under tolerant species. *Lantana camara* was the only species having APTI equal to 18.14 (Table 3.), which falls in the range of 17-29 APTI and is designated as intermediate species. The variation of the APTI of tree leaves can be attributed to the variation in any of the four physiological factors which governs the computation of the index. This study revealed the highest average value of APTI by *Eucalyptus globus* (95.20) and the least value was shown by *Lantana camara* (18.14). The most significant change in APTI in the tree leaves was found in *Polyalthia longifolia* from 68.17 to 79.01 where an

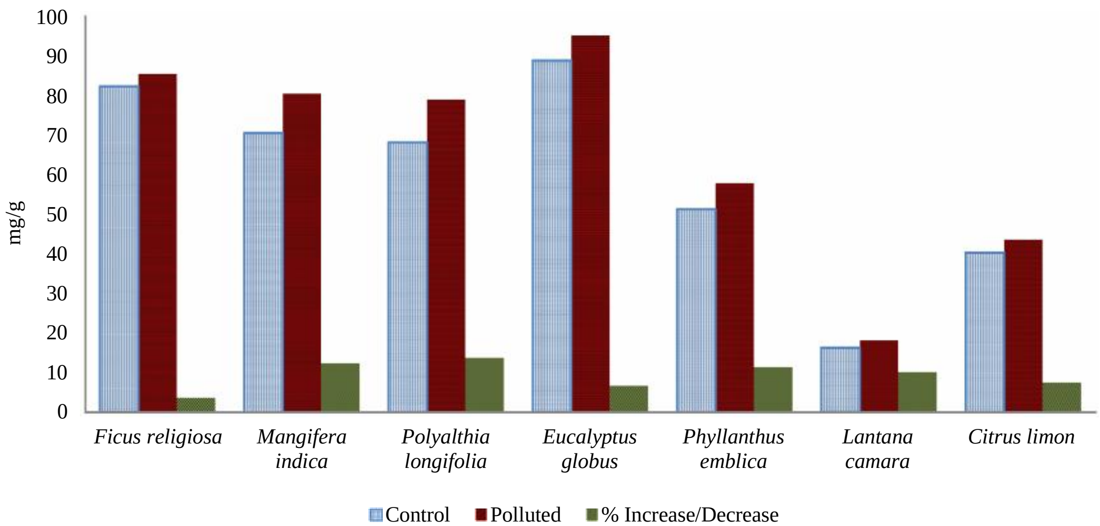

Fig. 6: Air Pollution Tolerance Index content in different tree species at control and polluted site

increase of about 15.90% was observed (Tables 1 and 2). Least change was found in *Ficus religiosa* from 82.36 to 85.45 where a reduction of about 3.75 % was observed (Table 2 and Fig. 6). Better tolerant species were *Eucalyptus globus*, *Ficus religiosa*, *Mangifera indica*, *Polyalthia longifolia*. Similar findings were also reported by several researchers (Beg *et al.*, 1990; Dwivedi and Tripathi, 2007; Agbaire and Esiefarienrhe, 2009; Chauhan, 2010; Adamsab *et al.*, 2011; Chandawat *et al*, 2011; Chouhan *et al*, 2012; Bhattacharya *et al*, 2013). The seven tree species can be ordered by the tolerance level as *Eucalyptus globus* which exhibited the highest degree of tolerance at all the sites, followed by *Ficus religiosa*, *Mangifera indica*, *Polyalthia longifolia*, *Phyllanthus emblica*, *Citrus limon* and *Lantana camara* (Table 3).

Statistical Analysis

Paired t-tests were carried out for all parameters between the control and the experimental group to find out if there were any statistically significant differences between the means of respective groups. Results of t-tests showed that there was no statistically significant difference in RWC, t(6)=-2.267, p=.064, pH, t(6)=1.751, p=.131 and Chorophyll, t(6)=-2.384,p=.054 between the control and the experimental group. However statistically significant difference was observed between control and experimental group for Ascorbic Acid, t (6) =-4.848, p=.003. Paired t-test for APTI between the two groups showed a statistically significant difference, t(6)= -4.548,p=.004.

CONCLUSION

Based on the percentage increase in APTI values calculated for the seven different plant species it can be concluded that *Eucalyptus globus* (95.20) is the most tolerant species followed by *Ficus religiosa* (85.45) and hence these species can be grown in the city road sides as well as in industrial zones for controlling the effect of air pollution. In conclusion, it appears that with increase in industrialization and urbanization, there is an increase threat of deforestation and hence such type of APTI determinations will gain significant importance for future planning. Firstly, this study revealed the impact of air pollution in terms of changes took place in various biochemical parameters of studied species. Secondly, this work threw light on the selection of air pollution tolerant species in terms of their APTI values. Thus this study provides useful information for selecting tolerant species for landscaping and urban heat island reduction and for future planning. The present study recommends various tree species for urban planting so that a wider usage of local, as well as exotic tree species, can be explored for controlling air born pollution in urban climate.

CONFLICT OF INTEREST

The authors declare that there are no conflicts of interests regarding the publication of this manuscript.

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