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Screening of Plant Species Response and Performance for Green Belt Development: Implications for Semi-Urban Ecosystem Restoration

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Abstract: Screened plant species with potential for green belt development can act as eco-sustainable tools for restoring the polluted ecosystem. Eight plant species from two study locations in Ado-Odo, Ota, Ogun State, Nigeria, were examined to identify their air pollution response and performance by deploying two air pollution indices, namely air pollution tolerance index (APTI) and anticipated performance index (API). APTI results identified all screened plants as sensitive species suitable as bio-indicators of air pollution, with *Ficus auriculata* (2.42) common to the non-industrial location being the most sensitive. API scores categorized *Ficus auriculata* (56.25%) as a moderate performer, while *Syzygium malaccense* (75%) and *Mangifera indica* (75%) were identified as very good performers, suitable for green belt development. The relationship between each biochemical parameter with APTI was investigated using regression analysis and two-way analysis of variance. The model result showed a significant relationship between each biochemical parameter with APTI, and relative water content had the highest influence on APTI (R^2 = 0.99436). Both indices (APTI and API) are suitable for screening and recommending native plant species for cultivation in the polluted environment, thus promoting ecological restoration. Hence, *Syzygium malaccense*, *Mangifera indica* and *Ficus auriculata*, respectively, were recommended for green belts design. Further intensive screening to identify tolerant species and best to excellent performer's trees suitable for restoring the ecosystem is advised.

Keywords: ecological restoration; green belt; air pollution control; tree leaves; anticipated performance index; semi-urban area; SDGs

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1. Introduction

Air pollution introduces chemical substances, particles, and other biological materials into the air around us in amounts toxic to human beings, plants, animals, and the entire environment [1,2]. The significant sources of airborne pollutants that have caused deterioration in the quality of air include an increase in vehicular and industrial emissions as well as rapid urbanization leading to declining vegetation growth in such environment [3–5]. Airborne pollutants such as dust, the particulate matter having an aerodynamic diameter of less than 0.1 μm to 10 μm ($PM_{0.1}$–PM_{10}), gaseous pollutants (nitrogen dioxide, sulphur dioxide, ozone, carbon monoxide, volatile organic compounds, etc.) and toxic metals, reduce the ambient air quality. They are also dangerous to human health and alter the atmosphere and plant ecosystem [6–10]. To mitigate the dangerous impact of these toxic pollutants, environmental analysts emphasize the use of recurring green belts adaptive to the native surrounding of the polluted areas to promote ecological restoration [11–15].

Cultivating greenbelt identified vegetation in urban environmental stressed areas improves the quality of air by absorbing and accumulating dust pollutants on leaf surfaces, reduces noise, regulates atmospheric temperature, thus reducing urban heat island effect in addition to other ecosystem benefits [11,16–18]. Plants can get rid of particulate matter in several ways: absorbing the pollutants on the leaves, depositing it on the upper part of the leaves, and falling out of pollutants (particles) on the downward portion of the green belt [19,20]. On the contrary, some tree species in the urban area can negatively affect human health and air quality through pollen emission and biogenic volatile organic compounds [12,21,22]. Also, depending on the meteorological and climatic condition of the urban environment, tree spacing, and characteristics (thickness, height etc.) [23,24], trees can obstruct airflow, thus resulting in decreased air exchange and accumulation of larger pollutant concentrations [22,25].

Therefore, the effectiveness of different plant cultivation patterns and screening of specific adaptable plant species further enhances their pollutants abatement capacity [12,26,27]. The literature has explained the effects of particulate and gaseous pollutants on the biological and chemical parameters of plant leaves, such as the relative water content, chlorophyll content, ascorbic acid content, and leaf extract pH [10,28,29]. Using these various parameters provides different outputs of similar plants. As a result, just one criterion will likely not give an acceptable result of the changes caused by pollution prevalent in plants. This is due to the fact that plants exhibit different responses to different pollutants [28,30,31]. According to Singh and Rao [31], the air pollution tolerance index (APTI) indicates the ability of plant leaves to act as air pollution tolerant and sensitive species [32,33]. Plants perceptivity and reaction to toxic pollutants vary, and susceptible plant types are used as bio-indicators to detect the biochemical changes in plants. In contrast, resistant types act as sinks of air pollutants [34–36]. APTI is excellent in determining the impact of toxic air pollutants on the biological and chemical parameters of the plants only [37–39]. Thus, to choose plants with potentials for green belt development, several factors contributing to the performance of plant species, such as biological characteristics and socio-economic in combination with biochemical parameters obtained from APTI, are also examined. Hence, the anticipated performance index (API) was developed [40,41]. API applies the obtained APTI value along with its own generated biological characteristics (plant size, hardiness, texture, canopy structure, habit) and socio-economic importance to predict the effectiveness of a given plant species to abate pollution. Based on the earlier characters, different grade points are allotted to the plant species. Generally, all plants are allotted a maximum of 16-grade points (positives). API is obtained by dividing the grade point of different plant species with the maximum 16 fixed points and scaled to percentages. With the resultant points, plants are grouped into different assessment formats ranging from best (91–100) to not recommended (<30) [17,37,38,41].

Investigating the significance and effect of the variables under consideration on air pollution requires statistical methods and models [42,43]. Regression models help establish the independent variable's influence and effect on the dependent variable by obtaining the slope and the intercept of the investigated variables. Analysis of variance shows the changes in the average quantitative variables with respect to the levels of categorical variables, as illustrated in several studies [44–47]. This study is significant since it promotes the use of cost-effective and eco-friendly use of passive bio-indicators to complement the physico-chemical approaches for air quality valuation [11,12,48], in line with the United Nations Sustainable Development Goals (SDGs) 3, 7, 11, and 13 for the substantial reduction of air pollution. This is apt, especially in environments devoid of air quality monitoring stations such as in the current study [49]. In this work, eight common plant species from two locations (industrial and non-industrial) in Ado-Odo Ota, Ogun State, Nigeria, have been screened to (a) determine their tolerance/sensitive potentials in polluted air (b) examine the significance of the plants biochemical variables, and (c) ascertain the plant's performance ability for green belt design.

2. Materials and Methods

2.1. Study Sites

This study was carried out in Ogun State, the southwestern part of Nigeria as depicted in Figure 1. The industrial location (Ota Industrial Estate), denoted as ILO, has over thirty-five functioning industries which are the primary sources of air pollutants emissions. The surrounding roads within these locations are untarred, thus adding to the emitted dust particles. The non-industrial community (Canaanland), denoted as NIC, comprises the church, schools, residential areas, commercial activities, and has tarred roads. It is surrounded by green vegetation and reduced traffic density. The daily mean measurement of the meteorological conditions at the study area was as follows: wind speed (3.69 ± 0.768 m/s), relative humidity (74.1 ± 14.8%), temperature min (24.40 ± 2.48 °C), max (35.1 ± 1.23 °C), and sunshine (6.14 ± 2.21 h), as provided by the Nigerian Meteorological Agency (NIMET).

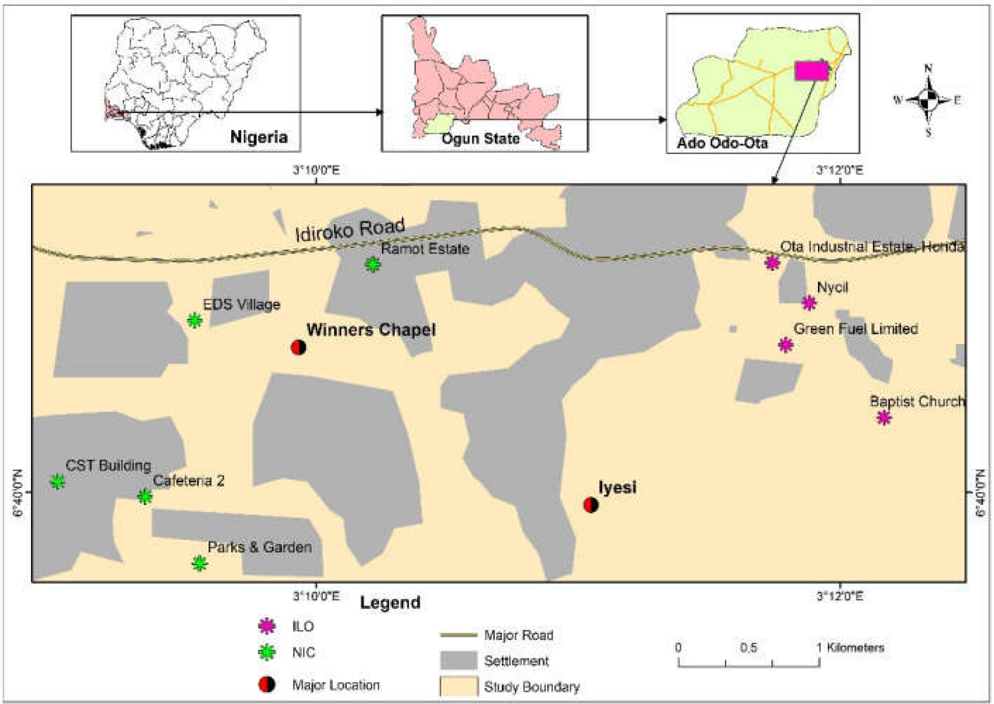

Figure 1. Map of the study sites.

2.2. Sample Collection

Eight matured trees species, including Terminalia catappa, Syzygium malaccense, Anacardium occidentale, Theobroma cacao, Citrus sinensis, Mangifera indica, Mussaenda erythrophylla, and Ficus auriculata, were selected and collected from ILO and NIC locations in Ado-Odo Ota, Ogun State, Nigeria. Triplicate plants samples were taken randomly during the month of January–March 2016 and assembled in an aluminum foil to prevent the loss of moisture. It was immediately transported to the laboratory for identification by a molecular plant systematist in their fresh form (Table 1), processed and stored in the refrigerator. All of the leaves were sampled within twenty-four hours to avoid variations in the results. To the best of our knowledge, this study is the first to screen Theobroma cacao, Mussaenda erythrophylla, and Ficus auriculata, for their APTI and API potentials in Nigeria.

Table 1. Plants species collected from the industrial location and non-industrial community.

Ota Industrial Estate (ILO)		Non-Industrial Community (NIC)	
Botanical Name	**Common Names**	**Botanical Name**	**Common Names**
Terminalia catappa	Almond	*Citrus sinensis*	Orange
Syzygium malaccense	Malay apple	*Mangifera indica*	Mango
Anacardium occidentale	Cashew	*Mussaenda erythrophylla*	Tropical Dogwood
Theobroma cacao	Cocoa	*Ficus auriculata*	Roxburgh Fig

2.3. Estimation of Biochemical Parameters

The four biochemical parameters employed in evaluating plants response or tolerance towards air pollution includes relative water content, pH of leaf extract, total chlorophyll content, and ascorbic acid content. A total of 5 g of fresh ground leaves was homogenized in 50 mL distilled water, the leaf extract was filtered and measured for pH using a calibrated glass electrode pH meter following Pandey et al. [40]. The relative water content was determined by first weighing the fresh leaves, then it was immediately soaked in water for a period of 24 h, blotted dry, and re-weighed to obtain the turgid weight. After which, the turgid leaves were oven dried at 70 °C for 12 h, and weighed again to determine the dry weight according to Pathak et al. [50]. The ascorbic acid content of leaves was analyzed using an ultraviolet spectrophotometer according to Prajapati and Tripathi method and the ascorbic acid levels in the sample was extrapolated from a standard ascorbic acid curve [51]. Total chlorophyll content was determined by adding 1 g of powdered fresh leaves sample to 10 mL of freshly prepared 80% acetone in a 15 mL centrifuge tube. The leaf extract was afterwards centrifuged at 2500 rpm for 180 s to achieve thorough separation and poured into test tubes using Whatman filter paper. The solutions absorbance was then measured at 645 nm and 663 nm with an ultraviolet spectrophotometer after calibration with 80% acetone as the reagent blank. Modified method of Arnon and Singh was used in the computation of total chlorophyll content as shown in Equation (1) [31,41,52].

$$\text{Total chlorophyll} \ \ (\text{mg/g}) = [20.2(A_{645}) + 8.02(A_{663})] \times \left[\frac{V}{W} \times 1000\right] \tag{1}$$

where, A_{645} is the absorbance at 645 nm, A_{663} is the absorbance at 663 nm, V is the volume of the sample extract (mL), and W is the weight of the extracted leaf (g).

2.4. Air Pollution Tolerance Index (APTI)

The formula for computing plants APTI is as shown in Equation (2)

$$\text{APTI} = \frac{A(T + P) + R}{10} \tag{2}$$

From Equation (2), A and T refers to the ascorbic acid content (mg/g), and the total chlorophyll content (mg/g), respectively, while P refers to the pH of the leaf extract, and R is the relative water content expressed in percentage (%). The APTI results obtained are further grouped as tolerant ($\geq$17), intermediate tolerant or sensitive (12–16), and sensitive (1–11) [53,54] in order to evaluate the susceptibility and resistivity of different plants species to air pollution.

2.5. Anticipated Performance Index (API)

API combines the obtained APTI results with plants biological parameters (plant size, hardiness, texture, canopy structure, habit) and socio-economic importance to ascertain individual plants performance. Plants' performance capacity is determined from their allotted sixteen (16) points, scaled to 100 per cent [16,55–57]. The API score is assigned to each plant species according to Prajapati [51] and Ogunkunle [54]. Based on API scores, plants are grouped in different assessment formats as follows: not recommended <30; very poor, from 31 to 40; poor, from 41 to 50; moderate, from 51 to 60; good, from 61 to 70; very good, from 71 to 80; excellent, from 81 to 90; and best, from 91 to 100 [16,55–57]. API is further calculated as depicted in Equation (3).

$$\text{API} = \frac{\text{No. of " + " obtained}}{\text{Total No. of " + "}} \times 100 \quad (3)$$

2.6. Statistical Analysis

The results were statistically analyzed using Microsoft Excel 2013 and Statistical Packages for Social Sciences (SPSS) software version 23.0. Individual samples were analyzed in triplicates and expressed as mean. The biochemical parameters were compared with APTI using multiple regression and two-way analysis of variance. R-square values for the data were obtained to investigate the variability level of the data under investigation.

3. Results and Discussion

3.1. APTI Biochemical Parameters

3.1.1. pH of Leaf Extract (P)

The pH of leaf extracts ranged from 2.88 to 5.96 in the acidic category both at the industrial (ILO) and non-industrial sites (NIC). Plants from NIC location had a higher range of pH (4.53–5.72) when compared with those from ILO (2.88–5.96) (Table 2). The pH is a sensitive indicator of airborne pollution as such a higher or lower pH value is an indication of the state of the environmental pollution. As a result of the influence of ambient air pollution on pH levels, investigated plants showed the following increasing trend: *Theobroma cacao* > *Terminalia catappa* > *Anacardium occidentale* > *Syzygium malaccense,* in the ILO site and *Citrus sinensis* > *Mussaenda erythrophylla* > *Mangifera indica* > *Ficus auriculata* in the NIC site. Reduced pH content of the leaves triggers changes in the stomatal activities, including respiration and transpiration. The outcome is a reduction in the photosynthetic capacity of the plants [18,19]. Also, the lower pH content of the leaves is associated with acidic pollutants, with the significant effect being more visible in sensitive plant species [17,58,59]. Several studies have confirmed a positive correlation between lower pH concentrations in plants and their sensitivity to air pollutants [41,60]. On the contrary, higher pH concentration in plants increases their ability to convert hexose sugar (glucose and galactose) into ascorbic acid. Thus, increasing their tolerance capacity to withstand atmospheric environmental pollutants such as sulphur dioxide and nitrogen oxides [18,61].

Table 2. Air pollution tolerance indices (APTI) and biochemical parameters of plant species.

Site Code	Taxon	A (mg/g)	T (mg/g)	P	R (%)	APTI
ILO	*Terminalia catappa*	0.22	1.49	5.41	71.00	7.25
	Syzygium malaccense	0.38	1.09	2.88	90.80	9.23
	Anacardium occidentale	1.80	2.93	3.80	98.90	11.10
	Theobroma cacao	1.86	1.56	5.96	78.80	9.28
NIC	*Citrus sinensis*	2.89	1.03	5.72	42.30	6.18
	Mangifera indica	1.81	1.57	4.92	84.4	9.61
	Mussaenda erythrophylla	1.80	1.18	5.15	69.50	8.09
	Ficus auriculata	0.72	2.25	4.53	19.30	2.42

3.1.2. Total Chlorophyll Content (T)

Chlorophyll performs a major function in plant metabolism. The extent of plants' growth and developmental processes depends on the amount of plants chlorophyll content [18,19]. All of the studied plants exhibited low concentrations of chlorophyll content, which varied between 1.03–2.93 mg/g amongst all of the studied sites (Table 2). Plants from ILO locations exhibited a higher range of leaf chlorophyll content (1.09–2.93 mg/g) when compared with those from NIC (1.03–2.25 mg/g) (Table 2). *Anacardium occidentale* (2.93 mg/g) and *Ficus auriculata* (2.25 mg/g) from industrial and non-industrial sites had the highest chlorophyll content. Variation in the chlorophyll content of the plant is a function of the type of species, nature of environmental pollution, age of leaves, amongst others [62,63]. Also, the levels of the synthesized chlorophyll content in the plant are directly influenced by the levels of particulate deposited on the leaves, which clogs the stomatal pores and reduces the rates of carbon dioxide transfer, carbon assimilation and transpiration [64,65]. This agrees with the research conducted by Karmakar et al. [19], Karmakar and Padhy [38], Mukhopadhyay et al. [46], and Timilsina et al. [47]. Since, chlorophyll content is sensitive to pollutants, it was conferred that reduced chlorophyll content is an indication of increased ambient pollution [34,40,47]. However, plants seen with increased chlorophyll content in the same environment are tolerant to airborne pollutants prevalent in that investigated location [55,66].

3.1.3. Relative Water Content (R)

The relative water content of the selected plant species across the study sites ranged from 19.30% in leaves of *Ficus auriculata* to 98.90% in leaves of *Anacardium occidentale* (Table 2). The industrial sites (71–98.90%), recorded the highest value compared to the non-industrial site (19.30–69.50%). Relative water content is a reflection of the transpiration capacity of the plant [35]. Seven out of the eight plant species recorded relative water content higher than 40% in this study. Depending on plant species, fully turgid transpiring leaves can retain very high relative water content above 98%, it can also reduce below 40% in severe drought conditions [11]. Increased R maintains plants physiological balance and increases their tolerance capacity towards ambient pollutants, while decreased R below 40% reduces stomatal conductance and carbon dioxide assimilation pollutants [41,57,67,68].

Manjunath and Reddy [2] reported that plants with higher R had better air pollution tolerance. In their work, V. rosea with a higher R of 88.59% from the non-polluted area reflected the highest APTI of 27.44. Similarly, in this study, *Anacardium occidentale* from the industrial site with the highest R of 98.90% had the highest APTI of 11.10. In comparison, *Mangifera indica* from the non-industrial site with the highest R of 84.4% showed the highest APTI of 9.61. Generally, relative water content was higher in all plant species at the industrial sites. The plant species in the industrial sites can be recommended for cultivation in polluted areas with similar climatic conditions and pollutant stress [47,57].

3.1.4. Ascorbic Acid Contents (A)

As indicated from the results in Table 2, ascorbic acid contents ranged from 0.22 mg/g (*Terminalia catappa*) to 2.89 mg/g (*Citrus sinensis*) across both study locations. Increased in the ascorbic acid content of plants due to air pollution stress observed highest at NIC site than those of the ILO. This finding indicates a correlation between pH and ascorbic acid. *Theobroma cacao* and *Citrus sinensis with* an ascorbic acid content of 1.86 and 2.89 showed the highest pH of 5.96 and 5.72 in ILO and NIC sites, respectively. Ascorbic acid acts as strong anti-oxidant in plants by inducing their defense mechanisms in diverse environmental stressed conditions against the formation of reactive oxygen species (ROS), which is induced in plants from the absorbed pollutants [69–73]. Hence, a higher concentration of ascorbic acid in leaves increases their tolerance ability towards air pollution [68]. The increased in the ascorbic acid content of plants as a function of their physiological response to air pollution stress indicated in this work supports the findings of Shreatha et al. [11] (0.975 to 30.2 mg/g); Timilsina et al. [47] (0.07 to 1.41 mg/g); Sen et al. [60] (2.220 to 23.400 mg/g) in the pre-monsoon season and (1.313 to 24.434 mg/g) in the post-monsoon; Rai. [73] (0.20 ± 0.02 to 0.72 ± 0.05 mg g^{-1}); Uka et al. [74] (10.91 to 19.81 mg/g); Aasawari et al. [75] (0.93 ± 0.1 mg/g to 8.24 ± 0.3605 mg/g); and Correa-Ochoa et al. [76] (1.11 to 12.33 mg/g).

3.2. Air Pollution Tolerance Index (APTI)

Table 2 presents the APTI results for all of the eight (8) plant species. Across both study locations, APTI ranged from 2.42 to 11.1. APTI results ranged from 7.25 to 11.1 and 2.42 to 9.61 for ILO and NIC, respectively. Plants with lower values of APTI can act as bio-indicators, while those with higher values act as sinks of atmospheric pollution in polluted environments [77–79]. Following the APTI classification, as described in Section 2.4, low APTI values in the range of 1–11 were recorded in this study. This implies that the plant species in both study sites are sensitive species. As such, these plant species can be assigned air pollution bio-indicators status [74,75,80]. Similarly, *Ficus auriculata* with a 2.42 APTI value was the most sensitive amongst the screened species, and the plant was common in NLO. On the contrary, when higher APTI values are obtained, the plants are tolerant of air pollutants. Previous studies reveals low APTI values recorded by Bui et al. [35] (<10.0); Kwak et al. [45] (<10.0); Ogunkunle et al. [54] (<13.0); and Karmakar et al. [19] (<24.0) for non-industrial study sites. The industrial locations had APTI values in the range of (<47) [5] to (<9.0) [80]. According to Ogunkunle et al. [54], the low APTI value results (<13.0) recorded for tree species is indicative of the moderate level of air pollutants within the investigated location. Similarly, this study APTI value (<12.0) implies a moderate level of air pollutants present in the study area.

Several authors have confirmed the importance of APTI in determining plants response regarding sensitivity or tolerance to atmospheric pollution. The plant species classified as sensitive with APTI score of 1–11 acts as bio-indicators of air quality, whereas those classified as tolerant with APTI score of (≥17), acts as sinks of air pollutants to alleviate deteriorated air quality [10,16,35,45,66,72].

3.3. Anticipated Performance Index (API)

Tables 3 and 4 categorizes ILO and NIC plant species according to their APTI, socio-economic importance and, biological parameters. Based on these characters, different grades (+ or −) were assigned to each plant species following the criteria in Tables S1 and S2 as documented by Prajapati [51]. In ILO, *Syzygium malaccense* showed the highest grade (75%), denoted as a very good performer (Table 4). *Mangifera indica* (75%) and *Ficus auriculata* (56.25%) from NIC were identified as very good and moderate performers, respectively. The other five tree species ranged from not recommended (25%) to poor (50%) performers in both locations and were not recommended for cultivation due to their low API grades. Those with higher API grades from best to moderate are usually recommended for setting up green belts in polluted areas [51,75,76].

In this work, *Anacardium* occidentale from ILO recorded the highest APTI value (11.1), but it is categorized as a poor performer when assessed along with its biological and socio-economic parameters. On the contrary, *Ficus auriculata* from NIC with the lowest APTI value (2.42) was categorized as a moderate performer when assessed along with its biological and socio-economic parameters. This result corroborates with other research findings [40,51,57,81], which emphasizes that the overall plant performance is not a function of only the APTI but a combination of both indices (APTI and API).

Table 5 compares this study APTI and API results with similar study sites carried out in other countries of the world. Amongst the various screened plant species, Mangifera indica L has been identified as a tolerant species and scored best to very good performer following the API assessment category.

Table 3. Assessment of plant species using the obtained APTI values, socioeconomic importance, and biological parameters.

Site Code	Taxon	APTI	Tree Habit	Canopy Structure	Type of Tree	Laminar		Economic Importance	Hardiness	Grade Allotted
						Texture	Size			Total Plus (+)
ILO	*Terminalia catappa*	-	++	++	-	-	+	++	+	8
	Syzygium malaccense	+	++	++	+	+	++	++	+	12
	Anacardium occidentale	+	+	+	+	+	-	++	+	8
	Theobroma cacao	+	+	+	+	-	++	+	+	8
NIC	*Citrus sinensis*	-	+	++	+	-	-	-	+	5
	Mangifera indica	+	++	++	+	++	+	++	+	12
	Mussaenda erythrophylla	+	-	-	+	+	+	-	-	4
	Ficus auriculata	-	+	++	+	+	++	+	+	9

Table 4. Anticipated Performance index (API) result of investigated plant species.

Site Code	Taxon	Grade Allotted	Scoring	API Value	Assessment
		Total Plus (+)	Percentage (%)		
ILO	*Terminalia catappa*	8	50	2	Poor
	Syzygium malaccense	12	75	5	Very good
	Anacardium occidentale	8	50	2	Poor
	Theobroma cacao	8	50	2	Poor
NIC	*Citrus sinensis*	5	31.25	1	Very poor
	Mangifera indica	12	75	5	Very good
	Mussaenda erythrophylla	4	25	0	Not recommended
	Ficus auriculata	9	56.25	3	Moderate

Table 5. Results of APTI and API of plant species from selected reports.

Location	Study Site	Range of APTI Value	No of Sampled Plants	Most Tolerant Species (Season)	Most Sensitive Species (Season) [Chamber Exposure Experiment]	API Performance Plants (Scores)	References
Jharkhand, India	Industrial	11.42 to 21.28 (M); 11.79 to 28.62 (P)	9	*Mangifera indica* (M) *Azadirachta indica* (P)	*Tectona grandis* (M) & (P)	*Mangifera indica* (E) *Ficus bengalensis*(VG) *Azadirachta indica* (G) *Ficus religiosa* (G)	[36]
Dąbrowa Gornicza city, Poland	Industrial	8.43–46.61	4	*Taraxacum officinale*	*Plantago lanceolata*	-	[5]
Jubail city, Saudi Arabia	Industrial	5.676 to 8.803	8	-	*Parkinsonia aculeata*	-	[75]
Isfahan City, Iran	Industrial	14.43 to 20.27	3	*Morus nigra*	*Ailanthus altissima*	*Morus nigra* (E); *Platanus orientalis*(VG)	[65]
Cheongju city, South Korea.	Chungbuk National University (CBNU)	7.11 to 9.52.	11	-	*Cercis chinensis*	*Pinus densiflora* (G)	[30]
Santiniketan, West Bengal, India	Non industrial & Semi Urban	9.53–23.90	18	*Mangifera indica, Peltophorum pterocarpum; Ficus benghalensis; Polyalthia longifolia; Saraca asoca*	*Ziziphus mauritiana Lam.*	*Mangifera indica*,(B) *Polyalthia longifolia; Saraca asoca; Ficus benghalensis* (E)	[19]
Ilorin, Nigeria	University of Ilorin,	7.80 to 12.30	4	*Terminalia catappa*	*Vitellaria paradoxa*	*Vitellaria paradoxa* (G)	[49]
Seoul, Korea	University of Seoul.	7.0 to 9.0 (T); 7.5 to 8.7(C)	6	-	*Ginkgo biloba* [T]; *Chionanthus retusus* [C]	*Pinus densiflora* (G); *Prunus × yedoensis* (G).	[40]
Ado-Odo Ota, Ogun State, Nigeria.	Industrial & Non industrial, (Canaanland)	7.25 to 11.10 2.42 to 9.61	8	- -	*Terminalia catappa Ficus auriculata*	*Syzygium malaccense* (VG) *Mangifera indica* (VG) *Ficus auriculata* (G	Present study

Season: M, monsoon; P, post-monsoon/ API Scores: E, excellent; VG, very good; G, good; T, treatment; C, control.

3.4. Statistical Modeling of Bio-Indicators Responses

Figure 2 shows a significant positive correlation between APTI and relative water content (R^2 = 0.9436). An insignificant and low correlation was between total chlorophyll content (R^2 = 0.0052), pH of plant leaf extract (R^2 = 0.0512), ascorbic acid content (R^2 = 0.0366), and the APTI. This implies that relative water content is the most significant factor when considering the plant's tolerance potential in the study location.

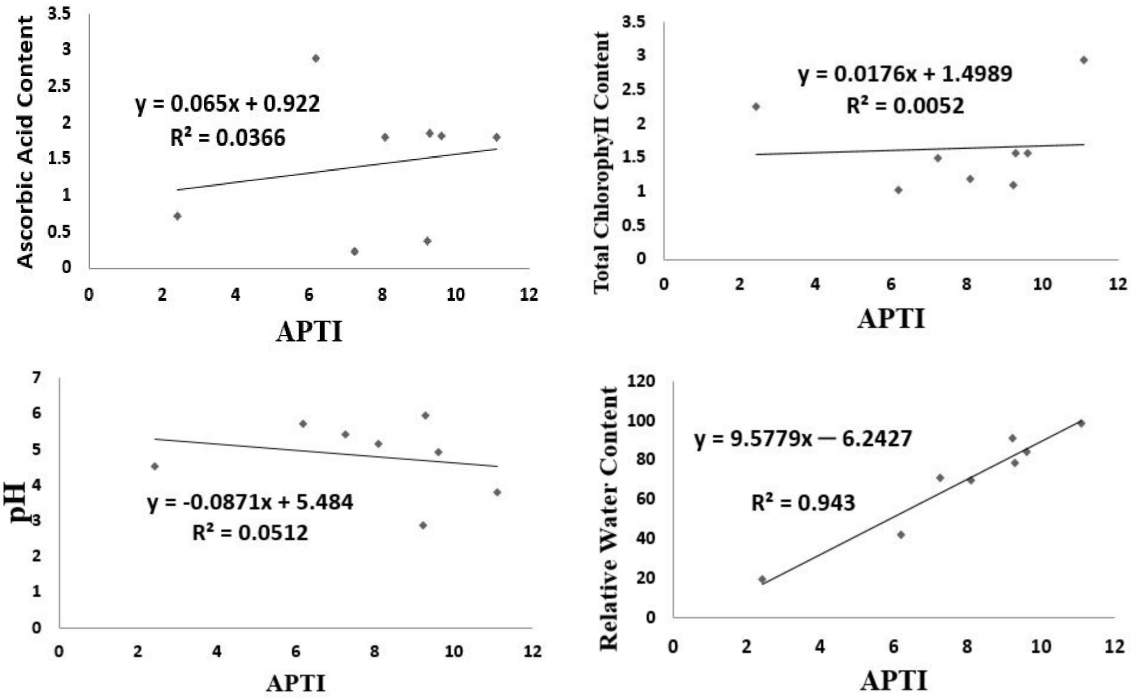

Figure 2. Linear regression analysis of APTI against individual biochemical parameters.

A multiple regression analysis model was developed to investigate and establish the relationship between biochemical parameters and APTI. The overall model presented in Table 6 reveals that the model is significant with a *p*-value of 0.0001 against the 0.05 significance level. The result implies that the biochemical parameters have a significant influence on APTI.

Table 6. Overall model for biochemical parameters and APTI.

Model	Sum of Squares	df	Mean Square	F	Sig.
Regression	50.269	4	12.567	2407.230	0.0001
Residual	0.016	3	0.005		
Total	50.285	7			

The effect and the relationship of individual biochemical parameters on APTI were investigated, and the model coefficient results are presented in Table 7. The result reveals that relative water content and ascorbic acid are significantly related to APTI. At the same time, the relationship of chlorophyll and pH with APTI is not significant although the relationship is positive.

Table 7. Multiple regression (linear function model) of each biochemical parameters on APTI.

Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
	−0.406	0.217		−1.877	0.157
pH of leaf extract	0.062	0.034	0.024	1.851	0.161
Total chlorophyll content (mg/g)	0.053	0.044	0.013	1.208	0.314
Relative water content (%)	0.100	0.001	0.989	89.606	0.000
Ascorbic acid content (mg/g)	0.665	0.035	0.226	19.274	0.000

Table 8 showed that the obtained taxon parameters were not significant with a p-value of 0.481, while biochemical parameters were significant, with a p-value of 0.000. In addition, the model R-square value was 0.915, implying a high level of variability among the analyzed data and the fitness of the data with the model.

Table 8. Two-way analysis of variance for Taxon and biochemical parameters.

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Model	39,919.110 [a]	11	3629.010	20.537	0.000
Taxon	1194.027	7	170.575	0.965	0.481
BioParameter	26,791.888	3	8930.629	50.541	0.000
Error	3710.749	21	176.702		
Total	43,629.859	32			

[a] R Squared = 0.915 (Adjusted R Squared = 0.870).

4. Conclusions

This study has screened common native plant species capable of acting as air pollution indicators and green belt development plants for restoring polluted ecosystem. This was achieved using two significant indices: the air pollution tolerance index (APTI) and the anticipated performance index (API). The results from the present study identified all of the studied plant species as bio indicators of air pollution with *Ficus auriculata* common to non-industrial sites being the most sensitive. Regression analysis and two-way analysis of variance indicated a significant relationship between each biochemical parameter with APTI, with relative water content showing the highest influence on APTI. API grading indicated three native tree species in the range of very good to moderate performers suitable for green belt development. Therefore, *Syzygium malaccense* from the industrial location, *Mangifera indica* and *Ficus auriculata* from the non-industrial location, respectively, are recommended based on API categorization for green belts purposes in the study locations.

Supplementary Materials: The following are available online at https://www.mdpi.com/article/10.3390/su14073968/s1, Table S1: Grade distribution of plant species based on APTI, biological parameters and socioeconomic importance, Table S2: Anticipated performance index (API) of plant species.

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