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Comparative Assessment of Air Pollution Tolerance Index of selected Tree Species of Bengaluru, India

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Abstract— Air Pollution Tolerance Index (APTI) was assessed for ten dominant tree species growing in different avenues of urban Bengaluru. The leaf samples were collected from Peenya – an industrial area; Koramangala - Residential area; Kamaraj road - commercial area in Shivajinagara and Bangalore University – a sensitive area were used to determine their Air Pollution Tolerance Index by analysing the ascorbic acid, chlorophyll, pH, and relative water contents. The tree species *Anacardium occidentale* (17.56) showed the highest APTI value followed by *Saraca asoca* (16.56), *Peltophorum pterocarpum* (12.85), *Spatodia campunalata* (12.91), *Cassia siamea* (11.65), *Michelia champaka* (10.76), *Pongamia pinnata* (9.39), *Albezia lebbeck* (7.83), *Delonix regia* (7.39) and *Muntingia calabura* (6.0). The tree species having higher APTI values are tolerant to air pollution and can be used as an effective indicator, pollution scavengers and thus, can be planted for pollution abatement in order to control and reduce environmental pollution to make the environment clean for healthy life.

Keywords— Air pollution, APTI, avenue, environment, trees, urban areas

I. INTRODUCTION

Urban tree species became increasingly important not only for social reasons but mostly for affecting local and regional air quality. Sensitivity and response of tree species to air pollutants is variable. It is a species dependent vegetation attribute which expresses the inherent ability of tree species to encounter stress arising from air pollution[1]. Tree species provides an enormous surface area, functioning efficiently to absorb pollutants in the air and serve as a sink for air pollutant[2][3]. Gaseous pollutants alone and in combination with particulate matter can cause numerous negative effects to the overall plant physiology[4] includes chemical transformation, accumulation and incorporation into the plant's metabolic system[3].

Air Pollution Tolerance Index (APTI) is used by landscapers to select tree species tolerant to air pollution[5]. Air pollution tolerance index has also been used to rank tree species in their order of tolerance to air pollution[6]. The tolerant species of tree species function as pollution "sink" and can be given priority for plantation program and the tree species with lower APTI value may act as bio-indicators of pollution[7]. The present study has been undertaken to determine the Air Pollution Tolerance Index of avenue tree species by analysing the ascorbic acid, chlorophyll, pH, and relative water contents.

II. STUDY AREA

The present study was carried out in urban Bengaluru which lies in the southeast of the south Indian state of Karnataka. Bengaluru is one of the fastest growing cites in India, with a population of 8.4 million[8] indicating a development of 800sq.km area; located 920m above mean sea level, has salubrious climate throughout the year with an annual rainfall of about 850-950mm. Bengaluru charm as a garden city may have diminished in the last three decades. However, some of the tree species that perhaps earned its name are still to be seen and cherished in Cuban Park, Lalbagh, IISc-Bangalore campus and Bangalore University-Jnanabharathi campus with rich vegetation[9].

Sampling sites: The tree species were sampled in four sites namely,

Site 1 – Peenya, Industrial area: Peenya is one of the oldest and biggest industrial areas in Asia. It houses small, medium and large scale industries. Peenya industrial estate was established in late 1970s by the Karnataka Small Industries Development Corporation as Stage 1, 2 and 3 and total extent of area is about 10 sq.Km. The samples collected for this study was taken from Stage 2.

Site 2 – Koramangala, Residential area: Koramangala is situated in the south-eastern part of Bangalore city and has an upscale locality with posh residency, wide, tree-lined boulevards and commercial structures. Koramangala is divided into 8 blocks and spread over approximately 1800 acres.

Site 3 - Kamraj road, Commercial area: Kamraj road is located near commercial street, Shivajinagara. The road is always loaded with heavy vehicular movement and is one of the busiest roads of Bengaluru city.

Site 4 - Bangalore University campus, Sensitive area: Bangalore University is the largest university in South-Asia. The university has two campuses: City campus: Central college and Jnana Bharathi campus. The Jnana Bharathi campus covers an area of 1100 acres with lush greenery. The campus also has a Bio-park covering an area of about 600 acres of land.

III. METHODOLOGY

Leaf samples were collected from 10 avenue tree species based on their dominance in the above mentioned four sites. Leaf samples were collected in triplicates of fully matured leaves and were immediately transferred to the laboratory for analysis. Leaf samples were preserved in a refrigerator for further examination. The following are the different methods used to determine APTI;

Leaf extract pH: 5g of the fresh leaves was homogenized in 10ml deionised water. This was then filtered and the pH of leaf extract was determined after calibrating pH meter-HI 98130 with buffer solution of pH 4, pH 7 and pH 9[10].

Total Chlorophyll Content (TCh): 3g of fresh leaves were blended and then extracted with 10 ml of 80% acetone and left for 15 minutes for thorough extraction. Then the liquid portion was poured into another text-tube and centrifuged at 2,500rpm for 3 minutes. The supernatant was then collected and the absorbance was then taken at 645nm and 663nm using Systronics UV-Vis spectrophotometer 118[10][11]. Calculations were made using the formula:

$$\text{Chlorophyll a} = 12.7_{DX663} - 2.69_{DX645} \times V/1000W \text{ mg/g}$$

$$\text{Chlorophyll b} = 22.9_{Dx645} - 4.68_{Dx663} \times V/1000W \text{ mg/g}$$

$$\text{TCh} = \text{Chlorophyll a + b mg/g}$$

Where,

Dx = Absorbance of the extract at the wavelength in nm,

V = total volume of the chlorophyll solution (ml), and

W = weight of the tissue extract (g).

Relative Water Content *of Leaf (RWC):* Fresh leaves were weighed and then then immersed in water over night, blotted dry and then weighed to get the turgid weight. Then, the leaves were dried overnight in an hot air oven at 70°C and reweighed to obtain the dry weight[10][12]. Calculations were made using the formula:

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

Where,

FW = Fresh weight, DW = Dry weight, and TW = Turgid weight.

Ascorbic Acid (AA) content: 1g of the leaf sample was measured into a test tube, 4ml of oxalic acid – EDTA extracting solution was added. Then 1ml of orthophosphoric acid followed by 1ml 5% tetraoxosulphate (vi) acid, 2ml of ammonium molybdate and then 3ml of water was added. The solution was then allowed to stand for 15 minutes, after which the absorbance at 760nm was measured with Systronics UV-Vis spectrophotometer 118. The concentration of ascorbic acid in the leaf samples were then extrapolated from a standard ascorbic acid curve[19].

Air Pollution Tolerance Index (APTI): The air pollution tolerance indices of twelve common plants were determined by the following standard method[10][1]. The formula of APTI is given as

$$APTI = [A(T+P) + R]/10$$

Where,

A = Ascorbic Acid content (mg/g), T = Total Chlorophyll content (mg/g), P = pH of leaf extract, and R = Relative Water content of leaf (%).

IV. RESULTS AND DISCUSSION

Air Pollution Tolerance Index (APTI) is assessed for 10 tree species collected from the different avenues of Urban Bengaluru (Table 1).

Table 1: Ten tree species and their sampling sites

Tree species	Sample site	Area classification
Peltophorum pterocarpum	Bangalore University	Sensitive area
Albizia lebbeck		
Saraca asoca		
Spathodia campanulata	Peenya	Industrial area
Michelia champaka		
Muntingia calabura		
Cassia siamea	Koramangala	Residential area
Pongamia pinnata		
Delonix regia	*Kamraj road*, Commercial street, Shivajinagar	Commercial area

The biochemical parameters analysed for APTI plays a significant role to determine resistivity and susceptibility of tree species. The analysis of biochemical parameters of tree species showed a marked variation between moderate, intermediate species and sensitive species (Table 2). The pH ranged between 5.8 to 6.3 in the intermediately tolerant species and 5.1 to 7.0 in sensitive plant species. Relative water content ranged between 62.3% to 88.2% in intermediately tolerant species and 38.6% to 67.6% in sensitive plant species. Chlorophyll content ranged between 8.37mg/g to 10.5mg/g in intermediately tolerant species and

5.34mg/g to 8.97mg/g in sensitive plants. Ascorbic acid content ranged between 4.61mg/g to 8.0mg/g in intermediately tolerant species and 1.0mg/g to 4.0mg/g in sensitive plant species.

Table 2: Air Pollution Tolerance Index (APTI) values and their collection site

Tree species	pH	Relative water content (%)	Ascor-bic Acid content (mg/g)	Total Chloro-phyll content (mg/g)	APTI
Peltophorum pterocarpum	6.7	67.2	4.0	8.64	12.85
Albezia lebbeck	6.4	66.6	1.0	5.34	7.83
Saraca asoca	6.3	88.2	4.61	10.5	16.56
Spathodia campunalata	6.13	69.3	4.0	8.84	12.91
Michelia champaka	7.0	67.6	3.0	6.34	10.76
Muntingia calabura	6.2	38.6	1.6	7.22	6.0
Cassia siamea	5.1	65.9	3.6	8.97	11.65
Pongamia pinnata	6.5	54.4	2.6	8.73	9.39
Delonix regia	6.2	57.3	1.42	5.55	7.39
Anacardium occidentale	5.8	62.3	8.0	8.37	17.56

pH of leaf extract: 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[1]. But in overall observation, most tree species showed alkaline pH except for *Cassia siamea* (5.1) and *Anacardium occidentale* (5.8) which exhibited a pH towards acidic side, which may be due to the presence of sulphur dioxide and oxides of nitrogen in the ambient air causing a change in pH of the leaf sap towards acidic and also because the two species were from residential area and commercial site, respectively. The pH for *Michelia champaka* (7.0), which was collected from Peenya industrial area showed resistant to air pollution. The remaining plant species showed less tolerance values, *Peltophorum pterocarpum* (6.7), *Pongamia pinnata* (6.5), *Albizia lebbeck* (6.4), *Saraca asoca* (6.3), *Muntingia calabura* (6.2), *Delonix regia* (6.2), *Spathodia campanulata* (6.13).

Relative Water Content (RWC): RWC of a leaf is the water present in it relative to its full turgidity. The highest value of average relative water content was noticed in *Saraca asoca* (88.2%) from sensitive area, which showed great tolerance to drought. The other species like *Spathodia campunalata* (69.3%), *Michelia champaka* (67.6%), *Peltophorum pterocarpum* (67.2), *Albezia Lebbeck* (66.6%), *Cassia siamea* (65.9%), *Anacardium occidentale* (62.3%), *Delonix regia* (57.3%) and *pongamia pinnata* (54.4%) showed medium tolerance. *Muntingia calabura* showed the least RWC, 38.6%. Thus, the high RWCs of tree species in an industrial site sample may be responsible for the normal function of plant biological processes[6]. Reduction in relative water content in tree species is due to impact of pollutants on transpiration rate in leaves. Increased RWC in a particular species improves its drought tolerance.

Ascorbic acid content: 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). It is an antioxidant that increases the resistance of plants against pollutant[13]. The analysis revealed that *Anacardium occidentale* (8.0mg/g) had the highest ascorbic acid content followed by *Saraca asoca* (4.6mg/g), *Peltophorum pterocarpum* (4.0mg/g), *Spathodia campunalata* (4.0mg/g), *Cassia siamea* (3.6mg/g), *Michelia champaka* (3.0mg/g) and *Pongamia pinnata* (2.6mg/g). The lowest ascorbic acid content was found in *Albizia lebbeck* (1 mg/g) followed by *Delonix regia* (1.4mg/g) and *Muntingia calabura* (1.6mg/g) which were from sensitive area, commercial area and residential areas, respectively. Tree species with high amount of ascorbic acid are considered to be tolerant to air pollutants[14].

Total Chlorophyll content: The tree species with the highest chlorophyll content was found in *Saraca asoca* (10.5 mg/g) followed by *Cassia siamea* (8.97 mg/g), *Spathodia campanulata* (8.84 mg/g), *Pongamiapinnata* (8.73 mg/g), *Peltophorum pterocarpum* (8.64 mg/g), *Anacardium occidentale* (8.37 mg/g), *Muntingia calabura* (7.22 mg/g), *Michelia champaka* (6.34 mg/g), and *Delonix regia* (5.55 mg/g). The least number of chlorophyll content was found in *Albezia lebbeck* (5.34 mg/g). The chlorophyll content decreases with increasing pollutant level because certain pollutants generally reduce the total chlorophyll content[15] and high amount of chlorophyll in plants increases air pollution tolerance[17]. The chlorophyll contents of plants varied with the pollution status of the area, as well as the tolerance and sensitivity of the plant species[16].

Air Pollution Tolerance Index (APTI): The APTI values calculated for each tree species are presented in Table 4. As given in Table 3, the APTI response of the ten tree species is given below:

Table 3: Classification of APTI values

APTI Value	Response
30 - 100	Tolerant
29 - 17	Intermediate
16 - 1	Sensitive
< 1	Very sensitive

Table 4: Tree species and their response towards air pollutants

Tree species	APTI value	Response
Peltophorum pterocarpum	12.85	Sensitive
Albizia lebbeck	7.83	Sensitive
Saraca asoca	16.56	Intermediate
Spathodia campanulata	12.91	Sensitive
Michelia champaka	10.76	Sensitive
Muntingia calabura	6.0	Sensitive
Cassia siamea	11.65	Sensitive
Pongamia pinnata	9.39	Sensitive
Delonix regia	7.39	Sensitive
Anacardium occidentale	17.56	Intermediate

Tree species that have higher APTI values are tolerant to air pollution, whereas plants with lower APTI values show generally low tolerance and sensitive to pollutants[20]. As given in Table 4, Tree species like *Anacardium occidentale* and *Saraca asoca* showed high APTI and intermediate response whereas the rest of the tree species showed a decrease in APTI value and sensitive response. The tree species with higher APTI are said to be resistant and also act as a bioaccumulator for air pollutants. Based on the result, the higher APTI of *Anacardium occidentale* and *Saraca asoca* proved to be the most resistant trees and can be grown along road sides as avenue trees.

Low APTI of the remaining plant species like *Delonix regia, Cassia siamea, Peltophorom pterocarpum, Albezia lebbeck, Spathodia campunalata, Michelia Champaka, Pongammia pinnata and Muntingia calabura*shows susceptibility towards dust pollution[9]. These trees being sensitive species act as bio-indicator of pollution as they integrate the effects of all environmental factors including interactions with air pollutants and climatic conditions[4].

Tree species with low APTI value like *Pongamia pinnata, Delonix regia, Saraca asoca and Cassia fistula* also showed similar APTI values[1]. The tolerant species of plants function as "sink" and therefore a number of environmental benefits can be desired by planting tolerant species in polluted areas. For this purpose, evaluation of plants with respect to their tolerance level to air pollution may be essential.

V. CONCLUSION AND FUTURE SCOPE

The tree species act as biological filters by removing large quantities of gaseous and particulates from the atmosphere. The study concluded that, the tree species having higher APTI value can be given priority for plantation program in newly urbanized areas and avenues of Urban Bengaluru; so as to reduce the stress of motorists at traffic junctions, effect of air pollution and make the environment clean for healthy life. And also, APTI determination are of importance because with increase urbanization and industrialization, there is increasing danger of deforestation due to air pollution and are therefore handing for landscaping. The results of these kinds of studies are expected to fulfil the gap to check the further degradation of environment and to provide pollution free environment to forthcoming generation.

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