International Journal of Science and Research (IJSR)
ISSN: 2319-7064
Impact Factor (2018): 7.426

Evaluation of Air Pollution Tolerance Index of Selected Tree Species along Roadsides in Vidyanagar, Gujarat (India)

Leena Abraham

Post Graduate and Research Department of Botany, St. Thomas College, Kozhencherry, India
Affiliated to Mahatma Gandhi University, Kottayam, Pathanamthitta District-689641, Kerala State, India

Abstract: ***Air Pollution Tolerance Index (APTI) is used by landscapers to select plant species tolerant to air pollution. To develop the usefulness of plants as bioindicators requires an appropriate selection of plant species which entail an utmost importance for a particular situation. Four physiological and biochemical parameters including leaf relative water content (RWC), ascorbic acid (AA) content, total leaf chlorophyll (TCh) and leaf extract pH were used to develop an APTI. The present study was designed to categorise trees commonly used as roadside plantations, as sensitive or resistant based on their air pollution tolerance index (APTI) values. The study area selected for the same was the educational hub of Gujarat State i.e. Vidyanagar. The seasonal variations in the APTI values of the selected tree species were studied. From the present study the order of tolerance of the selected tree species was Cassia renigera>Cassia fistula> Delonix regia>Azadirachta indica >Samanea saman >Ficus religiosa >Albizzia amara >Peltophorum pterocarpum>Lagerstroemia indica>Pongamia pinnata. It could be also noted that the tree species belonging to Cesalpinaceae family showed greater tolerance to air pollution as compared to other trees. The results of such studies are handy for future town planning.***

Keywords: Air Pollution Tolerance Index, Relative Water Content, Ascorbic Acid, pH, tolerance, bioinidicators

1. Introduction

Air pollution is one of the serious problem faced by the people globally, especially in urban areas of developing countries like India. The major cause of air pollution is industrialization [20]. Population growth and underestimated future plan of city development are the major triggers for the increase in the air pollution level in cities [14]. It has been suggested that 60% of the air pollution in city is caused by automobiles only [12].

Plants developed characteristic response and symptoms in response to different types of pollutants and level of air pollution. Sensitivity and response of plants to air pollutants is variable. Sensitive plant species are suggested as bio-indicators [21. 28]. Different plant species showed a different behaviour for different pollutants and any plant part could be indifferently used as biomonitors [18]. It has also been reported that when exposed to air pollutants most plant experience physiological changes before exhibiting visible damage to leaves.

In terrestrial plant species, the enormous foliar surface area acts as a natural sink for pollutants especially the gaseous ones. The harmful effects of air pollution on vegetation have already been well documented [1, 9, 16, 22]. Plants act as excellent scavengers of air pollution but the efficiency various from species to species [5,7, 13].

Biomonitoring of plants is an important tool to evaluate the impact of air pollution. Plants play an important role in monitoring and maintaining the ecological balance by actively participating in the cycling of nutrients and gases like carbon dioxide, oxygen and also provide enormous leaf area for impingement, absorption and accumulation of air pollutants to reduce the pollution level in the air environment [11].

Previous studies also showed the impact of air pollution on ascorbic acid content, chlorophyll content, leaf extract, pH and relative water content. These separate parameters gave conflicting results for same species. However, the air pollution tolerance index (APTI) based on all four parameters has been used for identifying tolerance levels of plant species. Air pollution tolerance index is used by landscapers to select plant species tolerant to air pollution [30]. It has also been used to rank plant species in their order of tolerance to air pollution [27]. The present paper determined variations in the APTI values of selected tree species commonly selected for road side plantation in Vidyanagar, Gujarat, State India. This study had also identified the plant species tolerant as well as sensitive to the vehicular pollution.

2. Materials and Methods

The study area selected for the present study was Anand-Vidyanagar Road (Gujarat, India), major transport corridor between two towns i.e. Anand and Vallabh Vidyanagar. Vidyanagar is the educational hub of Gujarat state with a high population density. The geographic location of the study area is 22.56 ° N, 72.95° E. After initial field survey, 10 tree species viz. *Azadirachta indica* A. Juss., *Cassia renigera* Wall., *Largestroemia indica* L., *Peltophorum pterocarpum* Backer., *Delonix regia* Rafi., *Pongamia piñnata* Pierre., *Albizia amara* L., *Ficus religiosa* L., *Cassia fistula* L. and *Samanea saman* Jacqu. Were selected based on their predominance of occurrence as a road side plantation along the Anand-Vidyanagar road. Three trees of each species selected were spotted on the study area.

The leaf samples of selected trees from the site of study were collected in the morning hours, every month during July to March. Fully mature leaves in triplicates were collected from the selected tress of almost same diameter at breast height (DBH). The fresh leaf samples were analyzed for pH of leaf extract, total chlorophyll content, ascorbic acid and relative water content using standard procedures [4, 25, 29, 6]. The obtained results culminated in the evaluation of air pollution tolerance index.

APTI:
Air Pollution Tolerance Index (APTI) was done based on the method given by [27].

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

A = Ascorbic acid content (mg/g)
T = Total chlorophyll (mg/g)
P = pH of leaf extract
R = Relative water content of leaf (%)

3. Results

All the biochemical parameters studied exhibited significant variation from species to species and season to season. Air Pollution Tolerance Index (APTI) proved as effective tool in calculating the tolerance level of different tree species when compared to individual bio-chemical parameters such as pH of the plant extract, relative water content, ascorbic acid content and chlorophyll content.

3.1 Changes in Ascorbic Acid Content:

Seasonal variation in leaf ascorbic acid contents in the selected tree species during monsoon, winter and post-winter seasons is presented in Table 1. Ascorbic acid content peaked in the winter months among all the species. In all the species except in *Delonix*, maximum AA content was found either in the month of October or in the month of January. Tree species belonging to Cesalpiniaceae family (*Delonix* spp., *Cassia* spp. & *Peltophorum* spp.) showed highest as well as similar pattern of seasonal variation in their ascorbic acid content. *Cassia renigera* and *Cassia fistula* showed the maximum average ascorbic acid contents i.e. 2.55 mg/ml and 2.49 mg/ml respectively. *Pongamia pinnata* showed relatively much lower level of the average ascorbic acid (0.41 mg/ml).

3.2 Changes in Total Chlorophyll Content

Cassia renigera, Cassia fistula and Samanea saman, all belonging to Cesalpiniaceae family showed high levels of chlorophyll in monsoon season while; *Lagerstroemia indica, Peltophorum pterocarpum, Delonix regia, Ficus religiosa* and *Pongamia pinnata* showed the highest chlorophyll content in winter season. In all the seasons, highest chlorophyll content was found in *Cassia renigera* indicating its high productivity. The chlorophyll content of all the tree species is presented in table 2.

3.3 Changes in the leaf extract pH

The leaf pH values of the selected plant species for different season are depicted in the table 3. pH values for all the species varied from acidic to slightly alkaline.

3.4 Relative Water Content

The relative water content was high among the plant species studied during monsoon months with a decline in the level during winter months followed by post winter season. Majority of the species showed the highest water content in the month of August (Table 4).

3.5 APTI

The results of Air Pollution Tolerance Index (APTI) calculated for each tree species studied during different seasons is depicted in table 5. All the Cesalpinaceae members showed the highest APTI levels in the month of October. Different plant species shows considerable variation in their susceptibility to air pollution. The plants with high and low APTI can serve as tolerant and sensitive species respectively. In the present study, based on the tolerance nature, the trees can be arranged in the order as the most tolerant species *Cassia renigera>Cassia fistula> Delonix regia>Azadirachta indica >Samanea saman >Ficus religiosa >Albizzia amara >Peltophorum pterocarpum> Lagerstroemia indica>Pongamia pinnata.*

Table 1: Ascorbic Acid Content(µg/ml) of Selected Tree Species

Species Name	July	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar
Albizzia amara	0.18	0.32	0.48	0.95	0.3	0.45	1.26	0.52	0.39
Azadirachta indica	0.42	0.39	0.75	1.27	1.29	1.2	1.83	0.92	0.6
Cassia fistula	0.78	0.45	0.6	6.98	2.88	4.68	1.92	1.72	2.4
Cassia renigera	0.45	0.6	0.51	6.4	2.91	3.21	6.39	0.36	2.13
Delonix regia	0.39	0.26	0.63	1.51	0.99	1.62	0.88	0.92	0.9
Ficus religiosa	0.21	0.3	0.33	0.61	0.54	0.48	0.84	0.56	0.3
Lagerstroemia indica	0.24	0.3	0.6	0.85	1.08	1.02	1.32	1.24	0.24
Peltophorum pterocarpum	0.27	0.24	0.42	1.23	1.98	1.23	2.1	1.08	1.08
Pongamia pinnata	0.24	0.15	0.24	0.82	0.3	0.66	0.72	0.44	0.12
Samanea saman	0.33	0.69	0.51	2.8	1.29	1.98	1.38	1.56	0.6

Table 2: Chlorophyll Content (mg/g) of Selected Tree Species

Species Name	July	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar
Albizzia amara	6.12	4.03	1.74	12.86	9.44	6.27	9.53	8.79	24.61
Azadirachta indica	34.4	18.46	25.33	23.4	31.1	27.37	20.2	37.16	17.73
Cassia fistula	33.82	10.34	23.85	26.51	13.32	19.48	7.16	13.31	26.2
Cassia renigera	40.19	13.06	25.79	25.77	28.08	35.76	27.6	14.78	29.62
Delonix regia	19	10.28	9.36	21.55	33.75	23.25	21.75	9.68	3.63
Ficus religiosa	9.4	16.83	14.29	23.5	23.8	22.55	22.22	19.53	18.26
Lagerstroemia indica	10.93	8.58	10.44	21.47	22.98	15.56	7.32	16.93	6.67
Peltophorum pterocarpum	17.68	18.98	15.44	7.22	21.15	15.82	18.88	21.04	10.15
Pongamia pinnata	6.42	10.55	4.99	36.1	24.39	21.09	6.02	13.56	30.02
Samanea saman	14.51	38.6	33.86	37.89	14.99	34.15	14.75	24.45	34.22

Table 3: Leaf Extract pH of Selected Tree Species

Species Name	July	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar
Albizzia amara	7	6	6.5	6.5	6.5	6.5	6.5	6.5	6.5
Azadirachta indica	7.1	7	7.5	7.5	6.5	6.5	6.5	6.5	6.5
Cassia fistula	7.1	7	6.5	6.5	7	7.2	7.2	7	6.5
Cassia renigera	7.2	7	6.5	6.5	6.5	6.5	6.5	6.5	6.5
Delonix regia	6.1	6	6.5	6.5	6.5	6.5	6.5	6.5	6.5
Ficus religiosa	7.1	7	6.5	6.5	6.5	6.5	6.5	6.5	6.5
Lagerstroemia indica	7	7	6.5	6.5	7	7.1	7.2	7.1	7.2
Peltophorum pterocarpum	7	7.1	7.2	7.2	6.5	6.5	6.5	6.5	6.5
Pongamia pinnata	7	7.1	7.1	7.2	7.5	7.5	7.5	7.1	7.1
Samanea saman	6.1	7	6.5	6.5	7.1	7.1	7.2	7.1	6.5

Table 4: Relative Water Content (%) of Selected Tree Species

Species Name	July	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar
Albizzia amara	89	92	28	27	29	29	25	90	6
Azadirachta indica	67	69	52	55	62	40	26	15	23
Cassia fistula	89	87	48	44	50	39	34	11	4
Cassia renigera	86	91	50	50	47	49	25	14	15
Delonix regia	59	61	71	73	70	60	44	27	26
Ficus religiosa	87	89	47	48	51	35	30	25	32
Lagerstroemia indica	67	65	29	30	31	26	17	13	24
Peltophorum pterocarpum	40	46	35	37	34	27	22	18	3
Pongamia pinnata	79	82	21	21	25	24	27	50	12
Samanea saman	36	38	19	20	24	22	20	17	12

Table 5: Seasonal Variation in APTI levels of the Selected Tree Species

Species Name	July	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar
Albizzia amara	9.14	9.52	3.2	4.55	3.38	3.51	4.56	9.8	1.82
Azadirachta indica	8.44	7.87	7.66	9.42	11.05	8.02	7.46	5.55	3.78
Cassia fistula	12.08	9.48	6.62	27.45	10.85	16.29	6.16	4.6	8.28
Cassia renigera	10.72	10.29	6.65	25.66	14.76	18.44	24.24	2.21	9.21
Delonix regia	6.87	6.52	8.1	11.52	10.98	10.82	6.86	4.15	3.48
Ficus religiosa	9.04	9.62	5.39	6.63	6.74	4.93	5.36	3.96	3.98
Lagerstroemia indica	7.13	6.97	3.92	5.39	6.34	4.86	3.57	4.27	2.71
Peltophorum pterocarpum	4.67	5.22	4.44	5.45	8.87	5.47	7.51	4.72	2.1
Pongamia pinnata	8.22	8.46	2.39	5.65	3.46	4.31	3.66	5.9	1.65
Samanea saman	4.28	6.95	3.96	14.41	5.24	10.35	4.98	6.57	3.6

4. Discussion

Ascorbic acid or vitamin C is a sugar acid. It is required for normal formation of connective tissue collagen, specifically for hydroxylation of certain porline and lysine residues. It is also required for iron metabolism. It is strong reducing agent losing hydrogen atom readily to become dehydroascorbic acid which has also vitamin C activity. Ascorbic acid acts as antioxidants and protects the cell membrane from the toxic action of powerful oxidising agent. Ascorbic acid is found abundantly in berries, fresh fruits like citrus, guavas, chillies and green leafy vegetables. Ascorbic acid plays a role in cell wall synthesis, defense and cell division. It is a strong reductant and it activates many physiological and defence mechanism. It's reducing power is directly proportional to its concentration [23]. It plays important roles in photosynthetic carbon fixation, with the reducing power directly proportional to its concentration. So it has been given top priority and used as a multiplication factor in the formula of APTI. However it's reducing activity is pH dependent, being more at higher pH levels.

Present study showed elevation in concentration of ascorbic acid of the selected tree species in winter season. Pollution load dependent increase in ascorbic acid content of all the plant species may be due to the increased rate of production of reactive oxygen species during photo-oxidation of SO_2 to SO_3 where sulfites are generated from SO_2 absorbed. Researchers are of the opinion that higher ascorbic acid content of the plant is a sign of its tolerance against sulphur dioxide pollution [8]. In the present study higher baseline levels of ascorbic acid content in the leaves of *Cassia fistula* and *Cassia renigera* suggests its tolerance towards the pollutants which are normally affecting the road side vegetations. Lower ascorbic acid contents in the leaves of other tree species viz. *Pongamia pinnata* studied supports the sensitive nature of these plants towards pollutants, particularly automobile exhausts. Similar studies have also been reported [2, 17, 24].

High pH may increase the efficiency of conversion from hexose sugar to ascorbic acid, while low leaf extract pH showed good correlation with sensitivity to air pollution. Measurement of pH is one of the most common and useful analytical procedures in biochemistry since the pH determines many important aspects of structure and activity of biological macromolecules. It have reported that in presence of an acidic pollutant, the leaf pH is lowered and the decline is greater in sensitive species [26]. A shift in cell sap pH towards the acid side in presence of an acidic pollutant might decrease the efficiency of conversion of hexose sugar to ascorbic acid. However the reducing activity of ascorbic acid is pH dependent being more at higher and lesser at lower pH. Hence the leaf extract pH on the higher side gives tolerance to plants against pollution [3].

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 plant varies from species to species; age of leaf and also with the pollution level as well as with other biotic and abiotic conditions [15]. Degradation of photosynthetic pigment has been widely used as an indication of air pollution [19]. Present study revealed that chlorophyll content in all the species varies with the pollution stress of the area i.e. higher the pollution level in the form of vehicular exhausts lower the chlorophyll content.

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. High RWC favors drought resistance in plants. If the leaf transpiration rate reduces due to the air pollution, plant cannot live well due to losing its engine that pulls water up from the roots to supply photosynthesis. Then, the plants neither bring minerals from the roots to leaf where biosynthesis occurs, nor cool the leaf. Therefore, the product of AA and sum of leaf extract pH and total chlorophyll is added with R, the RWC in the APTI formula. The relative water content in a plant body helps in maintaining it's physiological balance under stress conditions of air pollution [10]. RWC of a leaf is the water present in it relative to its full turgidity. Relative water content is associated with protoplasmic permeability in cells causes loss of water and dissolved nutrients. Therefore, the plants with high relative water content under polluted conditions may be tolerant to pollutants. This was also supported from the present study.

5. Conclusion

The observations in this study suggest that plants have the potential to serve as excellent quantitative and qualitative indices of pollution. Since biomonitoring of plants is an important tool to evaluate the impact of air pollution on plants. Thus the results of the study reveal that the tolerant plant species serves sink to air pollutants as well as indicators. Among the different tree species selected for the study, it can be concluded that species such as *Cassia renigera* and *Cassia fistula* can effectively be used in the air pollution amelioration purposes. The results of such studies are handy for future town planning. It is worth noting that combining a variety of parameters gave a more reliable result than when based on a single biochemical parameter. This study also provides useful information to select tolerant species fit for landscape on sites continuously exposed to air pollutants. By these studies we can conclude that plantations which are done along the side of the road should include tolerant species so that air pollution can be controlled to certain extent.

References

[1] **Agarwal, M., Singh, J. & Rao, D. N.**, 1991. *Bio monitoring of air pollution around urban and industrial sites*, Environ, BIO 211-222.

[2] **Agbaire, P.O. & Esiefarienrha, E**.,2009. *Air pollution tolerance indices of some plants around Otorogun gas plant in Delta State, Nigeria.* Journal of Applied Sciences and Environmental Management, 13:11-14.

[3] **Agrawal, A.L.,** 1988. *Air Pollution control Studies and impact assessment of stack and fugitive emissions from CCI Akaltara Cement Factory.NEERI, Nagpur.*

[4] **Arnon, D. I.,** 1949. *Copper enzymes in isolated chloroplasts polyphenol oxidase in Beta vulgaris.* Plant Physiol, (24) 1-15.

[5] **Bannett, J.H. & Hill, H.C.** 1973. *Inhibition of apparent photosynthesis by air pollutants.* J. Environ. Qual 2 :526-530.

[6] **Barr, H.D. and Weatherly, P. E.,** 1962. A re-examination of the relative turgidity technique for estimating water deficit in leaves. Aust. J. Biol. Sci., 15: 413-428.

[7] **Bernatsky, A.,**1969. *Proc. First European conger. On the influence of air pollution on plants and animals, wageningen*, 383-395.

[8] **Chaudhary, C.S. & D.N. Rao, D. N.,** 1977. *Study of some factors in plants controlling their susceptibility to sulphur dioxide pollution*. Proc. Ind. Natl. Sci. Acad. Part B., 46, 236-241.

[9] **Das Gupta, S.N**. 1957. *Air Pollution in relation to plant disease.* Presidential address, section of Botany, 45th session. Proc. Indian Sci. Cong. Associ. 43:88-107.

[10] **Dedio, W.,**1975. *Water relations in wheat leaves as screening test for drought resistance*, can J.Plant. Sci.,55 :369-378.

[11] **Escobedo, F. J., Wagner, J. E. & Nowak, D. J.,** 2008. *Analysing the cost effectiveness of Santiago, Chile's policy of using urban forests to improve air quality*, Journal of environmental management, 86:148-157.

[12] **Gaikwad, U.S., Ranade, C.D. & Gadgin, J.M.,** 2004. *Plantsa as Bioindicators of Automobile.*

[13] **Gilbert, O.L.,** 1968. *Biological indicators of air pollution*, Ph.D. Thesis, univ. of New castle.

[14] **Jayanthi, V. and R. Krishnamoorthy:** (2006);Status of ambient air quality at selected sites in Chennai. IJEP, 25, 696-704.

[15] **Katiyar, V. & Dubey, P. S.,** 2001. *Sulphur dioxide sensitivity on two stage of leaf development in a few tropical tree species.* Int. J. Environ. Toxicol. 11, 78-81.

[16] **Keller, T. & Schwanger, H.** 1983. *Air pollution and ascorbic acid.* European Jour, pathology. 7 :338-378.

[17] **Kotecha, M., Naik, K., & Abraham, L.,** 2014. *Study of Air Pollution Tolerance Index (APTI) and Distribution Pattern By Using Importance Value Index (IVI) of Plants in Disturbed and Undisturbed Locality around Anand City (India),* Carpathian Journal Of Earth And Environmental Sciences, 9(1):163 – 169.

[18] **Mingorance, M.D., Valdes, B. & Oliva, S.R.,** 2007. *Strategies of heavy metal uptake by plants growing under industrial emissions.* Environ. Intern; 33, 514-520.

[19] **Ninave, S.Y., Chaudhari, P.R., Gajghata D.G., & J.L. Tarar, J. L.,** 2001. *Foliar Biochemical features of plants as indicators of air pollution.* Bull, Environ. Contam. Toxicol. 67: 133-140

[20] **Odiloara, C.A., Egwaikhide, P.A., Esekheigbe, A. & Emua, S.A.**, 2006. *Air pollution Tolerance Indices (APTI) of some plant species around llupeju Industrial Area, Lagos.* Journal of Engineering Science and Applications 4 (2): 97- 101.

[21] **Raina, A.K. & Sharma, A.,** 2006. *Assessment of air pollution and its impact on the leaves of some plant species.* Pollute. Res., 25:543-547.

[22] **Rayappa, M. & Singara Charya, M.A.,** 1993. *Pollution tolerance index in some common plants around some major industries in Warangal city Andhrapredesh.* Poll Res. 12: 57-59.

[23] **Raza, S.H. & Murthy, M.S.R.**,1988. *Air Pollution Tolerance index of certain plants of Nacharam Industrial Area, Hyderabad,* Indian J. Bot 11(1). 91-95.

[24] **Siti Noor Aisyah Mohd Sabr., Mardiana Idayu Ahmad, Yusri Yusup,** 2015. Assessment of Air Pollution Tolerance Index of Selected Plant Species Commonly Found along Roadsides in Pulau Pinang, Malaysia, International Journal of Science and Research (IJSR), 4(11).

[25] **Sadasivam, S. & Manickam, A., 1996.** Biochemical methods. 2nd Edn. New age International Publishers, New Delhi.

[26] **Scholz, F. & Reck, S.,** 1977. *Effects of acids on forest trees as measured by titration invitro inheritance of buffering capacity in Picea.Abies.* Water, Air soil pollut. 8:41-45.

[27] **Singh, S.K. & Rao, D.N.,** 1983. *Evaluation of plants for their tolerance to air pollution.* Symp. On Air Pollution Control. New Delhi, Proceedings, 218-224.
[28] **Tripathi, A., Tripathi, D. S. & Prakash, V.,** 1999. *Phytomonitoring and NOx pollution around silver refineries.* Environ. Pollute; 25:403-410.
[29] **Varshney, C.K.,** 1992. *Buffering capacity of Trees growing near a coal-fired thermal power station. In: Tropical ecosystems: Ecology and Management* (Eds.: K.P. Singh and J.S. Singh), Wiley Eastern Ltd., New Delhi.
[30] **Yan-Ju Liu & Hui Ding** 2001.*Variation in air pollution Tolerance index of plants near a steel factory: Implications for landscape plant species selection for industrial areas:*

Author Profile

Leena Abraham, received her Ph. D. and Masters in Botany from Maharaja Sayajirao University of Baroda, Gujarat. She is B. Sc. And M. Sc. Gold Medalist from same university. Currently she is working as Assistant Professor in Post Graduate and Research Department of Botany, St. Thomas College, Kozhencherry, Kerala.