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AMBIENT AIR POLLUTION CONTROL USING AIR POLLUTION TOLERANCE INDEX AND ANTICIPATED PERFORMANCE INDEX OF TREES

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ABSTRACT

Bio-indicators and tolerant tree species have been confirmed as eco-sustainable tool for monitoring and abatement of atmospheric air pollutants. This study was designed to estimate the potential of six common tree species growing at residential areas of Ota industrial estate and Canaanland in Ota, Ogun State, Nigeria; using air pollution tolerance index (APTI) and anticipated performance index (API) model. The APTI results ranged between 2.98 and 12.0 which fell within APTI category of <11 for sensitive species, and 12-16 intermediate sensitive species as such they were classified as bio indicators of air pollution. Also, API confirmed Mangifera indica and Syzygium malaccense as very good performers while Terminalia catappa and Carica papaya were considered as moderate performers suitable for green belt development programmes. Further comparative screening of green infrastructure using APTI-API model and big-leaf resistance model, as well as application of green walls and roofs in the study locations is recommended.

Keywords: Environmental pollution, Air pollution control, APTI, API, Urban green infrastructures

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1. INTRODUCTION

Environmental stress in the form of deteriorating air quality, noise pollution, water pollution, solid waste pollution and traffic congestion is a disturbing trend due to increased industrialization and urbanization [1 - 6]. To curb this menace, effort of scientists, engineers and policymakers toward improved technology via upgrading of existing processes and designing of new processes is an inevitable solution [7-9]. Another suitable option includes but not limited to urban green infrastructures (UGI). UGI have been reported for improving air quality by several researchers [10-12]. Some examples include trees [13-15], shrubs [16-18], green walls [19] and green roofs [20-21]. Exception of mitigation of air pollution, other important benefits of UGI are reduction of urban heat, aesthetic and economic benefits from trees [22-23], energy saving, noise reduction, and ecological preservation by green roofs [11, 24-25], and potential for energy saving using green walls [20, 25-26].

Cultivation of plants at different strata such as trees, shrubs, herbs and climbers serves as an effective and economic measure for the abatement of air pollution by filtering, intercepting and absorbing pollutants [27]. Different plant species have shown good potential in reducing pollution levels in the atmosphere to varied extents by providing sizable leaf area for air pollutant impression, absorption and accumulation [28-29]. Identification of these appropriate plant species are normally screened following certain physicochemical characteristic which is embedded in two methodology or indices commonly known as air pollution tolerance index (APTI) and anticipated performance index (API). APTI provides information on plants ability to act as sensitive or tolerance species based on certain examined biochemical parameters (pH of leaf extract, ascorbic acid content, relative water content, and total chlorophyll content) [1, 27, 28]. API involves the screening of appropriate plant species using some relevant biological and socioeconomic parameters such as leaf surface and texture, canopy structure, tree height and hardness along with the APTI value [29-31]. Values obtained from APTI and API are further subjected to a grading scale to assess tolerance, bio-monitoring and performance ability. These parameters have been useful in the choice of suitable green infrastructures for air pollution abatement programme [30-34].

Ota industrial estate and Canaan land is situated in Ota, the capital of Ado-Odo/Ota local government area both in Ogun State, Nigeria. The industrial estate is faced with increasing levels of air pollutants, among which elevated levels of fine particulate matter ($PM_{2.5}$) and bioavailable metals such as Cr, Cd etc., have been identified as the dominant pollutants [3, 35]. Canaanland is a non-industrial community, with a mix of Church, Schools and Commercial activities. Following the dearth of monitoring stations for particulate and gaseous pollutants, lack of air quality index system and inadequate enforcement of pollution control by authorized agencies [2]. There is need for adopting greener measures for ambient air pollution control. Hence, the objective of this work is to: (1) screen the pollution tolerance ability and performance scores of common economic trees in the residential areas of Ota and Canaanland: (2) to identify appropriate trees suitable for the development of a greener environment.

2. MATERIALS AND METHODS

2.1. Study Location

The focus of this study was on a densely populated residential location within Ota Industrial Estate and Canaan Land Residential areas designated as OTR (*06 ˚40.325 N. 003 ˚12.143 E)* and CLR (06 ˚40.936 N, 003 ˚10.282E) respectively. OTR is surrounded by several industries such as Tower, Kolorkote Nigeria Limited, LEXCEL Limited, Vego Nigeria Limited, West African Building Materials, MINL Nigeria Limited, Human Nigeria Limited (steel and galvanized pipes). The access road are unpaved roads, contributing to a very dusty environment. CLR is majorly surrounded by residential estates, filling stations, banks, schools, cafeteria, publishing house, bakery water/drinks manufacturing company, etc. Lots of trees can be seen in this environment with less pollution generating activities.

2.2. Plant Sampling

The matured leaves of six common trees species were collected in triplicates along with the stalk in the early hours of the day from January to March, 2016. The botanical name of collected samples and their common names are as follows OTR: *Mangifera indica* (Mango), *Carica papaya* (Pawpaw), and *Citrus sinensis* (Orange); CLR: *Syzygium malaccense* (Malay apple), *Terminalia catappa* (Almond) and *Fiscus triangularis* (Triangle Ficus). Samples were packed in an aluminium foil wrapper to avoid moisture loss, they were identified, and preserved in the refrigerator.

*2.3. B*iochemical Parameters Analysis

Biochemical parameters analysed were relative water content (R), pH of leaf extract (P), total chlorophyll content (T) and ascorbic acid content (A). 5 g of fresh leaf material was ground with agate mortar and pestle, mixed in 50 ml of distilled water, after which the leaf extract pH of the filtrate was measured with calibrated digital pH metre [31]. Relative water content was computed using a modified method of Pathak et al. [20]. The fresh weight of leaves sample was weighed and recorded. The samples were dipped in water for 24hrs, blotted to dryness and reweighed to determine the turgid weight of the leaves. Thereafter, dry weight of the turgid leaves was oven dried overnight at 60°C, and re-weighed. The leaves ascorbic acid content was analysed following the spectrophotometric method of Prajapati and Tripathi [32]. Total chlorophyll content was evaluated following the method by Arnon [36]. The extracts were centrifuged for 3 minutes at 2,500rpm for thorough separation. The supernatant absorbance was measured at 645 and 663 nm using a UV spectrophotometer and further calculated according to Arnon’s equation [36, 37].

2.4. Air Pollution Tolerance Index (APTI)

The method for the estimation of APTI value of plants was developed by Singh and Rao [37] as follows:

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

Where A is the ascorbic acid content (mg/g), T is the total chlorophyll (mg/g), P is the pH of the leaf extract, and R is the relative water content of leaf (%). Following the APTI groupings, three categories were used to ascertain plants resistivity or susceptibility to air pollution as follows: ≥ 17 as tolerant, 12-16 as intermediate and 1-11 as sensitive [38, 39].

2.5. Anticipated Performance Index (API)

The APTI value, along with various plant parameters including plant habit, size, texture, hardiness, canopy structure, economic value etc. [31, 33, 40] was employed in API computation following the grade distribution pattern which apportion plants into grade, scores and differs assessment categories as follows: Grade 0 is scored < 30%, assess as not recommended; grade 1 is scored 31- 40%, assess as very poor; grade 2 is scored 41-50%, assess as poor; grade 3 is scored 51-60%, assess as moderate; grade 4 is scored 61-70%, assess as good; grade 5 is scored 71-80%, assess as very good; grade 6 is scored 81-79%, assess as excellent and grade 7 is scored 91-100%, assess as best [30, 32, 33]. API is further computed thus:

$$API = \frac{No.of \text{ "+" } obtained}{Total\ No.of \text{ "+" }} \times 100$$

3. RESULTS AND DISCUSSION

3.1. Biochemical Analysis

Table 1 refers to the results of ascorbic acid content (A), total chlorophyll content (T) pH of leaf extract (P), and relative water content (R) which gives a collective information on the investigated samples biochemical parameters. In polluted conditions, cell membrane ability of plants to maintain their permeability is indicated by the relative water content [41-42]. Following the strength of different plant species, relative water content values may range from 30-40% to ≥ 95% in severely desiccated leaves to turgid transpiring leaves respectively. Table 1 shows higher relative water content ranging from 61.80 - 94.50 among the investigated tree species at OTR and CLR with exception of 21.50 recorded by *Fiscus triangularis* in the later. The plants studied shows a difference in tolerance degree as a reflection of the variations in the relative water content.

Table 1. Biochemical parameters and air pollution tolerance indices (APTI) of the studied tree species

Study Area	Taxon	Family	A (mg/g)	T (mg/g)	P	R (%)	APTI	Rating
Ota Residential	*Mangifera indica*	*Anacardicaceae*	2.15	1.05	4.41	94.50	10.60	Sensitive
(OTR)	*Carica papaya*	*Caricaceae*	3.60	0.62	6.50	72.10	9.77	Sensitive
	Citrus sinensis	*Rutaceae*	3.34	1.74	6.01	61.80	8.77	Sensitive
Canaanland Residential	*Syzygium malaccense*	*Myrtaceae*	0.38	1.09	2.88	90.80	9.23	Sensitive
(CLR)	*Terminalia catappa*	*Combretaceae*	5.16	1.09	4.51	88.90	12.0	Intermediate Sensitive
	Fiscus triangularis	*Moraceae*	1.72	0.48	4.33	21.50	2.98	Sensitive

The results of the extract pH are shown in Table 1. Low leaf extract pH values of 4.41-6.50 and 2.88-4.51 were observed in OTR and CLR respectively across the studied plants. This implies reduction in the photosynthetic activities of the plant species, an indication of atmospheric presence of acidic pollutants [40, 43]. With respect to the total chlorophyll content, lower and higher value of 1.05 and 1.74 mg/g were recorded by *Mangifera indica* and *Citrus* *sinensi* respectively in OTR. Similarly, lower value of 0.48 mg/g were recorded by *Fiscus triangularis* while both *Syzygium malaccense* and *Terminalia catappa* recorded higher value of 1.09 mg/g in OTR. Chlorophyll content varies with plant species, leaf age, as well as the pollution stress. Lower chlorophyll content reflects increased in the sensitivity of the plant species, and *vice versa*. Overall, the decreased in total chlorophyll content is a reflection of higher sensitivity of all plant species across the studied locations [15, 31, 33, 40, 41, 43].

Results of the ascorbic acid content in OTR and CLR showed that *Carica papaya recorded* 3.60 mg/g against *Mangifera indica* having the lowest ascorbic acid content of *2*.15 mg/g and *Terminalia catappa recorded 5*.16 mg/g against *Syzygium malaccense* having the lowest ascorbic acid content of *0*.38 mg/g. In this study, *Carica papaya and Terminalia catappa in OTR and CLR* respectively, exhibited higher pH values as well as higher ascorbic acid contents, establishing a correlation pattern between both biochemical parameters. This finding is in line with other research work, which associated the decreased in ascorbic acid content to the pH of the leaf extract [43-45].

3.2. Air pollution tolerance index (APTI)

The gradation of all computed tree species is shown in Table 1. APTI values of *Mangifera indica*, *Carica papaya and Citrus sinensi,* for OTR ranged from 8.77 to 10.60, while that of *Syzygium malaccense*, *Terminalia catappa* and *Fiscus triangularis* for CLR ranged from 2.98 to 12.0 respectively. All plants but one (1) were found within the APTI range of 1 to 11, and thus categorized as sensitive plant species. Only *Terminalia catappa* had APTI value of 12 classifying it as intermediate sensitive specie [15, 39-40]. Based on the APTI gradation all investigated tree species in OTR and CLR were considered as bio-indicators of ambient airborne pollution. Furthermore, *Ficus triangularis* with 2.98 APTI values was identified as the most sensitive amongst the species studied and was only common to CLR study site.

3.3. Anticipated Performance Index (API)

Table 2 and 3 presents the API result based on gradation parameters discussed in section 2.5. As shown in Table 2, 75 % was the highest grade obtained by *Mangifera indica and Syzygium malaccense* from OTR and CLR respectively. The moderate grade of 56.3 % was found with *Carica papaya* and *Terminalia catappa* from OTR and CLR respectively while 37.5 % and 31.2 % was recorded by *Citrus sinensis* and *Fiscus triangularis* from OTR and CLR respectively. Higher API values is used in identifying tree species suitable for plantation purpose and in developing suitable green belt programme. Table 3 shows the performance of individual tree species. *Mangifera indica and Syzygium malaccense* are categorized as very good performers. Similarly, *Carica papaya* and *Terminalia catappa* are identified as moderate performers while *Citrus sinensis* and *Fiscus triangularis* are classified as very poor performers. *Carica papaya* result obtained in this study compares with the results reported in literature [24], while *Mangifera indica* was reported as very good performer [30-31]. Tree species within API gradation of excellent to moderate performers are recommended suitable for air pollution mitigation [15, 30, 31, and 33].

Table 2. Evaluation of plant species based on their APTI values, biological parameters and socioeconomic importance

Study Area	Taxon	APTI	Plant habit	Canopy structure	Type of tree	Laminar		Economic importance	Hardiness	Grade allotted	
						Texture	Size			Total plus(+)	Scoring (%)
	Mangifera indica	+	++	++	+	+	++	++	+	12	75
OTR	*Carica papaya*	+	++	+	+	-	+	++	+	9	56.3
	Citrus sinensis	-	+	++	+	-	-	+	+	6	37.5
	Syzygium malaccense	+	++	++	+	+	++	++	+	12	75
CLR	*Terminalia catappa*	+	++	++	+	-	-	++	+	9	56.3
	Fiscus triangularis	-	++	+	+	-	-	-	+	5	31.3

Table 3. Anticipated Performance Index (API) value of the studied Tree species

Study Area	Taxon	Grade allotted		API value	Assessment
		Total plus (+)	Percentage (%)		
OTR	*Mangifera indica*	12	75	5	Very good
	Carica papaya	9	56.3	3	Moderate
	Citrus sinensis	6	37.5	1	Very Poor
CLR	*Syzygium malaccense*	12	75	5	Very good
	Terminalia catappa	9	56.3	3	Moderate
	Fiscus triangularis	5	31.2	1	Very Poor

4. CONCLUSIONS

Both APTI and API have been confirmed as very effective tools in selecting tree species for polluted locations. Variation in (A), (T), (P) and (R) biochemical parameters which collectively reflects the APTI values have been highlighted. In the present study, the highest APTI value was observed for *Terminalia catappa* (12.0) while *Fiscus triangularis (2.98)* had the lowest. It further identified the plants species; *Mangifera indica*, *Carica papaya, Citrus sinensis Syzygium malaccense*, *Terminalia catappa* and *Fiscus triangularis* as pollution sensitive species that can serve as bio-indicators of air pollution for the OTR and CLR study locations in Ota. API scores highlighted, *Mangifera indica and Syzygium malaccense* as very good performers while *Terminalia catappa* and *Carica papaya* were considered as moderate performers for green infrastructure project in the investigated study locations. The comparative analysis of other air pollution mitigation model for screening of trees, investigation on green walls and roofs, identification of tolerant species and excellent performer's trees is required.

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