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RESEARCH ARTICLE

Air Pollution Tolerance Index of Some Tree Species of Pashupati and Budhanilkantha Area, Kathmandu

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Highlights

- APTI of 21 plants species of Pashupati and Budhanilkantha area were evaluated.
- Relative water content, total chlorophyll content, ascorbic acid and leaf extract pH were observed.
- Tolerant plant species have been identified from APTI and those could be grown in green belt development.

Abstract

The present study aims to assess the air pollution tolerant trees from the roadside of Pashupati area of Kathmandu exposed to vehicular air pollution. This area with heavy traffic density was considered as the polluted site and Budhanilkantha, lying at the outskirt of Kathmandu with very less traffic density was considered as the less-polluted site and was selected as the control site of the study. Commonly available 21 roadside same tree species from both polluted and control sites were chosen. Air pollution tolerance index (APTI) values of the trees were calculated considering the biochemical parameters - relative water content, total leaf chlorophyll, ascorbic acid and leaf extract pH by using standard method. Significantly higher APTI values ($P \leq 0.05$) were obtained in Cinnamomum camphora, Ficus elastica, F. religiosa, F. benghalensis and Grevillea robusta indicating that they are tolerant tree species. Phyllanthus emblica and Schima wallichii were found to be sensitive tree species.

Key words: *Air Pollution Tolerance Index, Relative water content, leaf extract pH, chlorophyll content, ascorbic acid*

Introduction

Air pollution is the contamination of air by any chemical, physical or biological agents that modifies the natural characteristics of the atmosphere. Complex mixture of pollutants like air borne particulate matter (PM), heavy metals, nitrogen dioxide (NO_2), sulphur dioxide (SO_2), carbon monoxide (CO), ozone (O_3), benzene, uncombust hydrocarbons etc. contribute for the air pollutions. Long term exposure to these air suspended pollutants can cause harm or discomfort to human with different diseases such as respiratory, cardiovascular, neuropsychiatric complications, cancer and even death (Ghorani-Azam *et al*. 2016). Air pollution also has adverse impacts on biodiversity, infrastructure, cultural heritage and the natural climate system (Pradhan 2012).

Trees are stationary and are continuously exposed to the air pollutants. Plants which are growing along roadsides are exposed to many pollutants emitted from motor vehicles such as suspended particulate matters, NO_2, SO_2, CO, heavy metals, benzene, smoke, dust and soot particles. These air pollutants may alter the physiological process of plants, thereby affecting the growth of plants (Jitin & Jain 2014).

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The primary receptor of air pollutants are leaves of the plants. The leaves provide large surface area for absorption and accumulation and hence act as a sink to accumulate pollutants (Liu & Ding 2008). The effects of pollutants are most apparent on leaves showing direct harmful impact on them (Lohe *et al*. 2015). Hence, leaves are generally used to analyze the sensitivity of plants to air pollutants because of its absorbance of largest amount of air pollutants. The leaves of roadside plants may act as stressors for pollutants as they are in direct contact with air pollutants, hence the plant leaves have been advocated for examination to access their ability for absorption and/or adsorption of pollutants (Sharma *et al*. 2007). Plants are further classified as tolerant and sensitive plants. Tolerant plants can thrive in polluted environment and help in cleaning the various sources of man-made pollution but the sensitive plants cannot withstand pollutants and hence can be used as indicator. The efficiency of tolerant plants in absorbing pollutants is such that it can produce pockets of clean air (Gilbert 1968). Thus, these plants act as the scavengers of air pollutants as they are the initial acceptors of air pollution (Mahecha *et al*. 2013). Hence, such tolerant trees can play a major role in improving air quality by exchanging gases as they act as a sink of the air pollutants which can reduce the concentration of pollutants in air and help in mitigating air pollution (Prajapati & Tripathi 2008).

Air pollution tolerance index (APTI) is measured by using four parameters such as relative water content (RWC), total chlorophyll content (Tchl), leaf extract pH and ascorbic acid content (AA) in leaves to ascertain the response of plants bio-chemically and physiologically (Singh & Verma 2007). Higher APTI values indicates more tolerance of plants to air pollution than those with low APTI value. Hence, APTI assessment of the trees is an important tool for evaluating plants' response to air pollutants. The value of APTI is obtained. This study was mainly designed to investigate the impact of air pollutants (especially in high traffic areas) on physiological parameters of road side trees. Hence Pasupati area, where a small patch of forest remains are present with nearly 8,600 vehicles per day are reported to be plying around it (unpublished data of Traffic police, Gaushala) and Budhanilkantha area with comparatively less vehicular traffic at the base of Shivapuri-Nagrjune national park were selected for this study.

Materials and Methods

Field experiments were conducted in the periphery of Pashupatinath and Budhanilkantha (Narayanthan) area of Kathmandu valley from November 2018 to January 2019. Pashupati was considered as polluted site because of more vehicular movement, and Budhanilkantha (Narayanthan) was considered as control sites because of less vehicular movement and less heavy metal concentrations in ambient air (Shakya *et al*. 2012).

The tree species were identified with the help of literatures and experts. Fresh leaves of each plant were collected in winter season from both the polluted and the control sites. Five trees of each species were selected at each site for the study. Five replicates of fully mature leaves of each individual plants were collected from above 3m height of all 21 plants species in morning and immediately brought to the laboratory. In the laboratory, first of all the loose dust particles accumulated on leaf surface was cleaned by removing it with fine brush. The fresh weight of leaves was taken immediately upon getting to the laboratory. The leaf samples were then analyzed for relative water content, total chlorophyll content, leaf extract pH, and ascorbic acid content.

Relative leaf water content (RWC)

RWC was calculated as described by Turner (1981). Fresh leaves were collected and fresh weight was recorded. The leaves were then dipped in water over night and then weighed to get the turgid weight. The leaves were then dried in an oven at 70°C for 24 h and reweighed to obtain the dry weight. Leaf relative water content was calculated using following formula:

$$\text{Relative water content (\%)} = \{(F-D)/(T-D)\} \times 100$$

F = Fresh weight of leaves (g)

D = Dry weight of leaves (g)

T = Turgid weight of leaves (g)

Estimation of chlorophyll (Tchl)

Chlorophyll content was measured according to protocol of Barnes *et al*. (1992) using DMSO solvent for extraction of chlorophyll. 0.05g fresh weight (FW) of leaves was placed in 5mL of DMSO solvent and then incubated in a water bath at 60-65°C for an hour. The extract was filtered after cooling and then the absorbance in the filtrate was measured at 665 nm and 648 nm using Atomic absorption Spectrophotometer (Model No. 31). Chlorophyll content in the leaves was calculated according to the formulae given by Barnes *et al* (1992).

$$\text{Chlorophyll a (mg/g F.W)} = (14.85\times A_{665} - 5.14\times A_{648}) \quad (1)$$

$$\text{Chlorophyll b (mg/g F.W)} = (25.48\times A_{648} - 7.36\times A_{665}) \quad (2)$$

$$\text{Total chlorophyll (mg/g F.W)} = (7.49\times A_{665} + 20.34\times A_{648}) \quad (3)$$

Ascorbic acid content (AA)

Ascorbic acid content is measured by the spectrophotometric method of Bajaj & Kaur (1981). Fresh leaf samples (1g) was taken in a test tube and then 4 mL of oxalic acid-EDTA, 1 mL of Orthophosphoric acid, 1 mL of sulfuric acid, 2 mL of ammonium molybdate solution and 2 mL of distilled water were added to it. The solution was allowed to rest for about 15 minutes and then the clear solution from the tube was taken for absorbance at 760 nm using a Spectrophotometer (Model No. 31). The concentration of ascorbic acid in the leaf was measured using a standard graph having absorbance and concentrations of ascorbic acid, which was prepared using the same procedure.

Leaf extract pH

Leaf extract pH was determined according to Datta & Sinha – Ray (1995). 5 g of fresh leaves were washed with distilled water and then crushed and homogenized with 25 mL of distilled water using mortar and pestle. pH of the leaf extract filtrate was measured with the help of pH meter (Model No. 10).

Air pollution tolerance index (APTI)

APTI values of plants was calculated using the equation given by Datta & Sinha – Ray (1995).

$$\text{APTI} = A\,(T + P) + R / 10$$

Where, A =Ascorbic Acid Content of leaf (mg/g)

P = pH of leaf extract

R = Relative Water Content of leaf (%)

T = Total Chlorophyll level of leaf extract (mg/g)

Statistical analysis

The quantitative data obtained from the above experiments were statistically analyzed by using SPSS version 16.0. To understand the significant differences among the different biochemical parameters of the study sites, Paired t-test was applied.

Results

The results of Air pollution tolerance index (APTI) of different trees, found both in Pashupati area (Polluted sites) and Narayanthan areas (control site) , along with its physiological parameters like relative water content (RWC), total chlorophyll content (Tchl), leaf extract pH and Ascorbic acid (AA) are given in Table 1 and 2. Increase or decreases in each parameter are given in Table 3. Descriptions of each parameter are given below.

Relative water content (RWC)

Highest value of average relative water content was noticed in *Ficus elastica* at the polluted site (Table 1) and in *Ficus auriculata* at the control site (Table 2) while the least water content was observed in *Phyllanthus emblica* from the both polluted site and control site. There was increase in relative water content in almost all tree species in Pashupati area than in control

site. Significant increase in RWC was observed in *Cinnamomum camphora, Ficus elastic, Ficus benghalensis, Ficus religiosa, Nyctanthes arbortristis and Pyrus pashia*. Highest increase in relative water content in the tree in the polluted site was recorded in *Ficus religiosa* (Table 3).

Total chlorophyll content (Tchl)

Cinnamomum camphora showed the highest value of average total chlorophyll content in polluted as well as in control site (Table 1 and 2). The lowest average value of total Chlorophyll content was observed in *Schima wallichii* (0.09 ± 0.01) mg/g from the polluted site (Table 1) and in *Nyctanthes arbor-tristis* (0.11 ± 0.02) mg/g from the control site (Table 2). There was decrease in Tchl in the tree leaves at polluted sites than in control and was found to be significant in many species (Table 3). Highest decrease in Tchl in the tree leaves was recorded in *Psidium guajava* and was followed by *Phyllanthus emblica* (Table 3).

Ascorbic acid (AA) content

Among studied plants high ascorbic acid content was found in *Ficus elastica* and *Cinnamomum camphora* in polluted site (Table 1). But the tree species such as *Phyllanthus emblica*, *Schima wallichii*, *Ziziphus incurva* had low ascorbic acid content in polluted sites (Table 1). Similarly, in control site the ascorbic acid content was found to be high in *Ficus elastica* and *Ficus benghalensis* and low in *Schima wallichii* and *Phyllanthus emblica* (Table 2). There was increase in AA in all tree leaves in polluted sites than in control and was significant in *Ficus religiosa*, *Ficus elastica*, *Cinnamomum camphora*, *Ficus benghalensis* and *Nyctanthes arbor-tristis* (Table 3). Highest increase in AA content in polluted site was recorded in *Cinnamomum camphora*.

Leaf extract pH

Highest value of leaf extract pH was recorded in *Ficus elastica* whereas its lowest value was observed in *Schima wallichii* in polluted sites. In control site, minimum value of pH was recorded in *Araucaria araucana* and its maximum value was observed in *Ficus elastica* (Table 2). Decrease in leaf extract pH was observed in polluted sites and was significant in *Elaeagnus parvifolia*, *Pyrus pashia, Myrsine semiserrata*, *Citrus grandis, Murraya exotica and Schima wallichii.* Highest decrease (%) in leaf extract pH was observed in *Schima wallichii* (Table 3).

Air pollution tolerance index (APTI)

The maximum and minimum APTI value observed in polluted site were 8.25 ± 0.82 and 4.47 ± 0.22 in *Ficus elastica* and *Phyllanthus emblica,* respectively (Table 1). Similarly, maximum and minimum APTI value recorded from control sites were 6.74 ± 0.85 and 3.77 ± 0.79 in *Ficus auriculata* and *Phyllanthus emblica,* respectively (Table 2). There was increase in APTI in all tree s in the polluted sites than in control and was significant in *Cinnamomum camphora, Ficus benghalensis, Ficus elastica, Ficus religiosa, Nyctanthes arbortristis* and *Pyrus pashia***.** The highest increase in APTI value at polluted sites was observed in the leaves of *Cinnamomum camphora* (Table 3).

Table 1 : *Different physiological parameters and APTI at Pashupati area (Polluted site)*

Plant species	RWC (%)	Tchl (mg/g)	Ascorbic acid (mg/g)	pH	APTI
Araucaria araucana	60.58 ± 5.94	0.2 ± 0.04	0.45 ± 0.08	3.93 ± 0.22	6.25 ±0.58
Celtis australis	55.99 ± 4.81	0.19 ± 0.03	0.42 ± 0.04	4.54 ± 0.12	5.8 ± 0.48
Cinnamomum camphora	72.73 ± 5.61	0.31 ± 0.02	0.83 ± 0.06	5.37 ± 0.05	7.74 ± 0.57
Citrus grandis	67.22 ± 5.73	0.13 ± 0.05	0.54 ± 0.07	4.36 ± 0.11	6.96 ± 0.57
Citrus sinensis	55.65 ± 3.70	0.16 ± 0.05	0.5 ± 0.02	4.39 ± 0.05	5.79 ± 0.36
Elaeagnus parvifolia	61.11 ± 3.54	0.17 ± 0.03	0.41 ± 0.06	4.37 ± 0.07	6.3 ± 0.35
Ficus auriculata	70.88 ± 11.12	0.29 ± 0.03	0.63 ± 0.13	5.66 ± 0.12	7.46 ± 1.11
Ficus benghalensis	70.83 ± 3.32	0.24 ± 0.04	0.75 ± 0.03	5.85 ± 0.10	7.54 ± 0.34
Ficus elastica	76.48 ± 8.34	0.25 ± 0.05	0.88 ± 0.03	6.61 ± 0.03	8.25 ± 0.82
Ficus religiosa	72.29 ± 12.93	0.26 ± 0.06	0.77 ± 0.05	5.57 ± 0.10	7.68 ± 1.28
Grevillea robusta	70.27 ± 8.83	0.28 ± 0.02	0.58 ± 0.12	5.21 ± 0.08	7.34 ± 0.93

Juniperus indica	59.65 ± 9.34	0.17 ± 0.04	0.48 ± 0.12	4.69 ± 0.08	6.2 ± 0.94
Murraya exotica	63.63 ± 3.34	0.21 ± 0.04	0.46 ± 0.08	4.59 ± 0.09	6.58 ± 0.33
Myrsine semiserrata	55.97 ± 7.10	0.18 ± 0.03	0.53 ± 0.07	3.61 ± 0.11	5.8 ± 0.71
Nyctanthes arbor-tristis	64.22 ± 6.60	0.1 ± 0.01	0.55 ± 0.07	4.28 ± 0.05	6.66 ± 0.65
Phyllanthus emblica	43.31 ± 2.17	0.1 ± 0.01	0.32 ± 0.04	4.13 ± 0.07	4.47 ± 0.22
Pinus roxburghii	55.16 ± 6.00	0.1 ± 0.02	0.52 ± 0.01	4.19 ± 0.16	5.74 ± 0.59
Psidium guajava	61.89 ± 3.61	0.09 ± 0.01	0.44 ± 0.05	5.34 ± 0.10	6.43 ± 0.37
Pyrus pashia	61.96 ± 3.78	0.19 ± 0.04	0.52 ± 0.03	3.58 ± 0.09	6.39 ± 0.37
Schima wallichii	50.13 ± 5.04	0.09 ± 0.01	0.33 ± 0.05	3.38 ± 0.11	5.13 ± 0.52
Ziziphus incurva	52.44 ± 8.17	0.18 ± 0.01	0.36 ± 0.02	5.31 ± 0.08	5.44 ± 0.81

Table 2: *Different physiological parameters and APTI at Budhanilkantha area (Control site)*

Plant species	RWC	Tchl	Ascorbic acid	pH	APTI
Araucaria araucana	57.36 ± 6.16	0.25 ± 0.02	0.38 ± 0.04	4.11 ± 0.05	5.9 ± 0.61
Celtis australis	49.6 ± 12.28	0.28 ± 0.07	0.39 ± 0.08	4.87 ± 0.15	5.16 ± 1.23
Cinnamomum camphora	58.62 ± 2.54	0.35 ± 0.03	0.51 ± 0.09	5.42 ± 0.08	6.15 ± 0.27
Citrus grandis	62.21 ± 3.49	0.18 ± 0.02	0.47 ± 0.02	5.01 ± 0.08	6.47 ± 0.35
Citrus sinensis	50.1 ± 7.04	0.21 ± 0.02	0.48 ± 0.07	4.45 ± 0.04	5.23 ± 0.72
Elaeagnus parvifolia	51.85 ± 8.61	0.23 ± 0.01	0.37 ± 0.11	4.98 ± 0.10	5.38 ± 0.84
Ficus auriculata	64.22 ± 8.48	0.3 ± 0.05	0.52 ± 0.03	5.86 ± 0.17	6.74 ± 0.85
Ficus benghalensis	59.64 ± 7.64	0.31 ± 0.05	0.61 ± 0.1	5.9 ± 0.06	6.34 ± 0.71
Ficus elastica	61.48 ± 4.41	0.3 ± 0.02	0.62 ± 0.10	6.69 ± 0.11	6.58 ± 0.45
Ficus religiosa	54.56 ± 4.52	0.3 ± 0.01	0.54 ± 0.02	5.68 ± 0.15	5.78 ± 0.45
Grevillea robusta	55.71 ± 10.48	0.3 ± 0.03	0.48 ± 0.05	5.25 ± 0.08	5.84 ± 1.04
Juniperus indica	54.41 ± 5.84	0.23 ± 0.02	0.43 ± 0.10	4.89 ± 0.18	5.66 ± 0.59
Murraya exotica	59.3 ± 10.42	0.26 ± 0.02	0.4 ± 0.07	5.01 ± 0.05	6.14 ± 1.03
Myrsine semiserrata	50.91 ± 9.17	0.26 ± 0.02	0.45 ± 0.14	4.24 ± 0.11	5.29 ± 0.94
Nyctanthes arbor-tristis	52.39 ± 5.97	0.11 ± 0.02	0.46 ± 0.02	4.37 ± 0.13	5.44 ± 0.59
Phyllanthus emblica	36.39 ± 7.97	0.15 ± 0.01	0.28 ± 0.03	4.29 ± 0.05	3.77 ± 0.79
Pinus roxburghii	50.07 ± 4.50	0.14 ± 0.01	0.42 ± 0.12	4.33 ± 0.06	5.19 ± 0.44
Psidium guajava	53.72 ± 8.45	0.24 ± 0.02	0.41 ± 0.03	5.41 ± 0.07	5.6 ± 0.85
Pyrus pashia	54.92 ± 4.47	0.24 ± 0.05	0.47 ± 0.03	4.17 ± 0.05	5.7 ± 0.44
Schima wallichii	43.6 ± 10.01	0.14 ± 0.01	0.27 ± 0.01	4.13 ± 0.13	4.47 ± 0.10
Ziziphus incurva	45.1 ± 6.73	0.2 ± 0.03	0.33 ± 0.08	5.39 ± 0.11	4.7 ± 0.66

Table 3: *Increase or decrease (%) in different physiological parameters at polluted sites in comparison to control sites*

Plant species	RWC (increase %)	Tchl (decrease %)	Ascorbic acid (increase %)	pH (decrease %)	APTI (increase %)
Araucaria araucana	5.32	2.45	15.56	4.38	0.77
Celtis australis	11.41	3.29*	7.14	6.78*	1.19

Cinnamomum camphora	19.4***	2.51	38.55**	0.92	10.63***
Citrus grandis	7.45	2.61	12.96	12.97***	2.39
Citrus sinensis	9.97	3.1*	4	1.35	1.75
Elaeagnus parvifolia	15.15	5.8**	9.76	12.25***	1.94
Ficus auriculata	9.4	0.39	17.46	3.41	1.21
Ficus benghalensis	15.8*	2.03	18.67*	0.85	5.01**
Ficus elastica	19.61**	2.4	29.55**	1.2	4.75**
Ficus religiosa	24.53*	1.86	29.87***	1.94	3.12*
Grevillea robusta	20.72	0.95	17.24	0.76	1.89
Juniperus indica	8.78	3.47*	10.42	4.09*	0.86
Murraya exotica	6.8	1.98	13.04	8.38***	0.76
Myrsine semiserrata	9.04	3.59*	15.09	14.86***	1.26
Nyctanthes arbor-tristis	18.42*	1.31	16.36*	2.06	3.43*
Phyllanthus emblica	15.98	8.72***	12.5	3.73**	1.87
Pinus roxburghii	9.23	5.9**	19.23	3.23	1.36
Psidium guajava	13.2	9.53***	6.82	1.29	2.35
Pyrus pashia	11.36*	1.27	9.62	14.15***	3.38*
Schima wallichii	13.03	6.43**	18.18	18.16**	0.99
Ziziphus incurva	13.99	1.71	8.33	1.48	1.67

Significance level *denotes P = 0.05, **denotes P = 0.01 and ***denotes P = 0.001 obtained from the student T test.

Discussion

Relative water content (RWC)

RWC value was detected to be higher in all plant species in polluted site than in control site denotes that most of the studied plants in this study are drought resistant, as high relative water content favors drought resistance in plants (Dedio 1975). *Ficus elastica* scored maximum value of RWC indicating that this species has improved drought tolerant ability among all the studied plants. *Phyllanthus emblica* has shown less value of RWC, possibly due to the impact of pollutants on transpiration rate as has been suggested by Swami *et al.* (2004) who also found the depletion in RWC of some plant species in industrial sites. Under air polluted conditions, some plants lose water due to higher rate of transpiration, which may lead to dehydration. Relative water content in *Cinnamomum camphora, Ficus elastic, Ficus benghalensis, Ficus religiosa, Nyctanthes arbortristis* and *Pyrus pashia* increased significantly ($P \leq 0.05$) in polluted site than in control site. All these plants have thick cuticle, which possibly help them to check transpiration and maintain high RWC under contaminated condition. This might be the strategy of these plant species to withstand and survive in polluted environment.

Total chlorophyll content

Chlorophyll varied in different plant species in control and polluted sites. The pollution level changes the chlorophyll content of plants from species to species with the age of leaf (Katiyar & Dubey 2001). Total chlorophyll content in *Psidium guajava* and *Phyllanthus emblica* were found to be decreased in high amount whereas the total chlorophyll content in *Ficus auriculata* and *Cinnamomum camphora* was found to be decreased in few amounts. This less degradation of total chlorophyll observed in *Ficus auriculata* and *Cinnamomum camphora* may be due to the tolerance nature of these studied trees (Jyothi & Jaya 2010). Plants maintaining their chlorophyll under polluted conditions indicate that these plants are adapted to the air with the air pollutants and hence, these plants are said to be tolerant (Santosh *et al*. 2008). But, the plant species with the degradation of photosynthetic pigment has been widely utilized as an indicator of air pollution (Ninavenave *et al.* 2001). In present study the total chlorophyll

content in polluted sites were found to be less than in the control sites, indicating decrease in total chlorophyll in polluted sites. This result support the observation of Giri *et al*. (2013) as they have also reported the decreasing amount of chlorophyll in tree leaves of polluted sites than in the clean areas. Decrease in total chlorophyll might be related to heavy metal uptake from the dusty ambient air. Heavy metals like Cu have been reported to have detrimental effect on chlorophyll in lower plants (Chettri *et al*. 1998 and Shakya *et al*. 2008).

Ascorbic acid (AA) content

Ascorbic acid known to prevent the damaging effect of air pollutant in plant species and also plays a vital role in cell wall synthesis and cell division (Singh *et al*. 1991). The selected 21 tree species varied in their Ascorbic acid content from 0.32mg/g to 0.88mg/g in polluted site and 0.27mg/g to 0.62mg/g in control site indicating the higher amount of ascorbic acid in polluted site than in control site. Similar findings have been obtained by Kousar *et al*. (2014). Increase in ascorbic acid may be due to the increased rate of production of reactive oxygen species (ROS) during photo-oxidation of SO_2 to SO_3 or other pollutants (Tripathi & Gautam 2007). High amount of AA in polluted site may prevent the effects of air pollution in plant tissues (Begum & Harkrishna 2010). Generally, plant species with high ascorbic acid content are considered as resistant to air pollution while those with low ascorbic acid content as sensitive species (Varshney & Varshney 1984). In plants AA activate many physiological and defense mechanism for pollution tolerance (Conklin 2001). Among all the species, *Ficus religiosa* showed significantly higher amount ($p \leq 0.05$) of AA. Similarly significantly different value of AA in *Ficus elastica*, *Cinnamomum camphora*, *Nyctanthes arbor-tristis* and *Ficus benghalensis* showed that these are the plant species with high amount of AA in polluted site. The higher ascorbic acid content in the leaves of these trees might be due to its higher adaptive capacity to tolerate the stresses of air pollution, as suggested by Achakzai *et al*. (2017), than the other tree species with lower AA

Leaf extract pH

The pH value of leaf extract in polluted site was found to be low than in control site in all plant species. High value of leaf extract pH at control site and low value of leaf extract pH at polluted site may be due to high level of pollution at the polluted sites. At control site high pH might have assisted to have the toleration capacity of plants towards air pollutants by increasing the rate of conversion of hexose sugar to ascorbic acid, whereas lower pH at polluted site might have declined the efficiency of conversion of hexose sugar to ascorbic acid thereby causing the reduction in photosynthesis rate (Joshi & Bora 2011). Thus, the plants with low pH value shows good correlation with sensitivity to air pollution and plants with high pH may be considered to be tolerant under polluted environment (Escobedo *et al*. 2008) as high pH is known to boost tolerance of plants to air pollution (Agarwal 1986). High pH of leaf extract in *Ficus elastica* even in polluted site indicates its tolerance nature. Acidic pH found in *Schima wallichii* showed that this is more susceptible to the pollutants in comparison to other plant species.

Air pollution tolerance index (APTI)

APTI values of different plant species responded differently to air pollution. Higher values of APTI found in all plants at polluted site than in control site indicate that these plants are tolerant. Rai *et al.* (2013) also found higher APTI values in the plants growing near industrial site than in those growing in non- industrial site. Among all the studied plants *Ficus elastica, Cinnamomum camphora, F. religiosa, F. benghalensis, F. auriculata*, *Grevillea robusta* showed high APTI value indicating that these plants are found to be tolerant to air pollution. The plants with the tolerance capacity act as important bio accumulators of air pollutants (Kumari & Deswal 2017). The APTI value in *Phyllanthus emblica* and *Schima wallichii* in both polluted as well as control site had minimum value. These plant species *(Phyllanthus emblica* and *Schima wallichii)* with less APTI value are sensitive to air pollution and can be used as bioindicator of air pollution as suggested by Lakshmi *et al*. (2008).

Conclusions

Based on the APTI values calculated for the twenty one different plant species from polluted and control sites, it was observed that *Ficus elastica, Cinnamomum camphora, Ficus religiosa, Ficus benghalensis, Ficus auriculata* and *Grevillea robusta* are the most tolerant tree species. Furthermore, based on APTI values it can be concluded that the tree species such as *Phyllanthus emblica* and *Schima wallichii* are highly sensitive to air pollution and can be used as bioindicator of air pollution. Hence, these tolerant plant species mentioned above can be suggested for green belt development in urban areas.

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