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RESEARCH PAPER

Air Pollution Tolerance Index (APTI) and Expected performance index (EPI) of Selected Plants at RGSC, (BHU), Mirzapur, India

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ABSTRACT

This study carries the evaluation of tolerance of sixteen plants against pollution. These plants have been selected and assessed for several phyto-socio-economic (tree height, canopy, type of tree, laminar structure, hardiness and economic value) and biochemical qualities (pH, Relative water content (R), Ascorbic acid (AA), Chlorophyll a (Chl a), (Chl b), Carotenoids (Car) and total Chlorophyll (TC)) and tested for Air pollution tolerance index (APTI) and Expected performance Index (EPI) and then EPI score used as grades of plants (Not Recommended, Very poor, Poor, Moderate, Good, Very good, Excellent and Best Plus Plant). Statistical analysis tool like correlation matrix among plant parameters and ANNOA test has been applied to understand the relationship among plant parameters and plant species. The best EPI score means best suited plant for the area for plantation and green belt development while plant with lower EPI may be used as bioindicators for the pollution because they are very sensitive for the air pollution.

Keywords: Air Pollution, Bio-indicator, Green Belt, Grading Scale

INTRODUCTION

Minor change in configuration of air may affect the growth, development and persistence of organisms (Chou, 2014). The majority of countries are struggling with air pollution issues today (Santos et al., 2015). Reduction in Emission is the objective of the states today, which may be obtained by Biofiltration (Pathak et al., 2011; Arndt and Schweizer, 1991; Dzierzanowski et al., 2011). A greenbelt is used to restrict air pollution (Sharma and Roy, 1997). It is Preferable to have a green belt of native tree species. To employ sensitive plants as an indicator and tolerating plants as a sink for pollutants, plants must be classified into tolerant and sensitive categories (Kuddus et al., 2011). Any variation in the atmosphere has an impact on physiological processes of plants (Hamraz et al., 2014). When plants are exposed to environmental pollution, they generally go through internal variations before showing visible damage (Lie et al., 2008). Plants react differently to different contaminants; so, plant features can be utilised as bioindicators (Mingorance et al., 2007). Plants acts as sink for pollutants (Joshi et al., 2009). Plants show noticeable alterations according to their sensitivity level (Trivedi and Raman, 2001). Leaves can act as filters which can filter huge amount of air pollutants (Beckett et al., 1998).

APTI is an index that measures a plant's potential to resist air pollution (Chauhan, 2010). APTI is a parameter which determines capability of plants to endure air pollution (Pathak et al., 2011). Chlorophyll content, AA, leaf pH and Relative water content (R), and external factors like temperature, humidity, soil chemistry, soil pH, oxygen levels and salinity

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influence plant susceptibility and tolerance to air contaminants. In different environments, different plants have varied levels of tolerance. Tree leaves in contaminated areas shrank in size, and the stomata changed as well (Panda et al., 2018). APTI assists in the monitoring of air pollution in a specific region over a certain timeframe and is more cost-effective than air samplers (Satpute and Bhalerao, 2017).

EPI is an indicator of expected performance that is derived by incorporating APTI scores with other phyto-socio-economic variables. Plants reduce pollution in the air through collecting, immobilizing, detoxing, aggregating, and/or metabolism (Shannigrahi et al., 2004). APTI and associated phyto-socio-economic parameters can be used to assess the EPI of plants (Chaulya et al., 2001). Biomonitoring is an effective tool because of its sustainability, affordability and eco-friendliness (Badamasi, 2017). Planting is advised for species in the first four groups. Plant species with an EPI higher than 60% are chosen for the following characteristics: (I) native in nature to thrive in microclimatic, soil, and human interactions, (ii) trees reaching a height of 10 m or more with thick perennial foliage, and (iii) fast-growing plant species that hit their peak height in a brief span of time. The aim of this study was to select suitable plant species for the development of a green belt around the research area on the basis of their resistance capability against the air pollution and their bio-socio-economic importance.

MATERIALS AND METHODS

Many researchers had worked on different plants on APTI and EPI in different cities e.g. Haridwar (Nayak, et al., 2018), Coiambatore (Balasubramanian et al., 2018), Sambalpur (Sahu et al., 2020), Allahabad (Kuddus et al., 2011), Varanasi (Prajapati and Tripathi, 2008), Rourkela and Aizawl (Rai et al., 2013), Hyderabad (Raja and Murty, 1988), Virudhunagar (Thambavani and Maheswari, 2012), Asansol (Choudhury and Banerjee, 2009), Thiruvanantapuram (Jyothi and Jaya, 2010), Bangalore (Kumar, 2013), Yamuna Nagar (Sharma et al., 2013), Nanded (Yannawar and Bhosle, 2014) etc. Expressions of APTI and EPI were prepared by combined efforts of many workers (Singh and Rao, 1983; Bora and Joshi, 2014; Mondal et al., 2011; Panda and Rai, 2014; Thambavani and Maheswari, 2012; Raza and Murthy, 1988; Prajapati and Tripathi, 2008).

For the present study sixteen plant species growing in the campus were selected based on density, canopy, leaf structure and height. These species included *Butea monosperma*, *Ficus benghalensis*, *Azadirachata indica*, *Polyalthia longifolia*, *Ficus religiosa*, *Delonix regia*, *Cascabela thevetia*, *Terminalia arjuna*, *Albizzia lebbeck*, *Pongamia glabra*, *Dalbergia sissoo*, *Emblica officinalis*, *Aegle marmelos*, *Accacia catechu*, *Madhuca indica*, *Tamerindus indica.* Forty eight samples were collected from different sites which were selected according to their abundance and growth near sources of pollution. Biochemical analysis of leaf extract considering pH, R, AA, Chlorophyll a (Chl a), (Chl b), Carotenoids (Car) and total Chlorophyll (TC) were conducted by the use of following formulas:-

Leaves extract pH: In 10 mL deionized water, 100 mg of leaf sample was crushed, homogenized and centrifuged; and then the supernatant collected for pH determination using a digital pH meter.

R: It was measured by calculating the fresh weight (W_f), dry weight (W_d) after immersion overnight in distilled water and turgid weight (W_t) of leaves after drying in hot air oven at 105 °C for 2 hour and by the formula of Prajapati and Tripathi (2008):

$$R(\%) = [(W_f - W_d)/(W_t - W_d)] \times 100$$

AA: A spectrophotometer was used to determine the AA concentration of the leaf sample. The extraction solution was used to homogenies a known weight of leaves. (Prepared by oxalic acid and Sodium Salt of EDTA in distilled water). The homogenate was centrifuged for 45 minutes at 4000 rpm. The optical density of the supernatant solution was observed (ES) at 520 nm. The optical density was observed again at 520 nm after adding 2.6 dichlorophenol endophenol (ED). After adding a 1% bleach solution, the optical density was observed at 520 nm once again (ET).

AA content was calculated by Keller and Schwager (1977).

$$\text{Ascorbic acid (mg/g fresh weight)} = \frac{[\{(ED - (ES - ET)\}\ V]}{(W\ X\ 1000)}$$

Where, V is the extract volume, W is the weight of the leaf (g), and optical densities of the blank, plant and AA samples are denoted by ED, ES, and ET, respectively.

Photosynthetic pigments: Leaf sample placed in 80% acetone kept overnight in a refrigerator at 4°C and centrifuged at 4000 rpm for 30 min. The optical density of the solution was measured at 480, 510, 645 and 663 nm respectively using spectrophotometer. Chlorophyll-a, chlorophyll-b, carotenoids and total chlorophyll respectively were calculated by Maclachlan and Zalik (1963).

$$\text{Chl. a (mg/gm) fresh weight} = \frac{\{(912.3\times OD_{663}) - (0.86\times OD_{645})\}\ x\ V}{(D\times 1000\times W)}$$

$$\text{Chl. b (mg/gm) fresh weight} = \frac{\{(19.3\times OD_{645}) - (3.6\times OD_{663})\}\times V}{(D\times 1000\times W)}$$

$$\text{Carotenoied (mg/gm) fresh weight} = \frac{\{(7.6\times OD_{480}) - (1.49\times OD_{510})\}\times V}{(D\times 1000\times W)}$$

$$\text{Total chlorophyll (mg/gm) fresh weight} = \frac{\{(20.2\times OD_{645}) + (8.02\times OD_{663})\}\times V}{(D\times 1000\times W)}$$

Where, OD= optical density, V=volume of pigment extract, W=fresh weight of leaf sample, D=length of light path

APTI calculation: The APTI was measured by method given by Singh and Rao (1983).

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

Where, A is the AA content in mg/g of fresh weight; T is the TC in mg/g of fresh weight; P is the pH of leaf extract and R is the R in percentage.

Expected performance index: Plant species growing in industrial/urban areas are analyzed for various phyto-socio-economic as well as few biochemical parameters-air pollution tolerance index, tree height, canopy, type of tree, laminar structure, hardiness and economic value. These parameters are then subjected to a grading scale to prepare the EPI.

Table 1. EPI of plant species

Arbitrary grade	Score (%)	Assessment for plantation
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 Plus Plant

Table 2. Gradation of plant species (Singh and Rao, 1983)

Grading Character	Parameters	Pattern of assessment	Grade allotted
(a) Tolerance	APTI	9.0-12	+
		12.1-15	++
		15.1-18	+++
		18.1-21	++++
		21.1-24	+++++
(b) Biological and socioeconomic	Plant habit	Small	-
		Medium	+
		Large	++
	Canopy Structure	Sparse/irregular/globular	-
		Spreading Crown/ Open/Semi dense	+
		Spreading dense	++
	Type of Plant	Deciduous	-
		Evergreen	+
(c) Laminar Structure	Size	Small	-
		Medium	+
		Large	++
	Texture	Smooth	-
		Coriaceous	+
	Hardiness	Delineate	-
		Hardy	+
	Economic value	Less than three uses	-

The number of maximum grades that can be scored by a plant is less than 16. The grade can be used to classify a plant's expected performance. The best plus plant are very useful in green belt plantation in an area to the abatement of the pollution (Tiwari and Agarwal, 1994).

RESULTS AND DISCUSSIONS

Table 3 represents the results which clearly show that *Accacia catechu* has lowest APTI value of 7.21 and is a sensitive plant and it may be used as a Bioindicator for air pollution. All the 16 trees which were studied come under sensitive plant category because APTI values were below the standard given above.

Table 3. APTI of plants

S. No.	Plant species	pH	R (%)	Ascorbic acid (mg/g)	Total chlorophyll (mg/g)	Chlorophyll a (mg/g)	Chlorophyll b (mg/g)	Carotenoid (mg/g)	APTI
1	*Butea monosperma*	6.75	56	3.3	4.5	3	1	0.5	9.31
2	*Ficus benghalensis*	7.95	81	2.9	4.5	3	1.5	1.5	11.68
3	*Azadirachata indica*	6.3	77	2.1	11.5	8.5	3	2.5	11.44
4	*Polyalthia longifolia*	6.15	81	3.6	3	2	1	1	11.44
5	*Ficus religiosa*	6.25	84	3.65	8	5.5	2.5	2	13.63
6	*Delonix regia*	6.9	82	2.5	8.5	7	1.5	2.5	12.02
7	*Cascabela thevetia*	6.95	69	2.7	2.5	2	0.5	0.5	9.41
8	*Terminalia arjuna*	7.35	63	2.9	5.5	4.5	0.5	1	9.98
9	*Albizzia lebbeck*	4.35	64	3	1.5	1	1	1.5	8.17
10	*Pongamia glabra*	6.72	79	3.7	7.5	6.5	1.5	1	13.21
11	*Dalbergia sissoo*	6.35	76	3.15	7.5	5.5	2	2.5	11.91
12	*Emblica officinalis*	3.45	75	3.05	6.5	4.5	1.5	1	10.51
13	*Aegel mormelos*	5.6	64	3	6	4	2	1	9.83
14	*Accacia catechu*	5.9	56	0.9	12.5	10	2.5	2	7.21
15	*Madhuca indica*	4.55	73	2.85	4	3	1	1	9.77
16	*Tamerindus indica*	3.2	69	3.45	5.5	4	1	0.5	9.89

Table 4. Correlation matrix of different parameters
(Significant correlation are indicated by star in superscript)

	pH	RWC (%)	Ascorbic acid (mg/g)	Total chlorophyll (mg/g)	Chlorophyll a (mg/g)	Chlorophyll b (mg/g)	Carotenoid (mg/g)	APTI
pH	1							
RWC (%)	0.155	1.000						
Ascorbic acid (mg/g)	-0.097	0.397	1.000					
Total chlorophyll (mg/g)	0.122	0.061	-0.575*	1.000				
Chlorophyll a (mg/g)	0.156	0.044	-0.596*	0.987*	1.000			
Chlorophyll b (mg/g)	0.052	0.220	-0.388	0.822*	0.744*	1.000		
Carotenoid (mg/g)	0.248	0.378	-0.422	0.655	0.633*	0.730*	1.000	
APTI	0.338	0.872*	0.552*	0.169	0.150	0.274	0.321	1.000

The correlation matrix shows that there is significant positive correlation exists between APTI and RWC ($r= +0.872$, $p<0.05$) as well as between APTI and AA ($r=+0.552$, $p<0.05$). So higher values of RWC and AA indicates for the higher APTI values.

The F values of Plant species (Table 5) and socio-biological Parameters of plants are higher than the F-critical values, which indicate that there is significant differences present among APTI values of plant species.

Table 5. ANOVA Table

ANOVA						
Source of Variation	**SS**	**df**	**MS**	**F**	**P-value**	**F-critical**
Plant species	347.8998	15	23.19332	1.996183	0.022079	1.762656
Parameters	64004.09	7	9143.441	786.9501	1.18E-87	2.098005
Error	1219.977	105	11.61883			
Total	65571.97	127				

Expected performance index (EPI): The EPI is used to determine which species are suitable for the formation of green belts. The EPI of plants sampled was examined. *Madhuca indica* has the highest EPI grade (4) which is obtained through the (+) grade and score (%), with the help of table. This plant can be suggested for the plantation because it comes under arbitrary grade 'GOOD'. All other remaining species comes under 0, 1, 3 EPI grade which come under arbitrary grade 'not recommended', 'very poor' and 'moderate category' respectively.

Since, plant distribution varies with varying climatic conditions it is expected that similar plant species will be present in particular climatic regions and the plant species are expected to perform in the same way in varying air quality indices in a particular region.

Table 6. EPI of plant species

S. No.	**Name of the plant**	**APTI**	**Tree habit**	**Canopy structure**	**Type of tree**	**Laminar structure**		**Economic value**	**Hardiness**	**Grade obtained**		**EPI grade**
						Size	**Texture**			**Total (+)**	**% Scoring**	
1	*Butea monosperma*	+	+	-	+	++	+	++	+	9	53	3
2	*Ficus banghalensis*	+	++	+	+	++	+	+	+	10	59	3
3	*Azadirachata indica*	+	++	++	-	+	-	++	+	9	53	3
4	*Polyalthia longifolia*	+	+	+	+	+	-	-	-	5	29	0
5	*Ficus religiosa*	++	++	+	+	++	-	+	+	10	59	3
6	*Delonix regia*	++	+	-	+	-	-	-	-	4	24	0
7	*Cascabela thevetia*	+	-	-	+	+	-	-	-	3	18	0
8	*Terminalia arjuna*	+	+	+	+	+	-	-	-	5	29	0
9	*Albizzia lebbeck*	+	+	+	+	-	-	-	-	4	24	0
10	*Pongamia glabra*	++	+	-	+	+	+	-	-	6	35	1
11	*Dalbergia sissoo*	+	++	++	+	+	-	++	+	10	59	3
12	*Emblica officinalis*	+	+	-	+	-	-	+	-	4	24	0
13	*Aegelia marmelos*	+	+	+	+	+	-	+++	+	9	53	3
14	*Accacia catechu*	-	+	-	-	-	+	-	+	3	18	0
15	*Madhuca indica*	+	++	++	-	++	+	++	+	11	65	4
16	*Tamrindus indica*	+	++	+	-	-	-	+	+	6	35	1

CONCLUSIONS

This research reveals that evaluating the expected performance index of various plants will be quite valuable when selecting tree species for greenbelt construction. For green belt, plants with higher APTI and EPI values are recommended. The plants recognized as excellent, very good and good performers are recommended for plantation. Other species were also recommended for high socio-economic and aesthetic values like *Madhuca indica, Butea monosperma, Ficus religiosa, Ficus banghalensis, Azadirachata indica, Dalbergia sissoo, Aegle marmelos*. EPI does not advocate the planting of *Accacia catechu, Polyalthia longifolia, Delonix regia, Cascabela thevetia, Terminalia arjuna, Albizzia lebbeck, or Emblica officinalis.* The most sensitive plant is *Accacia catechu* with very low APTI and may be utiliized as Bioindicator for air pollution monitoring while *Ficus religiosa*, and *Pongamia glabra*are are the plants with the highest tolerance at the RGSC (BHU). Overall low value of all the parameter and APTI indicates that this area is pollution free and plant biochemical parameter show uniform behavior against the pollutants means pollution is under tolerance limit. The change in pH and carotenoids behavior because of high temperature (sample was collected in month May - June).

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