Comparative Study of Air Pollution Tolerance & Performance Index of Some Plants Growing in an Industrial Area

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Abstract

Plants are well known for their capabilities to reduce air pollution. Plant shows visible changes depending on the intensity level of air pollution. Hence, plants are commonly used as a pollution indicator. It is important that plants used for the development of urban forests, green belts near and around industrial sites must be tolerant to air pollutants.

The current investigation was focused on to screen the five different plants for their air pollution tolerance index (APTI) and anticipated performance index (API). APTI and API were calculated for five different species such as *Pithecellobium dulce*, *Anthocephalous cadamba*, *Ficus benghalensis*, *Butea monosperma* and *Terminalia cattapa* growing in two different areas, i.e. control area (Yeoor forest) and industrial area (polluted site) of Thane (India). Four plants (leaf) parameters i.e. leaf extract pH, total chlorophyll, ascorbic acid and relative water content were selected for the present study to calculate the tolerance index (APTI).

From the selected plants, the highest value of air pollution tolerance index (APTI) and anticipated performance index (API) was registered in *Anthocephalous cadamba* and *Pithecellobium dulce* while lower in *Terminalia cattapa*. Selected plants were assessed for its air pollution tolerance index in both the locations i.e. experimental (polluted) and control sites to compare its tolerance level to air pollution. The present study suggests a suitable alternative for selecting plants based on their tolerance and performance index (API) for greenbelt development in urban and industrial areas.

KEYWORDS: Air pollution tolerance index (APTI), Anticipated performance index (API), Air pollution, Urban Forests, Greenbelt

Introduction

Human-made industrialization and civilization, affecting vastly to the natural environment in a way that its divine beauty, vitality has been completely lost. Worldwide developing cities associated with industrial complexes located near to residential areas, without considering its prolonged effects. Automobile exhaust contributes 60% of air pollution in megacities (Gaikwad, et al., 2004). Vehicular and industrial pollution is responsible for the emission of significant urban air pollutants including nitrogen oxides (NO_x), carbon monoxide (CO), lead (Pb), sulphur oxides (SO_x), suspended particulate matter (SPM), photochemical oxidants such as ozone (O_3) and ozone precursors like hydrocarbons and volatile organic compounds (Costa, 2001).

Plants with greater tolerance index can only survive in the polluted environment. Tolerant plant species act as bio-indicators of air pollution. Biochemical alteration in leaves and air pollutants' adverse effect on plant growth is well-known fact (Rao, 2006; Bhatia, 2006; Sodhi, 2005; Horsefall, 1998).

Screening of plants depending on their susceptibility levels and anticipated performance index (API) will give a more consistent result than those of individual parameter. Resistant plant species having fast growing ability and to stand with rising air pollution will be useful for the abetment of air pollution (Warren, 1973; Singh and Rao, 1983; Tiwari, 1991).

The present study focused on to determine the variation of the biochemical parameters and socio-economic parameters for selecting pollution indicator plant species for the betterment of our environment.

Material and methods

Study area

Kolshet industrial area (Thane) considered as the experimental site (ES) and Yeoor hill forest area as a control site (CS) of the Thane city. Fully matured leaves samples from all trees growing in the ES and CS randomly collected in the early morning from the lower branches (at the height of 2-4 m) for determining APTI and API index. Four plants (leaf) parameters i.e. leaf extract pH, total chlorophyll, ascorbic acid and relative water content were selected for the present study to calculate the tolerance index (APTI).

Relative Water Content (RWC) by estimating the turgid & dry weight of leaf samples by method of Barr and Weatherley (1962). Leaf extract pH was determined by using pH meter after calibrating with buffer solution. Total chlorophyll (Tch) by the method of Arnon (1949) and Ascorbic Acid (AA) by the method of Bajaj and Kaur (1981).

Air pollution tolerance index (APTI)

APTI values determined by the method of Singh & Rao(1983).

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

Where: A=Ascorbic acid content (mg/gm), T=Total chlorophyll (mg/gm), P=pH of the leaf extract, R=Relative water content of leaf (%).

Anticipated performance index (API)

All resultant APTI values correlated with some significant biological and socio-economic characters and the API determined for different species. Based on these traits, different grades (+ or -) were allotted to plants. All plants score according to their performance grades (Mondal et al., 2011).

Table 1: Gradation of plant species based on APTI and other biological and socio-economic characters

S.N.	Grading	Character	Pattern of assessment	Grade allotted
A	Tolerance	Air pollution tolerance index (APTI)	12.0-16.0	+
			16.1-20.0	++
			20.1-24.0	+++
			24.1-28.0	++++
			28.1-32.0	+++++
			32.1-36.0	++++++
B	Biological & Socio-Economic	(i) Plant habitat	Small	-
			Medium	+
			Large	++
		(ii) Canopy structure	Sparse/irregular globular	-
			Spreading crown/ open semi dense	+
			Spreading dense	++
		(iii) Type of plant	Deciduous	-
			Evergreen	+
		(iv) Laminar structure : size	Small	-
			Medium	+
			Large	++
		: Texture	Smooth	-
			Coriaceous	+
		: Hardiness	Delineate	-
			Hardy	+
		(v) Economic value	Less than three uses	-
			Three or four uses	+
			Five or more uses	++

Table 2: API of plant species

Grade	Score (%)	Assessment category
0	Up to 30	Not recommended
1	31-40	Very poor
2	41-50	Poor
3	51-60	Moderate
4	61-70	Good
5	71-80	Very good
6	81-90	Excellent
7	91-100	Best

Statistical analysis:

Correlation coefficient calculated between dependent variable such as APTI and independent variable viz. pH, Tch, RWC, AA and to determine the degree of correlation between the variables by using Analysis ToolPack in Excel.

Results

At the experimental site it is observed that the total chlorophyll content was found higher in *Anthocephalous cadamba* (4.93 mg/gm) and lower in *Ficus benghalensis* (3.26 mg/gm) as shown in Table 3. Significant chlorophyll reduction observed as compared to control site. The leaf extract pH was the maximum in *Ficus benghalensis* (6.8) and minimum in *Terminalia catappa* (3.2). Also, reduction in relative water content was observed highest in *Anthocephalous cadamba* (76.2 %) and lower in *Butea monosperma* (58.5%) at the experimental site. Ascorbic acid content was maximum in *Pithecellobium dulce* (5.51 mg/gm) and the minimum in *Ficus benghalensis* (3.87 mg/gm). The highest value of APTI found in *Anthocephalous cadamba* (12.7), while lowest in *Terminalia catappa* (9.8).

It is revealed that APTI values are higher at control site as compared to the experimental site (Fig.1).

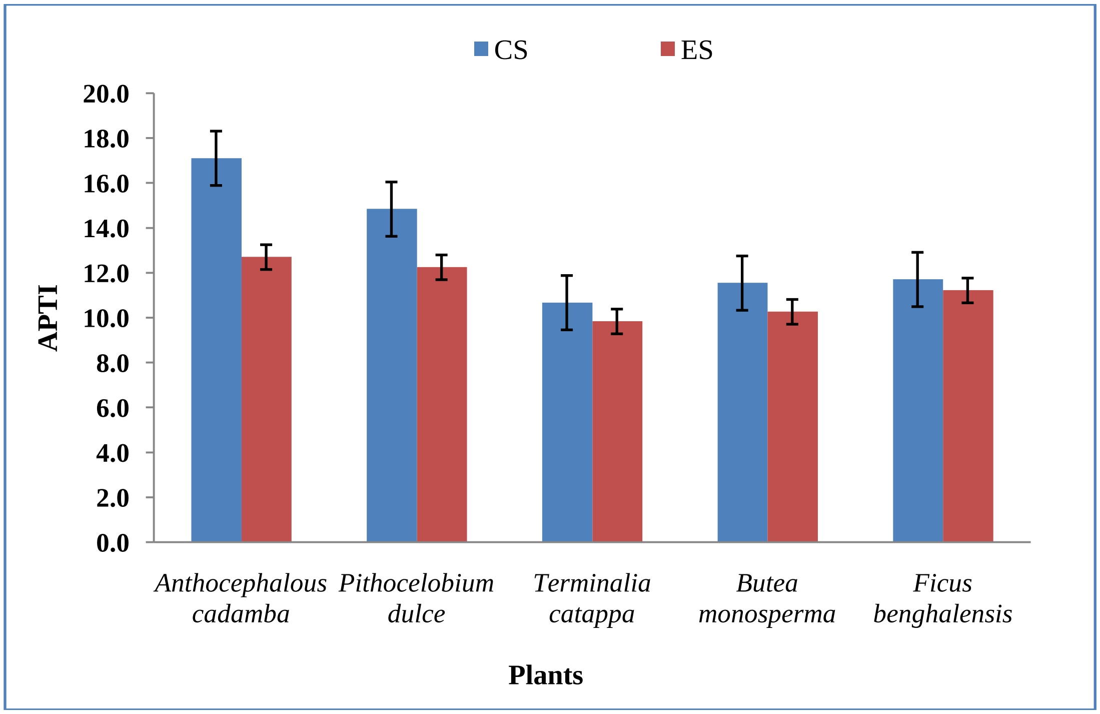
Evaluation of plant species based on APTI value and some biological and socio-economic characters has been done (viz., APTI, tree habitat, canopy structure, tree type, leaf size, texture, hardiness, economic importance as per Table 1 and 2). It is observed that all plants selected scored 81.2% as an excellent API grade except *Terminalia catappa* showed 75% API which scored as very good (Table 4 & 5).

Correlation matrix between biochemical parameters and APTI values at the experimental site given in Table 6 showed strong positive correlation between APTI values, RWC and ascorbic acid.

Table 3: APTI values for plants in control and experimental sites

Sr. No	Botanical Name	Total Chlorophyll (mg/gm)		pH of Leaf Extract		RWC (%)		Ascorbic Acid (mg/gm)		APTI	
		CS	ES	CS	ES	CS	ES	CS	ES	CS	ES
1	*Anthocephalous cadamba*	6.40	4.93	5.1	5.2	80.9	76.2	7.84	5.02	17.1	12.7
2	*Pithecellobium dulce*	5.46	4.34	6.1	5.3	74.2	69.4	6.42	5.51	14.8	12.3
3	*Terminalia catappa*	5.78	4.89	3.4	3.2	75.4	64.2	3.42	4.23	10.7	9.8
4	*Butea monosperma*	4.78	3.93	5.5	6.4	78.7	58.5	3.58	4.28	11.5	10.3
5	*Ficus benghalensis*	4.31	3.26	6.3	6.8	80.3	73.3	3.47	3.87	11.7	11.2

Where, CS – Control site (Yeoor hills), ES – Experimental site (Kolshet Industrial Area)



Where, CS – Control site, ES – Experimental site

Fig.1 APTI of plants at the experimental and control sites

Table 4: Evaluation of plant species based on APTI value and some biological and socio-economic characters

Sr. No.	Scientific name	1	2	3	4	5	6	7	8	Total plus	% Scoring	API grade
1.	*Anthocephalous cadamba*	+	++	++	++	++	+	+	++	13	81.2	Excellent
2.	*Pithecellobium dulce*	+	++	++	++	++	+	+	++	13	81.2	Excellent
3.	*Terminalia catappa*	+	++	++	+	++	+	+	++	12	75	V. Good
4.	*Butea monosperma*	+	++	++	++	++	+	+	++	13	81.2	Excellent
5.	*Ficus benghalensis*	+	++	++	++	++	+	+	++	13	81.2	Excellent

Where: 1-APTI, 2-Tree habitat, 3-Canopy structure, 4-Tree type, 5-Leaf size, 6-Texture, 7-Hardiness, 8-Economic importance

Table 5: Anticipated performance index (API) of plant species

S. N.	Scientific name	Grade allotted			Assessment
		Total	%	API value	
1.	*Anthocephalous cadamba*	13	81.2	6	Excellent
2.	*Pithecellobium dulce*	13	81.2	6	Excellent
3.	*Terminalia catappa*	12	75	5	V. Good
4.	*Butea monosperma*	13	81.2	6	Excellent
5.	*Ficus benghalensis*	13	81.2	6	Excellent

Table 6: Correlation matrix between biochemical parameters and APTI values at the experimental site

	APTI	Total chlorophyll	pH of leaf extract	RWC	Ascorbic acid
APTI	1				
Total chlorophyll	0.151	1			
pH of leaf extract	0.244	-0.830	1		
RWC	0.797	0.054	0.113	1	
Ascorbic acid	0.725	0.513	-0.189	0.283	1

Discussion

Alteration in photosynthetic pigment:

Plants with a high amount of chlorophyll favour the tolerance against pollutants (Prajapati and Tripathi, 2008). In the present study, the total chlorophyll content found higher at control site and lower at the experimental site. Reduction of chlorophyll content has been extensively used as biomarkers of pollution (Ninave et al., 2001). Many researchers reported similar findings in their APTI studies (Bakiyaraj and Ayyappan, 2014; Chaudhary and Rao, 1977; Govindraju, 2012). It is evident that any biochemical changes like inhibition of RuBp carboxylase and reversible inflammation of thylakoids occurred in chloroplast mostly responsible for chlorophyll reduction (Horsman and Wellburn, 1975; Wellburn et al., 1981).

Alteration in ascorbic acid:

Being an important part of plants growth, ascorbic acid acts as an anti-oxidant and helps in decreasing reactive oxygen species (ROS) concentration in leaves (Keller and Schwager, 1977; Liu and Ding, 2008; Pathak et. al., 2011). It was observed from the study that ascorbic acid content found higher than total photosynthetic pigment at the experimental site. It supports the argument that chloroplast is the primary site of an attack by the air pollutants (Speddiing and Thomas, 1973). Elevation of ascorbic acid concentration in plant leaves favours the tolerance in plants towards the pollutants as reported by various scholars (Chaudhary and Rao, 1977; Conklin, 2001; Bakiyaraj and Ayyappan, 2014; Jyothi and Jaya, 2010).

Alterations in leaf extract pH:

The pH in leaf extract was found the maximum in *Ficus benghalensis* and minimum in *Terminalia catappa*. Plants with lower pH are more susceptible than those of neutral pH around seven are more tolerant (Singh and Verma, 2007; Kumar and Nandini, 2013). As per previous research, showed that higher leaf extract pH of plants; especially in polluted condition increase their tolerance level to acidic air pollutants (Govindraju, 2012). Thus it is evident that leaf extract pH was affected by industrial pollution.

Alteration in relative water content (RWC):

As the RWC content in plants is responsible for the protoplasmic permeability and thus favours plants in drought resistance (Singh 1991; Matin et al., 1989). The present study shows decreased level of water content at the experimental site. Due to the effect of pollutants, the relative water content in plants decreases thus resulting in low transpiration rate and visible leaf damages (Swami et al., 2004). *Anthocephalous cadamba* and *Ficus benghalensis* were found with maximum RWC and hence to be tolerant to industrial pollution. Thus, it revealed from the study that industrial pollutants affected on plant's relative water content.

Alteration in APTI:

It is evident from the fig.1 that plants respond differently as they showed different APTI values. The biochemical parameters viz., pH, total chlorophyll content, relative water content and ascorbic acid content showed significant variation, resulting in various APTI values. APTI found the maximum in *Anthocephalous cadamba* and minimum in *Terminalia catappa*. Present study findings support the previous work done that each parameter is equally important for determining the tolerance and sensitivity of plants towards air pollution (Joshi and Swami, 2007 Jyothi and Jaya, 2010). It proves that various industrial pollutants affect plants tolerance.

Anticipated performance index and APTI:

When compared all biochemical parameters with the anticipated performance index of selected plant species it revealed that all plants proved as an excellent grade performers. Among which *Anthocephalous cadamba*, *Pithecellobium dulce*, *Butea monosperma*, *Ficus benghalensis* were categorized as an excellent performer having large canopy structure and hardiness, for the tolerance against air pollution. These plant species also have some medicinal and economic values and thus can act as natural filters of air pollution. Thus, to control the industrial pollution anticipated performance index and APTI might be very useful for the abatement of air pollution.

Correlation matrix interpretation:

All selected biochemical parameters and APTI values showed a positive correlation. Significant positive correlation observed between APTI value, RWC and pH.

Conclusion

The outcome of our results suggests plants with both higher APTI and very good API index viz., *Autocephalous cadamba*, *Ficus benghalensis*, *Butea monosperma* are the most tolerant plants found and useful as a bio-monitoring tool for the betterment of the environment. Hence, these plants can be planted and maintained in the industrial areas to control the effect of air pollution. Air pollution in the urban areas abetted partially by planting tolerant plant species as a greenbelt development initiative. Determination of APTI and API helps in identifying tolerant plant species.

Conflict of interest statement

The authors declared that there are no conflicts of interest.

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