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Evaluation of Air Pollution Tolerance Index (ATPI) of Selected Ornamental Tree Species of Bengaluru, India

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ABSTRACT

Urban air pollutants like particulate matter, sulphur dioxide, nitrogen oxides, ozone etc. can harm the plants but severely effects the human health. It can absorb through stomata and affects adversely its biochemical constituents and physiological process. The variation in biochemical parameters in the leaves can be used as indicators of air pollution for early diagnosis of stress or as a marker for physiological damage prior to the onset of visible injury symptoms. Tree species resistivity and susceptibility level to air pollution within avenues of Bangalore has been evaluated on the basis of Air Pollution Tolerance Index (APTI) value. Four parameters namely Leaf extract pH, Total Chlorophyll Content (TCh), Relative Water Content (RWC) of Leaf and Ascorbic Acid content were determined and APTI was computed. The tree species with higher APTI values like Samanea saman, Bougainvillea glabra, Tabubea argentia, Peltophorum pterocarpum, Bauhinia acuminata and Polyalthia longifolia were tolerant to air pollutants and can be used as effective indicators and pollution scavengers. The tree species having higher APTI value can be given priority for plantation program in newly urbanized areas and avenues of Bengaluru; effect of air pollution on stress and make the environment clean for healthy life.

Key words: *Pollutants, APTI, Nutrients, Ecological balance*

INTRODUCTION

In the present era, air pollution is one of the serious problems faced by the people globally due to its transboundary dispersion of pollutants over the entire world. One of the reasons is due to ambient environment of an urban area contaminated with several pollutants such as carbon monoxide, sulphur dioxide, oxides of nitrogen, heavy metals and the plants growing there would be exposed not only to one but too many pollutants and their different conditions. Trees play a very important role in monitoring and maintaining the ecological balance by actively participating in the cycling of nutrients and gases like carbon dioxide and also provide enormous leaf area for impingement, absorption and accumulation of air pollutants in order to reduce the pollution level in the ambient air environment[32].

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Air pollutions can directly affect plants via leaves or indirectly via soil acidification[31]. It has also been reported that when exposed to air pollutants, most of the plants experience physiological changes before exhibiting visible damage to leaves[15].

Pollutant gases like sulphur dioxide (SO_2), nitrogen oxides (NO_x) etc. are absorbed into the mesophyll of the leaves through stomata. Toxicity of gases like SO_2 and NO_x is depending on its reducing property. When its concentration is increased, the cells are first inactivated with or without plasmolysis, then ruptured and finally tissue collapse and dry up and killed[17]. Trees act as a sink of air pollutants and reduce their concentrations in the air. Vegetation naturally cleans the atmosphere by absorbing gases and particulate matter through leaves as plant leaf may act as a persistent absorber when exposed to the polluted environment. Sensitive plant species are suggested as bio-indicators. Different plant species showed a different behaviour for different pollutants and any plant part could be indifferently used as bio monitors[24].

In the present global environmental scenario, this problem has become increasingly severe. The particulates and gaseous pollutants, alone and in combination, can cause serious setbacks to the humans and overall physiology of plants. Dust may affect photosynthesis, respiration, transpiration and allow the penetration of phyto toxic gaseous pollutants[20,22]. As plants are very efficient in trapping atmospheric particles, leaves have been used as monitors of particulate pollution. Deposition of dust depends on the physical characteristics of particles, such as their size, shape and also the plant species. Air pollution tolerance levels of each plant do not show uniform behaviour. The tolerance depending upon topography and pollution condition may be either stress avoidance or stress sensitive[35]. In present study, the susceptibility levels of different plants have been determined on the basis of their Air Pollution Tolerance Indices. The plants with low index value were sensitive to air pollution and vice versa. Where the former can be planted as indicator species and the later as tolerant sink to mitigate pollution. With this background, the study was attempted to understand the air pollution tolerance indices of selected trees in Bengaluru at three different locations. The objective of the present study was to evaluate the Air Pollution Tolerance Index (APTI) of six different plant species used at three different locations of Bengaluru as to select particular plant species to grow in respective areas and their correlation with respective pollutants.

MATERIAL AND METHODS

Study Area: The present study was carried out in urban Bangalore; one of the fastest growing cites in India, with a population of 12.6million [12] indicating a development of 741 Sq. 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 two decades.

Climate: Bengaluru has a tropical savanna climate with distinct wet and dry seasons. Due to its high elevation, Bengaluru usually enjoys a more moderate climate throughout the year, although occasional heat waves can make summer somewhat uncomfortable[25]. Coolest month is January with an average low temperature of 15.1°C (59.2°F) and the hottest month is April with an average high temperature of 35°C (95°F)[8]. The highest temperature ever recorded in Bengaluru is 39.2°C (103°F) (recorded on 24 April 2016) as there was a strong El Nino in 2016 [10] There were also unofficial records of 41°C (106°F) on that day. The lowest ever recorded is 7.8°C (46°F) in January 1884[4,6]. Winter temperatures rarely drop below 14°C (57°F) and summer temperatures seldom exceed 36°C (97°F). Bengaluru receives rainfall from both the northeast and the southwest monsoons and the wettest months are September, October and August[8] in that order the summer heat is moderated by fairly frequent thunderstorms, which occasionally cause power outages and local flooding.

Plate 1: Map of Bengaluru

MATERIAL AND METHODS

Tree species were randomly selected from avenues of Bangalore. 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[2].

Total Chlorophyll Content (TChl) *was determined by blending* 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-Visible Spectrophotometer 118 [2,5]. Calculations were made using the below formula:

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) was carried out by collecting fresh leaves of different plants were weighed and then immersed in water over night, blotted dry and then weighed to get the turgid weight. Then, the leaves were dried overnight in a hot air oven at 70°C and reweighed to obtain the dry weight[2,28]. Calculations were made using the formula:

RWC = [(FW – DW)/ (TW – DW)] x 100

Where,

FW = Fresh weight, DW = dry weight, and TW = turgid weight.

Ascorbic Acid (AA) *content* was measured by weighing 1g of the leaf sample into a test tube, 4ml of oxalic acid – EDTA extracting solution was added. Then 1ml of ortho phosphoric 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[2,7].

The air pollution tolerance indices (APTI) of six common plants were determined by the following standard method[2,29]. 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 (%).

Statistical analysis: Statistical analysis was done by computing the standard deviation and analysis of variance (ANOVA) at 0.05 levels of probability and mean discrimination was done according to the Duncan's multiple range test using MSTATC 2.0.'

RESULTS AND DISCUSSION

The mean values and percentage increment in relative water content, pH, total chlorophyll, ascorbic acid and APTI for all the six species at respective sites of all the four biochemical parameters for six tree species at three sites are shown in Table 1.

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. The highest value of relative water content in all the three-selected location was noticed for *Samanea saman* with 87.22% at Indian institute of Horticulture, Hessaraghatta (IIHR) followed by Peenya industrial area 87.02% and lowest was at Yelahanka 84.19% while the least water content was observed for *Polyalthia longifolia* 73.59% at Yelahanka region and at Peenya industrial area *Bougainvillea glabra* recorded *79.34*% *and Tabubea argentia* 83.62% at IIHR. The most significant change in relative moisture content of the tree leaves from the experimental sites was found in *Polyalthia longifolia i.e.* from 73.59% to 86.75% (Table 1). An increase of about13.15% of relative water content in *Polyalthia longifolia* was observed during course of study (Table 1). Least change was found in *Samanea saman* i.e. from 84.18% to 87.22 % (Table 1) where a reduction of about 3.12 percent was observed[11]. Found higher Relative water content in the monsoon season[14]. Reported that high leaf RWC was recorded 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). It is observed that pH of the leaf extract changes across the species (Table 1). However, pH of leaf doesnt change to changing location. 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 [19]. Plants with lower pH are more susceptible while those with pH around 7 are tolerant[2130]. The change in leaf extract might influence the stomatal 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[25]. 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[1]. Whereas certain pollutants increase the total chlorophyll content other decrease it[3]. The most significant change in total chlorophyll content in the tree leaves from experimental site was found in *Bauhinia acuminata* i.e. from 1.08 mg/g FW to 2.19 mg/g FW (Table 1). An increase of about 50.68 % of total chlorophyll was observed in *Bauhinia acuminata* during course of study (Table 1). Least change was found in *Tabubea argentia* from 0.63 mg/g FW to 0.76 mg/g FW where an increase of about 20.63 % was observed (Table 1). Higher levels of total chlorophyll observed may be due to its tolerance nature. Beg *et al.*[9], Katiyar, *et al.*[18] and Mir *et al.*[23] also suggested that high levels of automobile pollution decrease chlorophyll content in higher plants near roadsides.

Ascorbic acid content

Ascorbic acid being a strong reculant protects chloroplasts against sulphur dioxide induced hydrogen peroxide, oxygen and OH accumulation and this protects the enzymes of the carbon dioxide fixation cycle and chlorophyll from inactivation[13]. Thus, tree species maintaining higher ascorbic acid level under polluted condition are considered to be tolerant to air pollutants. The results of the study revealed that, *Polyalthia longifolia* recorded the least ascorbic acid content in all the tree locations (0.67mg/g FW, 0.9567mg/g FW and 1.02167mg/g FW). And *Samanea saman*, recorded highest ascorbic acid in all the three locations (2.24 67mg/g FW, 3.21 67mg/g FW and 6.63 67mg/g FW) can be considered as pollution tolerant owing to their high ascorbic acid content (Table 1).

Table 1: Parameters of Air Pollution Tolerance Index

Species	Ascorbic acid (mg/g FW)	RWC (%)	Total chlorophyll (mg/g FW)	pH	ATPI
IIHR					
Polyalthia longifolia	0.67^{o}	86.75^{ab}	2.65^{a}	7^{a}	9.32^{jk}
Peltophorum pterocarpum	1.43^{k}	84.57^{bc}	2.65^{a}	7^{a}	9.84^{fg}
Bauhinia acuminata	1.86^{h}	87.53^{a}	1.81^{d}	7^{a}	10.39^{d}
Tabubea argentia	1.57^{j}	83.62^{cd}	0.76^{f}	6^{b}	9.42^{hij}
Bougainvillea glabra	1.81^{h}	87.06^{ab}	1.76^{d}	6^{b}	10.11^{e}
Samanea saman	2.24^{f}	87.22^{a}	2.29^{b}	7^{a}	10.80^{c}
PEENYA INDUSTRIAL AREA					
Polyalthia longifolia	0.95^{m}	83.07^{cde}	2.47^{ab}	7^{a}	9.21^{jk}
Peltophorum pterocarpum	1.05^{l}	80.94^{efg}	2.22^{bc}	7^{a}	9.06^{k}
Bauhinia acuminata	0.83^{n}	80.88^{efg}	1.08^{e}	7^{a}	8.75^{l}
Tabubea argentia	2.38^{e}	80.83^{efg}	0.63^{f}	6^{b}	9.66^{gh}
Bougainvillea glabra	1.70^{i}	79.34^{g}	0.86^{ef}	6^{b}	9.10^{k}
Samanea saman	3.21^{b}	87.02^{ab}	1.68^{d}	7^{a}	11.49^{b}
YELAHANKA					
Polyalthia longifolia	1.021^{m}	73.59^{h}	1.93^{cd}	7^{a}	8.27^{m}
Peltophorum pterocarpum	1.95^{g}	82.34^{cdef}	1.83^{d}	7^{a}	9.96^{ef}
Bauhinia acuminata	1.52^{j}	79.86^{fg}	2.19^{bc}	7^{a}	9.39^{ij}
Tabubea argentia	2.67^{c}	78.46^{g}	0.65^{f}	6^{b}	9.62^{ghi}
Bougainvillea glabra	2.48^{d}	81.94^{def}	1.69^{d}	6^{b}	10.10^{e}
Samanea saman	6.63^{a}	84.18^{cd}	1.78^{d}	7^{a}	14.24^{a}
SE(m)	0.002	2.363	0.035	0.001	0.024
CD (0.05%)	0.074	2.551	0.31	0.310	0.257
CV (%)	2.15	1.18	10.82	0.00	1.55

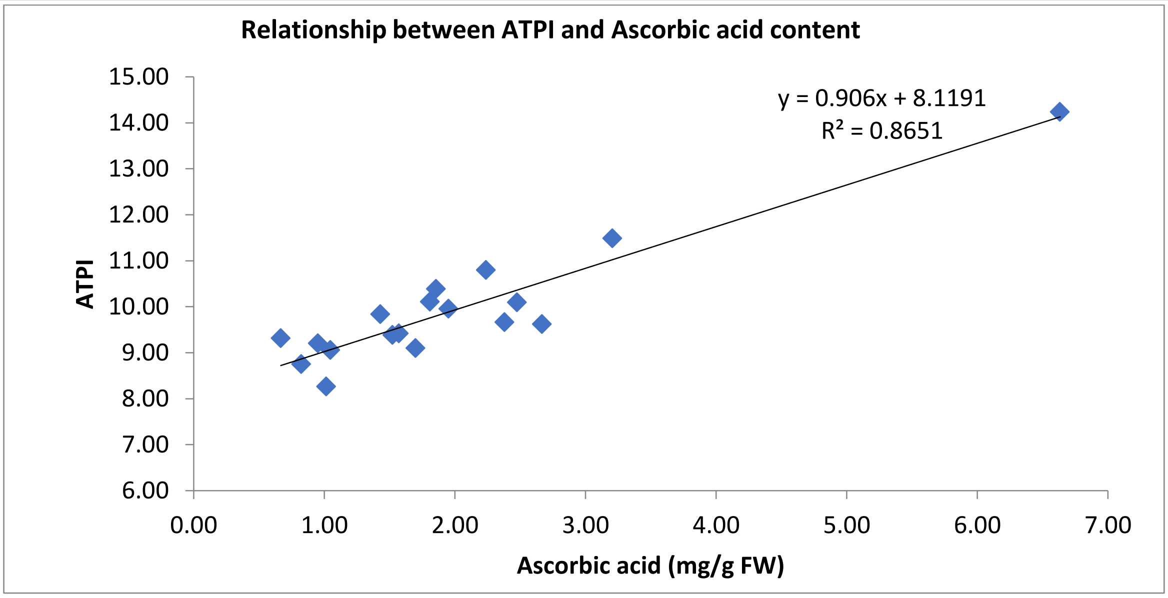

Fig. 1: Relationship betweem ATP1 and ascorbic acid in six different species to three different location

CONCLUSION

The tree species *Samanea saman* recorded highest ATPI value with 14.24; 11.49; 10.80 in all the three locations have secured higher APTI compared to other tree species (Table 1). However, *Polyalthia longifolia* (8.82) and *Bauhinia acuminata* (8.72) recorded least ATPI value at Yelahanka and Peenya industrial area respectively. Further it is also found that ascorbic acid content in leaf and ATPI are positively correlated (R^2=0.86) (Figure 1). The tree species with higher and low APTI value can serve as tolerant and sensitive respectively. Such tolerant tree species can effectively used as indicators and pollution scavengers[27].

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