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AIR POLLUTION TOLERANCE INDEX ASSESSMENT OFSOME TREE SPECIES IN IBADAN, SOUTHWEST NIGERIA

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ABSTRACT

The Air Pollution Tolerance Index (APTI) measures the resilient of a tree species to air pollution. Industrialization and increased human population have been identified as some of the causes of adversely increasing man-made pollution endangering human lives, plants, and animals. With APTI, tree species suitable for biomonitoring and pollution clean-up can be identified. Hence, we assessed the APTI for tree species (*Mangifera indica*, *Anacardium occidentale*, *Polyalthia longifolia*, *Tectona grandis*, and *Gmelina arborea)*exposed to regular vehicular air pollution in this study. Using standard methods, the bio-indicator APTI assessed are ascorbic acid content (AA), relative water content (RWC), chlorophyll content (TCh), and leaf extract pH in these locations L1 (FCF), L2 (FRIN), and L3(IAR&T).The results revealed most tree species in L3 had greater relative water contents owing to tree's ability to absorb more water as a coping mechanism to assist maintain their physiological balance. The pH levels at all three locations ranged from 4.20 to 6.02, which is on the acidic side confirming the presence of SO_x and NO_x from traffic emissions.Low Total Chlorophyll Content at the L3 Site Compared to L1 and L3 suggests the higher the pollutants, the lower the chlorophyll content. The order of the trees' resistance to air pollution among the five (5) tree species is *Gmelina arborea Roxb>Anacardium occidentale L. >Mangifera indica>Tectona grandis>Polyalthia longifolia*. While the order of locations is L3>L1>L2 due to traffic density, urbanization, industrialization, and their tolerance of APTI-tolerant tree species. For the purpose of reducing air pollution, tolerant tree species can act as a sink. Therefore, for future planning and Greenbelt growth in urban areas, this study offers helpful insights.

Keywords: Bio-indicators, APTI, Tolerance, Air particulate.

Introduction

Air pollution refers to the release of pollutant (usually toxic) into the air. A polluted air is considered to contain the presences of substance harmful of poisonous to the flora and fauna. Thus, human lives, plants, and animals have been endangered due to anthropogenic activities. As stated by Guo *et al.,* (2021), there is a global concern on the adversely increasing man-made pollution caused by industrialization and increased human population.

One of the major form of pollution responsible for this global concern is the burning of fossil fuels produced directly by human activities, also known as anthropogenic contamination. Authors have identified the use of vehicle as a major cause for burning of fossil fuels. For instance, Adedeji *et al.*,(2020) reported that motor vehicle traffic is a significant contributor to air pollution in many urban regions of the world, accounting for 57%–75% of all emissions.

Consequently, urban regions with more vehicular activities is expected to be more polluted than rural areas with lesser vehicular movement. The exhaust from this vehicular activities has been found to impact trees, human metabolism, and even roadside plants (Roozbahani *et al.*, 2015). Not minding the anthropogenic activities causing air pollution, man continues to demand and desire for a cleaner environment as more people migrate to metropolitan areas.

In order to mitigate the effect of anthropogenic activities on air pollution and provide a cleaner environment, researchers have investigated and proposed various techniques. (Sofia *et al*.,(2020)recommends the installation of domestic purifiers, urban green addition, and promotion of air quality monitoring system while (Abhijith*et al*., (2022) assessed the effectiveness of air purifiers. On the other hand, (Wang *et al.*, 2017)explored the possibility of using a tree tolerance index to mitigate air pollution. They discovered that air pollution changed the amount of chlorophyll and the activity of peroxidases in the leaves of a common species *Platanus orientalis* – an indication that the tree species absorbed the air pollutants.

The air pollution tolerance index (APTI) is a significant parameter for pollution mitigation which is based on biochemical parameters of plant. The biochemical parameters include pH, chlorophyll contents, relative water contents and ascorbic acid. It is used by landscapers to select plant species' tolerance to air pollution by using the data obtained from the parameters(Zhang *et al.*, 2016). The successful utilization of APTI confirms the contribution of tree species to mitigating air pollution. By filtering and absorbing gases and particles, urban forests and trees can therefore help improve the quality of the air in urban areas (Ncube andPhiri, 2015). However, since tree species are different in their anatomical, physical, and biochemical properties (Al-Ghanim *et al*., 2016),there is a need to assess the APTI for the different tree species exposed to air pollution.

Mangifera indica, is alarge green tree, valued mainly for its fruits, both green and ripe. Approximately 210 varieties of mango have been reported (Gostin, 2009). It can grow up to 15–30 metres (49–98 ft) tall. The tree grows best in well drained sandy loam; it does not grow well in heavy wet soils. The optimal pH of the soil should be between 5.2 and 7.5.Also*, Anacardium occidentale,* is a tropical evergreen tree that produces the cashew seed and the cashew apple pseudo fruit (Enete *et al*., 2012). The tree can grow as high as 14 m (46 ft), but the dwarf cultivars, growing up to 6 m (20 ft), prove more profitable, with earlier maturity and greater yields. *Monoon longifolium*, the false ashoka also commonly known by its synonym *Polyalthia longifolia*, is an Asian small tree species in the family Annonaceae. It is native to southern India and Sri Lanka, but has been widely introduced elsewhere in tropical Asia and Africa (Rai and Panda, 2014). This evergreen tree is known to grow over 10 m. in height and is commonly planted due to its effectiveness in alleviating noise pollution. It exhibits symmetrical pyramidal growth with willowy weeping pendulous branches and long narrow lanceolate leaves with undulate margins.

Tectona grandis, Teak (*Tectona grandis*) is a tropical hardwood tree species in the family *Lamiaceae*. It is a large, deciduous tree that occurs in mixed hardwood forests. Teak is a large deciduous tree up to 40 m (131 ft) tall with grey to greyish-brown branches, known for its high quality wood (Nayek *et al*., 2011). Its leaves are ovate-elliptic to ovate, 15–45 cm (5.9–17.7 in) long by 8–23 cm (3.1–9.1 in) wide, and are held on robust petioles which are 2–4 cm (0.8–1.6 in) long. Leaf margins are entire.

Gmelina arborea), is a fast-growing deciduous tree in the family Lamiaceae, which grows on different localities and prefers moist fertile valleys with 750–4500 mm rainfall. It does not thrive on ill drained soils and remains stunted on dry, sandy or poor soils; drought also reduces it to a shrubby form. The tree attains moderate to large heights of up to 30 m, with a girth of 1.2 to 4 m. It has a chlorophyll layer just under the outer bark, which is pale yellow on the outside and white inside.

Therefore in this study, the APTI of tree species (*Mangifera indica*, *Anacardium occidentale*, *Polyalthia longifolia*, *Tectona grandis*, and *Gmelina arborea)*found at three different vehicle parking lots within the urban area of Ibadan, Southwest Nigeria were assessed with a view of identifying the most functionally suitable tree species for remediating air pollution in urban areas.

Materials and Method

Description of study site

The areas of study are the parking lot of Federal College of Forestry (L1), located at Jericho Ibadan: Forestry Research Institute of Nigeria (L2) also located at Jericho, Ibadan and Federal college of Animal health and production, IAR&T (L3), Apata, Ibadan. They were selected due to influx of vehicular movement and availability of the same tree species at the three locations for adequate basis of comparison.

Sample collection

The samples were collected according to the procedure adopted by Agbaire and Esiefarienrhe (2010). Plant samples were identified at FRIN Herbarium. Mature leaf samples are collected inthreereplicates and sealed and marked in polythene bags with masking tape for easy identification and immediately transported to the soil laboratory of Federal College of Forestry for analysis.

Analysis of samples

The parameters obtained from these biochemical and physiological analysis: ascorbic acid content (AAC), leaf relative water content (RWC), pH of leaf extract and total leaf chlorophyll (TC) were extensively used to calculate the tolerance index values for the three sites: FCF, FRIN and IAR&T.

The relative leaf water content (RWC)

RWC was evaluated as described by (Singh *et al.*, 1991) below:

$$RWC = \frac{FRESHWEIGHT\,(FW) - DRYWEIGHT\,(DW)}{TURGIDWEIGHT\,(TW) - DRYWEIGHT\,(DW)} X\,100 \ldots\ldots \ldots\ldots 1$$

Fresh leaves were immediately weighed to prevent water loss to get FW while the leaves were further submerge overnight in water for 24 h, later wiped dry with Whatman filter paper and weighed to obtain TW. Then, finally dried in an oven for 48 h at 70°C and reweighed to estimate DW.

Total leaf chlorophyll content (*TCh*)

Adopting Agbaire and Esiefarienrhe (2010) method, 0.5g fresh leaves material was grounded and diluted to 10ml in distilled water. A subsample of 2.5 ml was mixed with 10ml acetone and filtered. Optical density was read at 645 nm (D645) and 663nm (D663). Optical density of *TCh* (CT) is the sum of chlorophyll at(D645) and (D663) density as follows:

$$C_T = 20.2(D645) + 8.02\ (D663) \ldots\ldots\ldots\ldots 2$$

TCh = (mg/g DW) was calculated as follows

$$TCh = 0.1 C_T X\ (\frac{leafDW}{leafFW}) \ldots\ldots\ldots\ldots\ldots\ldots\ldots 3$$

The leaf extract pH

Uniformly mixed 5g of fresh leaves was placed in a 10ml distilled water and was filtered. After which the pH was determined with already calibrated pH meter.

Ascorbic Acid (AA) Content Analysis

Ascorbic Acid (Mg/g) readings was obtained using spectrophotometric method (Tanee and Albert, 2013). Fresh leaf weighing 1g was placed in a text-tube and 4 ml of extracting solution oxalic acid EDTA was added, then 1 ml each of H_3PO_4 and 5% H_2SO_4 were added, with 2 ml of $(NH_4)\ Mo_7O_{24}$ and 3ml of H_2O. The absorbance reading was taken after at 760nm. Ascorbic acid concentration obtained was extrapolated from standard. The method of (Seyyednejad & Koochak, 2011) was applied in calculating APTI with this formula:

$$APTI = \frac{A(T+P)+R}{10} \ldots\ldots\ldots\ldots\ldots\ldots\ldots 4$$

Where, A = ascorbic acid content (mg/g);
T = total chlorophyll content (mg/g):
P = pH of leaf extract and;
R= relative leaf water content (%).

Results and Discussion

The amount of water retained on the leaf is referred to as relative water content (%) (RWC) which correlated with absorbing effect of the protoplasmic cells (Janhäll, 2015). Most tree species RWC (%) in IAR&T (L3) ranges from 92.12 to 102.70 was higher compared to FCF (L1: 82.40 to 93.75) and FRIN(L2: 84.34 to 97.05)as shown in Table 1 specifically *Magnifera indica*. This suggested that trees at polluted site because of heavy traffic around the area retain more water than those at less polluted site (Tanee and Albert, 2013).

Table 1: The Relative water content (RWC)of the tree species assessed with respect to locations

SPECIES	Site	RWC (%)
Anacardium occidentale L.	FCF:L1	84.56
	FRIN:L2	96.86
	IAR&T:L3	94.55
Magnifera Indica	FCF:L1	92.99
	FRIN:L2	97.05
	IAR&T:L3	102.70

Polyalthia longifolia	FCF:L1	83.50
	FRIN:L2	91.84
	IAR&T:L3	92.12
Tectona grandis	FCF:L1	93.75
	FRIN:L2	84.34
	IAR&T:L3	99.53
Gmelina arborea Roxb	FCF:L1	82.40
	FRIN:L2	95.26
	IAR&T:L3	94.60

According to (Enete *et al.*, 2012), they opined that trees at polluted site tends to absorb more water as a bid to adapt and aids to maintain physical stability to overcome pollution pressure. This suggests that the absorbed pollutants are hydrophilic which enables the trees to retain water and be able to endure to pollution stress. The pH levels at all three locations ranged from 4.20 to 6.02, which is on the acidic side. The presence of SOx, NOx, or other acidic pollutants from industrial and traffic emissions in the surrounding air may be the cause of the acidic character, shifting the pH of the leaf sap in a more acidic direction. Low leaf pH extract had a strong association with air pollution sensitivity and also reduced leaf photosynthetic activity. The pH of leaf extract examined revealed the basicity of tree species across the three sites. The ascorbic acid concentration is higher at IAR&T than FRIN and FCF. Even though it is a reducing agent, it however initiate quite a lot of physiological and defense mechanism (Ogbonna *et al.*, 2018). (Agbaire andEsiefarienrhe, 2010; Nwadinigwe, 2014) confirms according to their findings that the reducing power of Ascorbic Acid is completely proportionate to its concentration in the leaf but the reducing effect depends on thepH. This means that low ascorbic acid is related to low pH. The shifting of cell sap pH in the direction of acidity with acidic contaminant subtly reduce the efficacy of transitioning hexose sugar to ascorbic acid (Tanee *et al.*, 2014). Furthermore, chlorophyll depicts productivity in tree species because it is the principal photoreceptor in photosynthesis. However, it varies from biotic & abiotic forms, pollution level, species to species, and age of leaf (Gostin, 2009). However, it has been ascertained that specific air pollutants reduces chlorophyll content as reported by(Osuagwu *et al.*, 2013)(Ekpemerechi *et al.,* 2014) while others increase it (Enete *et al.*, 2012; Ogbonna *et al.*, 2018).

Table 2. The Leaf pHof the tree species assessed with respect to locations

SPECIES	Site	pH
Anacardiumoccidentale L.	FCF:L1	4.60
	FRIN:L2	4.25
	IAR&T:L3	4.20

MagniferaIndica	FCF:L1	5.0
	FRIN:L2	4.92
	IAR&T:L3	4.80
Polyalthialongifolia	FCF:L1	4.35
	FRIN:L2	4.49
	IAR&T:L3	4.10
Tectona grandis	FCF:L1	5.13
	FRIN:L2	5.0
	IAR&T:L3	5.02
Gmelina arborea Roxb	FCF:L1	6.02
	FRIN:L2	5.82
	IAR&T:L3	5.74

Table 3: The Ascorbic acid content (AAC)of the tree species assessed with respect to locations

SPECIES	Site	AA (mg/g)
Anacardiumoccidentale L.	FCF:L1	9.06
	FRIN:L2	9.02
	IAR&T:L3	9.10
MagniferaIndica	FCF:L1	7.56
	FRIN:L2	7.21
	IAR&T:L3	7.81
Polyalthia longifolia	FCF:L1	8.53
	FRIN:L2	8.17
	IAR&T:L3	8.76
Tectona grandis	FCF:L1	8.35
	FRIN:L2	8.74
	IAR&T:L3	8.91
Gmelina arborea Roxb	FCF:L1	8.90

	FRIN:L2	8.45
	IAR&T:L3	8.94

Table 4: The Total leaf Chlorophyll content (TLC)of the tree species assessed with respect to locations

SPECIES	Site	TLC(mg/g)
Anacardium occidentale L.	FCF:L1	13.26
	FRIN:L2	12.92
	IAR&T:L3	12.10
Magnifera Indica	FCF:L1	13.36
	FRIN:L2	12.10
	IAR&T:L3	12.01
Polyalthialongifolia	FCF:L1	11.31
	FRIN:L2	11.17
	IAR&T:L3	11.06
Tectonagrandis	FCF:L1	11.52
	FRIN:L2	10.84
	IAR&T:L3	10.21
Gmelina arborea Roxb	FCF:L1	12.40
	FRIN:L2	12.45
	IAR&T:L3	12.24

The result from this study shows low Total chlorophyll content in IAR&T site compared to FRIN and FCF sites (Table 4). This reduction in total chlorophyll may be due to degrading chlorophyll synthesis. Because some pollutants collectively lower the total chlorophyll content, the amount of chlorophyll decreases as pollution levels rise as reported by (Banerjee *et al.*, 2022). In addition, (Anand *et al.*,2022) noted a decrease in chlorophyll concentration brought on by acidic pollutants like SO_2, which cause the synthesis of phaeophytin by acidifying chlorophyll. There have also been reports of reductions in chlorophyll content in different agricultural plants owing to exposure to NO_2, SO_2, and O_3.This corroborate with (Ogunkunle *et al.*,2015) findings who reported that chlorophyll disappeared steadily resulting leaf chlorosis linked with decreasing photosynthetic carbon fixation as impacted by air pollution. Degrading photosynthetic pigment has been extensively used as an indicator of air pollution (Falusi *et al.*, 2016). APTI Result as shown in Table 5revealed that tree species in IAR&T: L3 site because of its proximity to vehicular emissions and urbanization had higher APTI values than those in the less polluted(FCF: L1 and FRIN: L2). Based on the APTI values, and in line with the report of (Ha, 2018), theycan be conveniently grouped as shown in Table 5.

Table 5: Air Pollution Tolerance Index values

APTI Value	Response
30 to 100	Tolerant
29 to 17	Intermediate
16 to 1	Sensitive
<1	Very sensitive

Table 6:The Air pollution tolerance index (APTI)of the tree species assessed with respect to locations

SPECIES	Site	APTI
Anacardium occidentale L.	FCF:L1	24.57
	FRIN:L2	25.47
	IAR&T:L3	24.28
Magnifera Indica	FCF:L1	23.17
	FRIN:L2	21.90
	IAR&T:L3	23.30
Polyalthialongifolia	FCF:L1	21.61
	FRIN:L2	21.92
	IAR&T:L3	22.40
Tectona grandis	FCF:L1	23.26
	FRIN:L2	22.25
	IAR&T:L3	23.53
Gmelina arborea Roxb	FCF:L1	24.62
	FRIN:L2	24.90
	IAR&T:L3	25.42

Therefore, the five species in this study which showed APTI values range of21.6 to 25.47(Table 6) are classified as intermediate as indicated in Table 5. The overall outcome of this study also shows various tree species response to air pollution in different ways. Therefore, these tree species are hereby certified to abate air pollution resulting from vehicular emissions, household and industrial incineration, for air quality improvement and their potential in serving as an unequalled qualitative and quantitative pollution indices.

Conclusion

The impact of biomonitoring on biochemical markers and the science of air pollution are both very important. The study unequivocally demonstrated that tree tolerance to air pollution may vary depending on the site. The higher the APTI value, the more tolerant the tree species and vice versa. Among the five (5) tree species assessed, theirtolerance to air pollution are *Gmelina arborea Roxb>Anacardium occidentale L.>Mangifera indica>Tectona grandis>Polyalthialongifolia* while the order of site due to tolerance of tree species to APTI are L3>L1>L2. These results provides useful information in selecting tolerant species capable of reducing air particulates and adversely reducing air pollution.

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