Tree Species for bio-monitoring and Green Belt Design: A Case Study of Ota Industrial Estate, Nigeria

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Abstract. Bio-chemical and physiological parameters of plants have been employed in the screening of suitable bio - monitors via the estimation of air pollution tolerance index (APTI) and anticipated performance index (API). In the present study, five plant species, *Elaesis guineensis, Mangifera indica, Terminate catappa, Musa spp and Araucaria heterophylla* within high concentrated industrial areas of Ota industrial estate were evaluated based on these two indices. APTI for all plant species ranged from 3.43 to 10.1 signifying their bio-monitoring status. Out of five species, *Terminate catappa* was identified as the most sensitive. Following API classification, *Mangifera indica* was graded as a good performer while *Elaesis guineensis* and *Terminate catappa* were grouped as moderate performers for green belt development. Further evaluation of screened trees for high grade tolerant species and carbon sequestration potential is recommended.

1. Introduction

Ambient air pollutants such as particulate matter and gaseous mixture released into the atmosphere from industrial chimneys, stacks, open burning of solid waste and mobile sources like cars have dramatically increased in Ota industrial estate, Nigeria [1] – [3]. The pollutants concentrations depend on the characteristics of the source of pollution such as influence area, meteorological and topographical conditions [4].

Different plant species have shown varied potentials in reducing air pollution levels by providing sizeable leaf area for air pollutant impression, absorption and accumulation [5], [6]. The impact of air pollution on the plants can be evaluated from a combination of Air Pollution Tolerance Index (APTI) and Anticipated Performance Index (API). APTI is a tool used for the identification and classification of plants into tolerant and sensitive group based on variation in the biochemical parameters namely relative water content, pH of leaf extract, total chlorophyll content and ascorbic acid content. It has been used by several researchers for the selection of air pollution tolerant species in industrial areas [7], [8]. Based on the response of plant towards a particular stress, they can be classified as sensitive or tolerant [9].

The anticipated performance index value gives a good and sensible reason to classify different plant species for the development of green belt, reforestation and afforestation. It takes into consideration the air pollution tolerance index as well as the biological and socio-economical parameters of plant. API is very useful in the selection of plants that can perform dual functions of improving air quality and providing appealing and recreational value [10], [11].

Hence, the objectives of the present study were to investigate the potentials of trees within the high concentrated industrial areas of Ota industrial estate, Ogun state, Nigeria for (a) monitoring environmental pollution, and (b) green belt design.

2. Materials and Methods

2.1. Sample collection
Plant species namely *Elaesis guineensis, Mangifera indica, Terminate catappa, Musa spp* and *Araucaria heterophylla* were collected in triplicates between 7 and 11am for a period of 3 months (January to March, 2018) around Federated mill, gas plant, horticulture garden and Alluminium tower in Ota industrial estate, Ogun State, Nigeria. The collected samples were wrapped in a foil paper, preserved in ice chest box and transported immediately to the laboratory for identification. Afterwards, samples were washed with distilled water, air dried, ground and refrigerated.

2.3. Determination of Leaf Bio-chemical Parameters
In order to determine the bio-chemical parameters of plant species, four (4) parameters were evaluated, they are; pH of leaf extract, total chlorophyll content, ascorbic acid content and relative water content of the leaf. For pH of leaf extract, 4 g of fresh leaves was extracted in 40 mL distilled water, filtered and measured using a glass electrode pH [12]. The relative water content was determined according to [12], [13]. Analysis of total chlorophyll content was done by extracting 1 g of ground fresh leaves with 10 mL acetone for 15 minutes using a centrifuge at 2500 rmp for 3 minutes and the absorbance was taken at 643nm, 645nm and 663nm with ultraviolet spectrophotometer (Genesys). Further calculations were done according to Arnon equation [12], [13]. For ascorbic acid determination, 1g leaves was extracted with 4 mL oxalic acid-EDTA solution, 1 mL orthophosphoric acid, 2 mL of 5% sulphuric acid, 4 mL of ammonium molybdate and 3 mL of water. After 15 minutes, the absorbance of the filtered extract was taken at 730 nm with a spectrophotometer [13], [14].

2.4. *Determination of Air Pollution Tolerance Index (APTI)*
The method of calculating the APTI was proposed by [15]

$$APTI = A(T+P)+R/10 \tag{1}$$

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

2.5. *Determination of Anticipated Performance Index*
The APTI value combined with some biological and socio economic characters such as plant habit, canopy structure, type of plant and economic value as shown in Table 1 was used in evaluating the API of

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various plants. Table 2 indicates the various categories of plant species based on their API score [9], [16]. Anticipated performance index (API) was calculated as follows:

$$API = \frac{No.of\ "+"\ obtained}{Total\ \ No.\ of\ "+"} \times 100 \tag{2}$$

Table 1. Grade distribution of plant species with respect to APTI, biological parameters and socioeconomic importance.

Character	Character State	Pattern of assessment	Grading allotted
Tolerance	APTI	9.0–12.0	+
		12.1–15.0	++
		15.1–18.0	+++
		18.1–21.0	++++
		21.1–24.0	+++++
Biological	Plant habit	Small	-
		Medium	+
		Large	++
	Canopy structure	Sparse/irregular/globular	-
		Spreading crown/open/semi-dense	+
		Spreading dense	++
	Type of plant	Deciduous	-
		Evergreen	+
Laminar structure	Size	Small	-
		Medium	+
		Large	++
	Texture	Smooth	-
		Coriaceous	+
	Hardness	Delineate	-
		Hardy	+
Socio economic	Economic value	< 3 uses	-
		3 or more uses	+
		5 or more uses	++

Table 2. Anticipated performance index (API) of plant species.

Grade	Scores (%)	Assessment category
0	< 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

3. Results and Discussion

3.1 *Bio-chemical Analysis of Plants*

The results of the bio-chemical parameters for various plants are presented in Table 3. The RWC ranged from 91.5 to 25.1 as observed in *Musa spp* and *Terminate catappa* respectively. High RWC in plants regulate the physiological performance of plants that are exposed to high concentration of atmospheric pollutants and favours tolerance to pollution [14], [17]. Maximum and minimum TC content in this study was observed in *Musa spp* (1.13 mg/g) from horticulture farm and Elaesis guineensis (0.356 mg/g), located near Federated mill surrounded by several industries. A reduction in the TCC content in plants leaves is a function of blockage of stomatal opening/ closing by pollutants, drought, heavy metals accumulation in the soil etc. [18], [19]. Hence, increased in pollution levels lowers the chlorophyll content [20]. The low and high TTC contents in plant leaves exhibits sensitive and tolerance ability of plants in polluted environments [21]. pH of plant species showed the highest and lowest potential of hydrogen ion concentration in leaf extract of *Araucaria heterophylla* (6.60) and *Musa spp* (5.47) respectively. A lower pH value shows good correlation with sensitivity to air pollution and also reduces photosynthesis process in plants.Plants with pH lower than 7 are more susceptible while those with pH around 7 are more tolerant to pollution. Earlier findings indicate that a reduction of ascorbic acid content in plants is pH dependent [22]–[25]. As such, change in leaf extract pH can influence the stomatal sensitivity due to air pollution [26] – [28]. In addition, *Araucaria heterophylla* (1.58) and *Elaesis guineensi* (0.578) recorded the highest and lowest ascorbic acid contents respectively. Ascorbic acid is a strong reductant and it activates many bio-chemical and physiological activities of the cell such as cell wall synthesis and cell division. It is generally higher in tolerant plant species due to its stress reducing factor [29], [30].

Table 3. Biochemical parameters and air pollution tolerance indices (APTI) of the studied plant species.

Sample code	Taxon	Common name	A(mg/g)	P	T(mg/g)	R(%)	APTI	Rating
Federated Mill	*Elaesis guineensis*	Oil Palm	0.578	6.00	0.356	89.4	9.31	Sensitive
	Mangiferia indica	Mango	1.40	5.91	0.599	66.6	7.57	Sensitive
By Gas plant	*Terminate catappa*	Almond	1.43	5.73	0.691	25.1	3.43	Sensitive
Honda/Horticulture	*Musa spp*	Plantain	1.36	5.47	1.13	91.5	10.1	Sensitive
Aluminum Tower	*Araucaria heterophylla*	Christmas Tree	1.58	6.60	0.549	28.9	4.02	Sensitive

3.2.*Assessment of APTI and API of tree species for green belts*

Table 3 shows the APTI values for the five investigated tree species within the Ota industrial estate. APTI, provides information on plants based on their sensitivity and tolerance to air pollutants using the bio-chemical parameters and APTI grading. APTI of screened plant species ranged from 3.43 (*Terminate catappa*) to 10.1 (*Musa. spp*). Based on APTI, plant species have been categorized into three gradations. Plants with APTI value 1 to11 are termed sensitive, 12 to 16 are known as intermediate and those with APTI ≥ 17 classified as tolerant [10], [14], [31]. Present finding suggested that *Elaesis guineensis, Mangifera indica, Terminate catappa, Musa spp* and *Araucaria heterophylla* can be used for biomonitoring of air pollution since their APTI value occurred in the ranged of sensitive species (APTI=1 to 11).

The API score categories presented in Table 1, were used in allotting scores for different selected plants as shown in Table 4 and 5. Plant species found under API category of excellent, very good, good and moderate performers can be recommended for cultivation as green belts species [16], [18], [32]. In the present study, according to table 4 and 5, tree species *Mangifera indica* (API = 4) was screened as a good performer, *Elaesis guineensis* and *Terminate catappa* (API = 3) as moderate performers while *Musa spp L.* and *Araucaria heterophylla (API =2)* were evaluated as poor performers. The API assessment of the tree species showed that *Mangifera indica, Elaesis guineensis* and *Terminate catappa* could be cultivated as ideal species for green belts, in the study area, to alleviate pollution [17].

Table 4. Evaluation of plant species based on their APTI values, biological parameters and socioeconomic importance.

Taxon	APTI	PH	CS	TT	LT	LS	EI	Hardiness	Grade allotted	
									Total plus (+)	Scoring %
Elaesis guineensis	+	++	+	+	-	+	++	+	9	56.2
Mangifera indica	-	++	++	+	+	++	++	+	11	68.8
Terminate catappa	-	++	++	+	+	-	++	+	9	56.2
Musa spp L.	+	+	+	+	-	++	+	_	8	50
Araucaria heterophylla	+	++	+	+	+	-	+	+	8	50

APTI: Air pollution tolerance index; PH: Plant habit; CS: Canopy structure; TT: Type of tree; LS: Laminar size; LT: Laminar texture; H: Hardiness and EI: Economic importance

Table 5. Anticipated Performance Index (API) value of the studied plant species.

Taxon	Grade allotted		API value	Assessment
	Total plus (+)	Percentage %		
Elaesis guineensis	9	56.2	3	Moderate
Mangifera indica	11	68.8	4	Good
Terminate catappa	9	56.2	3	Moderate
Musa spp L.	8	50	2	Poor
Araucaria heterophylla	8	50	2	Poor

4. Conclusions

Evaluation of anticipated performance index of plants is an important index for screening appropriate tree species. APTI gradation highlighted *Terminate catappa* as the most sensitive among other five species. *Mangifera indica, Elaesis guineensis* and *Terminate catappa* were found suitable for greenbelt design in Ota industrial estate.

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6. References

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