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Estimation of Air Pollution Tolerance Index (APTI) of selected ornamental tree species of Lalbagh, Bengaluru, India

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Abstract
Science for phyto-technologies has got immense application in air pollution science. The present study focuses on the determination of air pollution tolerance indices (APTI) from forty-six tree species of Lalbagh, Bangalore, India. The APTI was determined by synthesizing the four different physiological and biochemical parameters, *i.e.,* leaf relative water content (RWC), ascorbic acid content (AA), total leaf chlorophyll (TCh) and pH of leaf extract. There were total 46 different tree species selected to study Air pollution tolerance index. Among them (*Ceiba pentandra*) (9.81), *Terminalia myriocarpa* (9.75), *Calliandra brevipes* (9.60), *Bursera delpechiana* (9.37), *Saraca indica* (9.34), *Saroba eoipinaeace* (9.30) recorded highest ATPI value compared to *Bauhinia acuminata* (7.52) *Coffea liberica* (7.55) *Garcinia livingstonei* and *Ligustrum robustum* (7.78) which showed lowest value in ATPI. Remaining species lies under moderate category ranged between 8.02 to 8.86.

Keywords: Estimation of APTI, ornamental tree, Bengaluru, India

Introduction
From the past few decades air pollution has become a major problem, arising mainly from urbanization and industrialization. Air pollution tolerance index (APTI) is an inherent quality of plants to encounter air pollution stress which is presently of prime concern particularly in industrial and non - industrial areas. Therefore, APTI of the plants needs to be monitored and checked for the predominant species that are present in the polluted and non - polluted areas.
Particulate matter is of great concern in relation to their adverse impact on human health and vegetation (Rai, 2013) [21]. Gaseous pollutants and particulates, alone or in combination can cause serious setbacks in the overall physiology of plants (Ashenden and Williams, 1980; Mejstrik, 1980; Anda, 1986; Das and Prasad, 2010) [7, 19, 5, 13]. The responses of plants to pollutants may provide a simple method of monitoring air pollutants as well as providing the pollution abatement measures. Plantation of tolerant tree species may have a marked effect on varied aspects of the quality of the urban environment and the cleanliness of life in a city (Bamniya *et al*., 2011) [11].
Trees experience the greatest exposure and influenced greatly by pollutant concentration due to their perennial habit (Raina and Sharma, 2003; Chauhan, 2010) [22, 12]. Regional impact of air pollution on local plant species is one of the major ecological issues. The climate condition, the physico - chemical properties of air pollutants and their residence time in the atmosphere have impact on surrounding plants (Wagh *et al*., 2006) [34]. The most obvious damage occurs in the leaves which include chlorosis, necrosis and epinasty (Prasad and Choudhury, 1992) [20]. In the present study, APTI of common growing roadside plants in industrial and non - industrial site have been investigated.
With this background, the present study was attempted to understand the air pollution tolerance indices of selected trees in Lalbagh, Bengaluru. The objective of the present study was to evaluate the Air Pollution Tolerance Index (APTI) of forty six different plant species of Lalbagh, Bengaluru as to select particular plant species to grow in respective areas and their correlation with respective pollutants.

Materials and Methods
Study Area: The samples were collected from LalBagh and analysis was carried present study was carried out at IIHR, Bengaluru. Lalbagh is of royal origin and was started initially as a private garden in an area of 40 acres by Hyder Ali. It is located in the heart of the city, about 4 km from Vidhana Soudha. Bengaluru is one of the fastest growing cites in India, with a population of 12.6million (Census of India, 2011) [10]; 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. However, some of the trees that perhaps earned its name are still to be seen and cherished in Cuban park, Lalbagh, IISc-Bengaluru campus and Bengaluru University-Jnanabharathi campus with rich vegetation.

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.
(http://www.thehindu.com/2005/05/18/stories/2005051818670300.html). 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).(*India Meteorological Department-2007*) 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 (http://www.thehindu.com/news/cities/bangalore /Bengaluru-records-highest-temperature-since-1931/article14255317.ece) 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. (Amaresh and Vidyashree., 2006, Ashwini., 2006) [4, 8] 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.

Methodology
Tree species were randomly selected from avenues of Bengaluru. Fresh leaf samples (in triplicates of selected plants)were collected in early morning from height of 1 to 2 m from ground level of fully matured leaves and were immediately brought to the laboratory in polythene bag, kept in ice box for further analysis of various biochemical parameters such as.

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 (Agbaire *et al*., 2019) [1].
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 (Agbaire *et al*., 2019, Arnon., 1949) [1, 6] 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 an hot air oven at 70 °C and reweighed to obtain the dry weight (Agbaire *et al*., 2019, Singh *et al*., 1977) [1, 27]. 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 (Agbaire *et al*., 2019) [1].
The air pollution tolerance indices (APTI) of six common plants were determined by the following standard method (Agbaire *et al*., 2019, Singh *et al*., 1991) [1, 28]. 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
To examine the possible role of each biochemical component on air pollution tolerance index were analysed and presented in Table 1:
Ascorbic acid is regarded as an antioxidant found in large amount in all growing plant parts and influence resistance to adverse environmental condition including air pollution (Keller and Schwager, 1977; Lima *et al*., 2000) [16, 17]. Ascorbic acid content was significantly varied across the 46 species that were studied. And it ranges from 0.95- 0.11(mg/g FW) across the species. Highest and lowest ascorbic acid content in study area as shown below: Species like *Diospyros kaki* (0.95), *Saraca indica* (0.90), *Broch chitonse* (0.89), *Brownea grandsceps* (0.88) recorded highest ascorbic acid compared to species like *Coffea liberica*, *Tabebuia pallida* which recorded least ascorbic acid (0.11 mg/g FW). Ascorbic acid, a stress reducing factor is generally higher in tolerant plant species. Tripathi and Gautam (2007) [32] reported pollution load dependent increase in ascorbic acid content of all the plant species might be due to the increased rate of production of reactive oxygen species (ROS) during photo-oxidation process.
It is observed that all the plant species collected from the site exhibited a pH towards acidic side from 4.0 to 6.0. the acidic nature may be due to the presence of SOx, NOx or other acidic pollutants from the vehicles emission or from the industrial emission in the ambient air causing a change in pH of leaf sap towards acidic (Swami *et al* 2004). Plants like *Diasporour maesophulla*, *Ligustrum robustum, Bougainvillea glabra*, *Lagerstroemia speciosa*, *Schefflera actinophylla* and*Gardenia gummifera* however recorded high pH among them i.e., 6. pH. Low leaf pH extract showed good correlation with sensitivity to air pollution and also reduce photosynthetic process in plants (Yan-Ju and Hui, 2008; Thakar and Mishra, 2010) [35, 31]. A pH on higher site improves tolerance against air pollution (Agarwal, 1986; Shannigrahi *et al*., 2004) [26].
The relative water content (RWC) varied from 92.50% to73.26% across the studied tree species. The relative water

content was high in some of the species like *Terminalia myriocarpa* (92.50%), *Olive* (*Olea europaea*) (91.02%), *Kapok* (*Ceiba pentandra*) (90.41%) and low in species like *Bauhinia acuminata* (73.26%), *Tree falsa* (*Grew filiae folia vahl*) (73.82%), *Broch chitonse* (73.92%). However, in the remaining species moderate range of RWC was observed (89 to 74%). High water content within a plant body will help to maintain its physiological balance under stress condition such as exposure to air pollution when the transpiration rates are usually high which may lead to desiccation. Therefore, maintenance of RWC by the plant may decide the relative tolerance of plants towards air pollution (Verma, 2003) [33]. The higher the RWC in a particular species, the greater is its drought tolerance capacity (Dedio, 1975) [14]. Thus, the higher RWC in industrial site sample may be responsible for normal functioning of biological processes in plants (Meerabai *et al*., 2012) [18].

Chlorophyll content of plant signifies its photosynthetic activity as well as the growth and development of biomass. Chlorophyll content of plant varies from species to species depending upon the age of leaf, pollution level as well as other biotic and abiotic condition (Katiyar and Dubey, 2001) [15]. Among the studied species total chlorophyll content was found to highest in *Kapok* (*Ceiba pentandra*) (8.79 mg/g FW), followed by *Tradescantia Zebrina* (8.19 mg/g FW), *Saroba eoipinaeace* (7.8519 mg/g FW), *Ligustrum robustum* (7.5919 mg/g FW), *Nagakeshara* (*Mesua ferrea*) (7.4519 mg/g FW), *olive* (*Olea europaea*) (7.0319 mg/g FW). Moderate chlorophyll content ranged between 6.5 to 2.7 mg/g FW. However, the tree species like *Tree falsa* (*Grew filiae folia vahl*) (1.38 mg/g FW) *Andira fraxinifolia* (1.39 mg/g FW) showed lesser amount of chlorophyll content. The present study revealed that chlorophyll content in all the plants varied with the pollution status of the area. The higher the levels of pollutants, the lower the chlorophyll content as certain pollutants in totality reduce the total chlorophyll content (Allen *et al*., 1987) [3]. Rao and Leblanc (1966) [23] have also reported reduction in chlorophyll content brought by acidic pollutants like SO_2 which causes phaeophytin formation by acidification of chlorophyll. Reduction in chlorophyll content in variety of crop plant due to NO_2, SO_2 and O_3 exposure have also been reported by Agrawal *et al*. (2003) [2].

Air pollution tolerance index was analyzed and presented in the Table 1. The APTI value estimated using the four biochemical parameters in plant leaves namely RWC, total chlorophyll content, pH and ascorbic acid value can be used as a predictor of air quality. Plants having higher index value are tolerant to air pollution while plants with lower index value show less tolerance (Singh and Rao, 1983). Accordingly, the tolerance index for the studied species in Bengaluru (lalbagh) locality were as follows. Species like *Ceiba pentandra* (9.81), *Terminalia myriocarpa* (9.75), *Calliandrabrevepes* (9.60), *Bursera delpechiana* (9.37), *Saraca indica* (9.34), *Saroba eoipinaeace* (9.30) recorded highest ATPI value compared to species like *Bauhinia acuminata* (7.52) *Coffea liberica* (7.55) *Garcinia livingstonei* and *Ligustrum robustum* (7.78) which showed lowest value in ATPI. Remaining species lies under moderate category ranged between 8.86 to 8.02. This changes in ATPI mainly because of the pollutants tolerances level adapted in particular tree specious. From the above details it's clear that all the plants studied in the experiment locality was found to be sensitive to air pollution. A plant species known to be sensitive or tolerant in one geographical area may behave differently in another area (Raza *et al*., 1985) [24].

Later, it was observed that the Species like *Kapok* (*Ceiba pentandra*) and *Terminalia myriocarpa* which showed highest ATPI value also recorded highest relative water content chlorophyll and moderately high ascorbic acid content. It was also seen that, *bauhinia acuminata* which have low pH showed a least ATPI value. *Diasporour maesophulla* and *Diospyros kaki* recorded high pH and ascorbic acid content respectively also showed moderately high ATPI.

Biomonitoring of air pollution and its impact on biochemical parameters is extremely relevant in air pollution science. The study clearly reflects that the tolerance of plants towards air pollution may be site- specific. An overview of the entire result obtained from this study reveals that plants such as (*Ceiba pentandra*), *Terminalia myriocarpa*, *Calliandra brevepes*, *Bursera delpechiana*, *Saraca indica*, *Saroba eoipinaeace* recorded highest ATPI value compared to species like *Bauhinia acuminata* (7.52), *Coffea liberica* (7.55), *Garcinia livingstonei*. Further these plant species may be suitable for plantation at polluted areas.

Table 1: The biochemical characteristics and the APTI for plants from Lalbagh, Bengaluru.

S. No	Species	Ascorbic acid (mg/g FW)	RWC (%)	Total chlorophyll (mg/g FW)	pH	ATPI
1	*Kapok* (*Ceiba pentandra*)	0.58	90.41	8.79	5	9.81
2	*Terminalia myriocarpa*	0.49	92.59	4.48	5	9.75
3	*Calliandrabrevepes*	0.56	89.74	4.64	5	9.60
4	*Bursera delpechiana*	0.52	89.22	1.75	5	9.37
5	*Saraca indica*	0.90	85.15	6.58	5	9.34
6	*Saroba eoipinaeace*	0.56	87.10	7.85	5	9.30
7	*Guaniacum officinale linn*	0.77	86.18	4.47	4	9.29
8	*Terminalia catappa*	0.42	89.38	2.47	4	9.27
9	*Olive* (*Olea europaea*)	0.21	91.02	7.03	5	9.23
10	*Lagerstroemia speciosa*	0.73	85.28	1.59	6	9.17
11	*Nagakeshara* (*Mesua ferrea*)	0.50	82.44	7.45	5	9.17
12	*Polyalthia longifolia*	0.28	89.28	3.73	4	9.16
13	*Macadamia ternifolia*	0.60	88.42	1.49	5	9.15
14	*Eunomos rectangular*	0.68	87.90	1.43	4	9.15
15	*Tradescantia zebrina*	0.69	81.14	8.19	4	9.12
16	*Peltophorum pterocarpum*	0.16	89.91	3.54	4	9.07
17	*Eucalyptus deglupta*	0.85	76.52	4.80	5	8.86
18	*Amherstia nobilis*	0.37	86.99	2.25	4	8.84
19	*Tabebuia argentea*	0.31	87.37	1.98	4	8.75
20	*Cinnamomum camphora*	0.52	83.23	3.67	5	8.74

21	*Bauhinia monandra Kurz*	0.15	85.26	6.91	4	8.70
22	*Hamelia patens*	0.47	85.96	2.98	5	8.67
23	*Andira fraxinifolia*	0.67	80.96	1.39	4	8.64
24	*Mallotus philippensis*	0.85	79.82	5.34	5	8.64
25	*Barringtonia acutangula*	0.48	83.99	1.72	5	8.61
26	*Schefflera actinophylla*	0.23	83.96	2.56	6	8.58
27	*Diasporour maesophulla*	0.25	82.64	1.79	6	8.57
28	*Tabebuia pallida*	0.14	84.71	1.84	5	8.54
29	*Putranjina roxburghii*	0.85	78.53	4.42	6	8.53
30	*Eugenia fragrans*	0.75	77.88	3.38	5	8.52
31	*Gardenia gummifera linn*	0.59	80.84	1.50	6	8.47
32	*Vitex negundo*	0.61	75.54	3.37	5	8.45
33	*Samanea saman*	0.76	78.03	2.58	5	8.43
34	*Lagerstroemia tomentosa*	0.59	79.16	2.67	4	8.41
35	*Ligustrum thorelli*	0.18	81.75	1.88	6	8.38
36	*Erythrina umbrosa*	0.81	82.33	3.85	5	8.34
37	*Bougainvillea glabra*	0.23	80.80	3.07	6	8.26
38	*Broch chitonse*	0.89	73.92	4.30	5	8.24
39	*Solvodara persica*	0.82	76.22	2.17	5	8.23
40	*Diospyros kaki*	0.95	86.86	3.91	4	8.19
41	*Brownea grandsceps*	0.88	74.11	1.49	5	8.12
42	*Tree falsa* (*Grew filiae folia vahl*)	0.46	73.82	1.38	4	8.02
43	*Garcinia livingstonei*	0.18	78.25	1.79	5	7.78
44	*Ligustrum robustum*	0.16	74.07	7.59	5	7.78
45	*Coffea liberica*	0.14	74.38	3.51	5	7.55
46	*Bauhinia acuminata*	0.35	73.26	2.67	4	7.52
	C.D.	0.147	9.243	0.311	0.471	0.575
	C.V.	17.247	6.874	5.23	5.836	4.067

Table 2: Air pollution data recorded near Lalbagh

Months/Pollutants	So_2 (µg/m^3)	No_2 (µg/m^3)	NH_3 (µg/m^3)
Jan	2	35	33
Feb	2	40	78
Mar	2	35	71
April	2	35	37
May	2	30	40
June	2	33	37
July	2	33	31
Aug	2	33	34
Sep	2	32	34.3
Oct	2	35	37
Nov	2	31	34
Dec	2	32	33

Source: Karnataka state pollution control board

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