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Comparative study of roadside avenue trees as bio-indicators of air pollution in and around Mumbai, India: A case study

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Abstract

With rapid increase in urbanization followed by industrialization compounded due to ever-exploding population in the past few decades there is a steep rise in contamination of one of the most vital abiotic factors of the environment i.e., the air. In these circumstances, the clean and green measures to monitor and control air pollution have become inevitable. Air Pollution Tolerance Index (APTI) is one such index for indicating the extent of the plants to withstand air pollution. This includes analysis of physiological and biochemical parameters like total chlorophyll content, ascorbic acid content, pH of the leaf extract and relative water content of the leaves. In this study, the plants selected are mature tree species like *Polyalthia longifolia*, *Putranjiva roxburghii*, *Alstonia scholaris*, *Delonix regia* and *Peltophorum pterocarpum* from Mumbai and its surrounding regions. According to the Air Pollution Tolerance Index (APTI) values, plants can be classified as tolerant, intermediate, sensitive and highly sensitive. The tolerance of the plants studied in the decreasing order is as follows *P. roxburghii* > *P. pterocarpum* > *D. regia* > *P. longifolia* > *A. scholaris*. Species selected on the basis of their APTI values can then be used as bio-indicators of air pollution and in its mitigation for green belt development in urban areas.

Keywords: Air pollution; Air Pollution Tolerance Index (APTI); Bio-indicators; Urbanization

1. Introduction

In modern world, pollution has become the biggest enemy for the survival of the living organisms. Out of all pollutions, air pollution is the one which is increasing at an alarming rate due to rapid industrialization and urbanization and excessive use of automobiles resulting in the rapid decline in air quality contributed mainly by emissions of air pollutants like Sulphur dioxide (SO_2), Nitrogen oxides (NO_x), Carbon monoxide (CO) and Particulate matter (smaller than 10µm). Vehicular pollution contributes up to 70%, 52% and 30% of total air pollution in Delhi, Mumbai and Kolkata respectively [1]. The increasing environmental pollution has adverse effects on the human health, animal and plant life, infrastructure, etc.

The urban trees are the ones which are grown in urban areas on roadsides, in parks and gardens, in industrial and residential complexes, green belts, traffic islands, etc. to increase the green infrastructure in the concrete jungles. Urban trees not only increase the green infrastructure but also contribute in terms of environmental and socio-economic aspects. The plants in polluted areas show many changes in their morphology and metabolism like changes in concentration of chlorophyll, ascorbic acid, proteins, phenols and other metabolites, chlorosis, necrosis, and other types of injuries on leaf and other parts of the plant. This is the result of absorption of harmful gaseous pollutants like SO_2, CO, CO_2, NO_x, through leaf stomata also vegetation provides large surface area for deposition of dust and particulate matter [2]. This shows that plant helps to take-up the pollutants from the atmosphere and mitigates air pollution.

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The Air Pollution Tolerance Index (APTI) evaluates the tolerance level of plant species towards air pollution from leaf biochemical parameters such as leaf extract pH, relative water content of the leaf, ascorbic acid and total chlorophyll [3]. Some plants act as pollutant sink by absorbing the harmful pollutants, such plants are called as tolerant species while some plants exhibit physical, ecological, physiological, anatomical and biochemical aberrations due to derogatory effects of air pollution, such plants are called as sensitive species and can be used as bio indicators of air pollution.

Mumbai, the financial capital of India, due to its increasing population and its ever-growing demands, is facing destruction of green patches around the city. This research project will make an attempt to throw light on the level of increasing pollution in Mumbai and suburbs and the need for plantation of tolerant plant species along roadsides to mitigate air pollution.

2. Material and methods

2.1. Overview of study area

For the present study, areas selected are located in and around Mumbai. The areas are Sion, Dombivli and Sanpada which are located in different directions of the city i.e., Sion is located at 19.0390° N, 72.8619° E in the urban area of Mumbai city, Dombivli is located at 19.218433°N 73.086718°E in the Thane district of Maharashtra which is approximately 50km from Mumbai city and Sanpada is located at 19.0601° N, 73.0140° E in the Navi Mumbai region of Maharashtra which is approximately 25 km from Mumbai city and thus can be used to get overall mean results covering a larger area.

2.2. Plants under study and sample collection

The following species *Polyalthia longifolia* Sonn., *Alstonia scholaris* (L.) R.Br., *Delonix regia* (Boj. ex Hook.) Raf., *Putranjiva roxburghii* Wall., *Peltophorum pterocarpum (DC.)* Backer ex Heyne. were abundant in the areas selected for the study and were feasible to collect hence selected for the study. The plant samples i.e., mature twigs with leaves were collected from the month of July to March with all precautionary measures for further study.

2.3. Biochemical Parameters

- **Chlorophyll Estimation:** One gram of leaf sample was weighed and taken in a mortar and pestle. A pinch of Magnesium carbonate was added to avoid oxidation. 20 ml of 80% acetone was used to crush the leaf samples. The extract was filtered and the filtrate was used to calculate optical density. Optical density was measured at 663, 645 and 480 nm [4].
- **Ascorbic acid content:** 3 gram of leaf sample was extracted in 4% oxalic acid and was titrated against the 2, 6-dichlorophenol indophenol dye solution till the end point was pink in color. Similarly, blank was also prepared [5].
- **pH of the leaf:** Five gram of leaf sample was extracted in 50 ml of deionized water. The extract was filtered through the muslin cloth. pH was measured in a previously calibrated pH meter [3].
- **Relative water content of leaf:** Fresh weight (FW) was obtained by weighing the fresh leaves. The leaves were then immersed in water overnight, dried by blotting and then were weighed to get turgid weight (TW). Next, the leaves were dried overnight in an oven at 70°C and reweighed to get the dry weight (DW) [6].

  The Relative Water Content (RWC) was calculated using the formula:

$$RWC = \frac{FW - DW}{TW - DW} \times 100$$

2.4. Air Pollution Tolerance Index (APTI)

Using above four parameters Air Pollution Tolerance Indices were calculated using the formula:

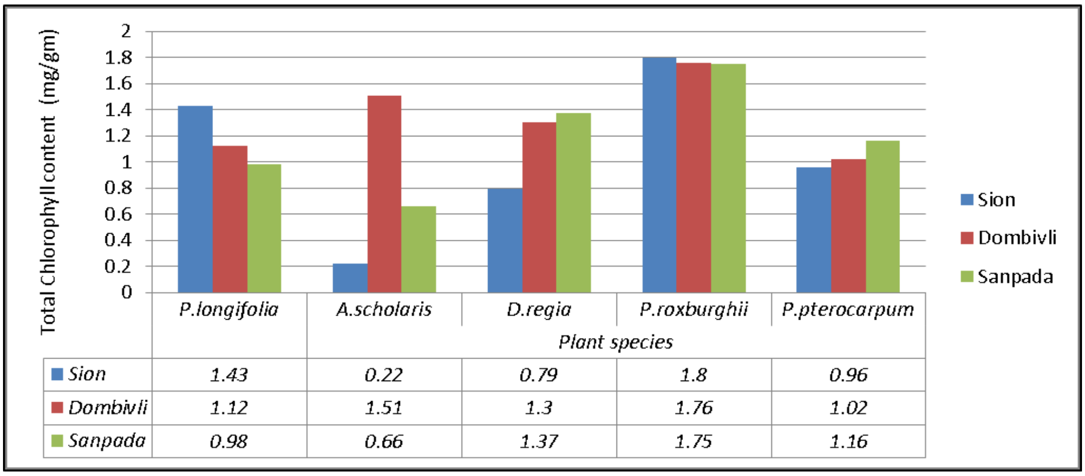
$$APTI = \frac{[A\,(T + P) + R]}{10}$$

Where, A is ascorbic acid content (mg/g fresh wt.), T is Total Chlorophyll content (mg/g fresh wt.), P is pH of leaf extract, R is Relative Water Content (%) [7].

3. Results and discussion

3.1. Total Chlorophyll content of leaf

Chlorophyll content signifies a plant's photosynthetic ability, growth and biomass development. Plants showing total chlorophyll content in their decreasing order is as follows *P. roxburghii* > *P. longifolia* > *D. regia* > *P. pterocarpum* > *A. scholaris* (Fig.1). The variations in the chlorophyll content of plant species may vary with pollution level of the area as well as the tolerance and sensitivity of the plant species [8, 9]. This result is also in line with the findings that the chlorophyll content varies from species to species and also by age, genetic makeup and other biotic and abiotic factors [10, 11]. As both the highest and lowest values of total chlorophyll content was observed in Sion area, it shows that under same pollution and environmental conditions *P. roxburghii* was able to produce more chlorophyll than other species and proved to be tolerant and on the other hand *A. scholaris* was found to be sensitive to pollution.

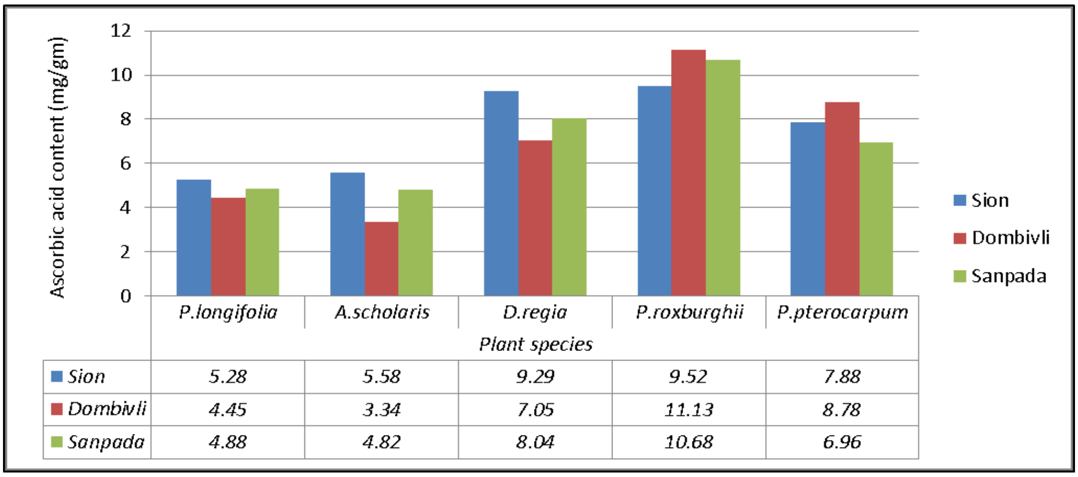


	P.longifolia	A.scholaris	D.regia	P.roxburghii	P.pterocarpum
Sion	1.43	0.22	0.79	1.8	0.96
Dombivli	1.12	1.51	1.3	1.76	1.02
Sanpada	0.98	0.66	1.37	1.75	1.16

Values are average of three individual experiments

Figure 1 Total Chlorophyll content (mg/gm) of all plants studied in all three areas

3.2. Ascorbic acid content of leaf



	P.longifolia	A.scholaris	D.regia	P.roxburghii	P.pterocarpum
Sion	5.28	5.58	9.29	9.52	7.88
Dombivli	4.45	3.34	7.05	11.13	8.78
Sanpada	4.88	4.82	8.04	10.68	6.96

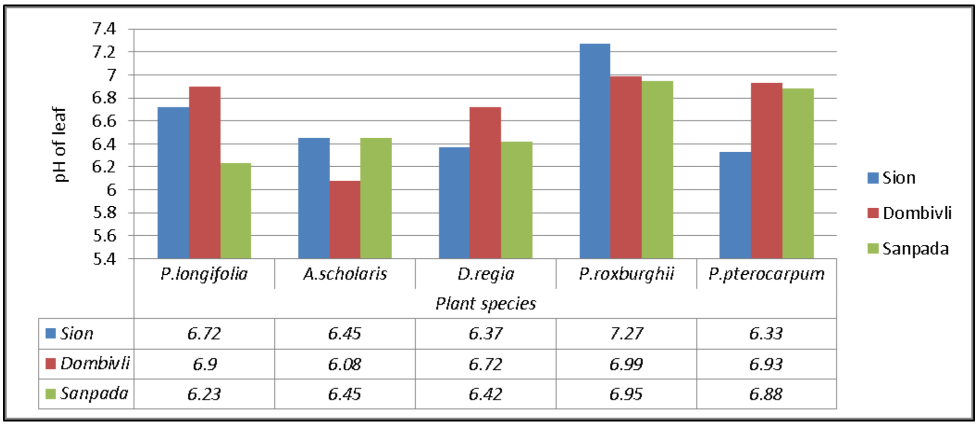
Values are average of three individual experiments

Figure 2 Ascorbic acid content (mg/gm) of all plants studied in all three areas

Ascorbic acid is an anti-oxidant that increases the resistance of plants against air pollution. Plants showing ascorbic acid content in their decreasing order is as follows *P. roxburghii* > *D. regia* > *P. pterocarpum* > *P. longifolia* > *A. scholaris* (Fig. 2). Higher ascorbic acid content may result due to genetic variation or due to higher adaptive capacity to tolerate environmental stresses. These results are in line with the findings that ascorbic acid is a stress reducing factor and it is present in higher amounts in tolerant plants [12]. The result is also supported by the findings that increased ascorbic acid content in plants enhances the pollution tolerance and it is the response of defense mechanism [13]. As both highest and lowest values of ascorbic acid content was from Dombivli area, it shows that the plants were growing under same pollution and environmental conditions still *P. roxburghii* showed higher ascorbic acid content which shows its higher capacity to adapt and withstand pollution which makes it tolerant whereas, *A. scholaris* showed lower ascorbic acid content and proved to be sensitive to pollution.

3.3. pH of leaf

pH is the biochemical parameter that serves as a sensitivity indicator of air pollution. Higher pH level of leaf extract indicates that the plant is tolerant under polluted conditions. Plants showing pH values in their decreasing order is as follows *P. roxburghii* > *P. pterocarpum* > *P. longifolia* > *D. regia* > *A. scholaris* (Fig.3). Most of the pH values are on the slightly acidic side i.e., below 7, which shows that the areas are polluted with acidic pollutants and also the lowest pH value of *A. scholaris* was from Dombivli's industrial area, this result is supported by findings that leaf pH is reduced in presence of acidic pollutants and reducing rate is more in sensitive plants as compared to tolerant ones [14, 15]. Therefore, *A. scholaris* with minimum value is sensitive whereas *P. roxburghii* with maximum value is tolerant.

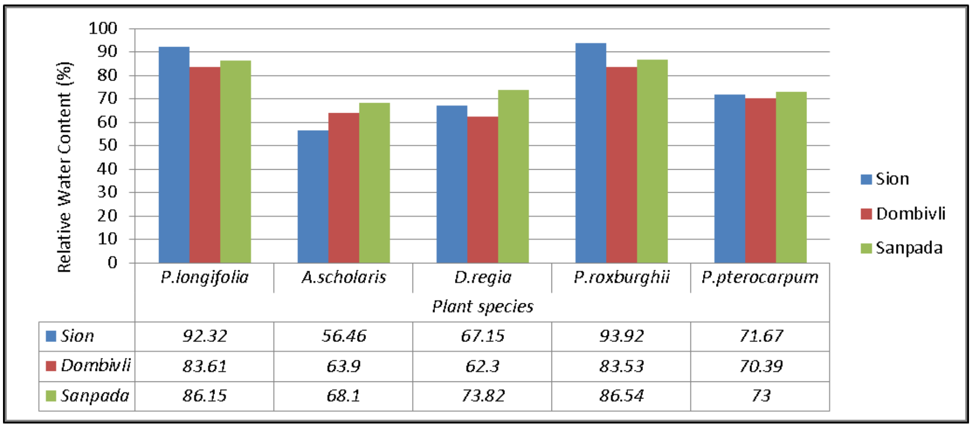


	P.longifolia	A.scholaris	D.regia	P.roxburghii	P.pterocarpum
Sion	6.72	6.45	6.37	7.27	6.33
Dombivli	6.9	6.08	6.72	6.99	6.93
Sanpada	6.23	6.45	6.42	6.95	6.88

Values are average of three individual experiments

Figure 3 pH of leaf of all plants studied in all three areas

3.4. Relative Water Content (RWC) of leaf



	P.longifolia	A.scholaris	D.regia	P.roxburghii	P.pterocarpum
Sion	92.32	56.46	67.15	93.92	71.67
Dombivli	83.61	63.9	62.3	83.53	70.39
Sanpada	86.15	68.1	73.82	86.54	73

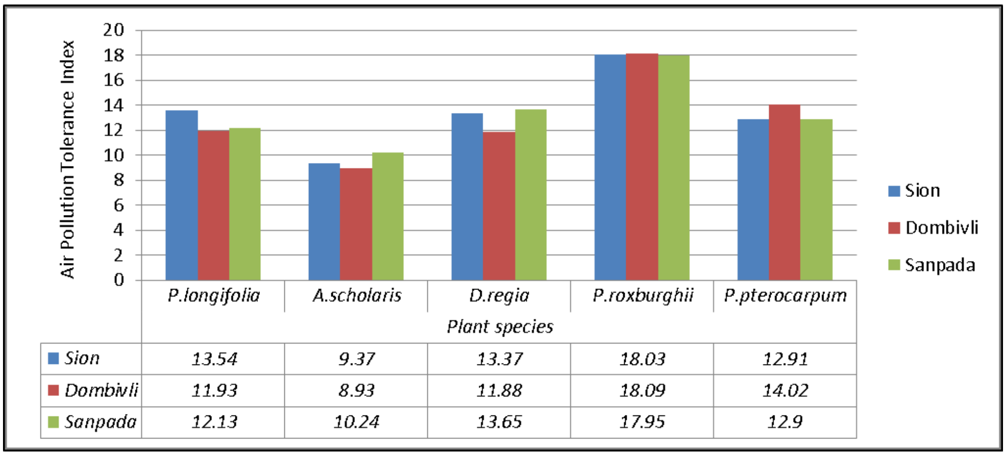
Values are average of three individual experiments

Figure 4 Relative water content of leaf (%) of all plants studied in all three areas

Relative water content is the measure of ability of the plant to take up water to its full turgidity. Plants showing RWC in their decreasing order are as follows *P. roxburghii* > *P. longifolia* > *P. pterocarpum* > *D. regia* > *A. scholaris* (Fig.4). These results are in line with the findings that RWC vary from species to species also the transpiration rates are frequently high in polluted conditions therefore, maintenance of RWC by plants may determine its relative tolerance to pollution [16, 15]. Therefore, *P. roxburghii* with highest RWC is tolerant and *A. scholaris* with lowest RWC is sensitive to pollution.

3.5. Air Pollution Tolerance Index (APTI)

The APTI value of all the plants species studied in their decreasing order is as follows *P. roxburghii* > *P. pterocarpum* > *D. regia* > *P. longifolia* > *A. scholaris* (Fig.5). The result is in line with the findings that *P. roxburghii* is the tolerant plant to air pollution and *A. scholaris* is sensitive to air pollution which is similar to our result [17,18]. Plants having APTI value in the range of 30-100 were tolerant to pollution and APTI value in the range of 17-29 were intermediate to pollution and below 16 and up to 1 are sensitive and value less than 1 are very sensitive [19]. Implying this in to our results, no plants were found to be very sensitive to pollution. As per this classification, *P. roxburghii* was the only plant that had the APTI value above 16 and thus serves as a plant intermediate to pollution which can be used as a sink to air pollution. All other plants were found to be sensitive as their APTI values were between 1 to 16 and can be helpful in indicating air pollution levels.



	P.longifolia	A.scholaris	D.regia	P.roxburghii	P.pterocarpum
Sion	13.54	9.37	13.37	18.03	12.91
Dombivli	11.93	8.93	11.88	18.09	14.02
Sanpada	12.13	10.24	13.65	17.95	12.9

Values are average of three individual experiments

Figure 5 Air Pollution Tolerance Index of all plants studied in all three areas

4. Conclusion

The physiological and biochemical parameters varied significantly for different species and areas. APTI is one of the best tools for bio-monitoring of air pollution as it is inexpensive and easy method which is even possible in smaller scale. The tolerance of the plants studied in the decreasing order is as follows *P. roxburghii* > *P. pterocarpum* > *D. regia* > *P. longifolia* > *A. scholaris*. In the study, all the species were found to be in sensitive category whereas *P. roxburghii* was the only species to be in intermediate category of the APTI classification. Thus, *P. roxburghii* can be used in the green belt development in areas with high pollution level like industrial areas and traffic islands to mitigate air pollution while other species may be used to indicate the levels of air pollution and serve as bio-indicators of air pollution.

Compliance with ethical standards

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Disclosure of conflict of interest

The authors declare that there is no conflict of interest between them.

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Authors short Biography

Dr. V. Vishnuprasad graduated in Botany in 2007 and completed his post-graduation studies in Botany in 2009 specializing in Environmental Botany. After qualifying CSIR-UGC NET Exam securing AIR 63 in June 2012, he went on to pursue Ph.D. in Wood Anatomy discipline of the Forest Botany Department at Forest Research Institute (Deemed) University, Dehradun and received the Honourable Doctorate degree in October 2017. Being passionate about teaching and encouraging young budding researchers to explore the various environmental aspects and correlate them with other disciplines to come out with interesting findings, he has been working as an Assistant Professor in Botany department at SIES College of Arts, Science and Commerce (Autonomous), Sion, Mumbai since 2016.

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