USING TREES AS URBAN HEAT ISLAND REDUCTION TOOL IN ENUGU CITY NIGERIA BASED ON THEIR AIR POLLUTION TOLERANCE INDEX

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Abstract

The Study examined the air pollution tolerance indices (APTI) of five plant species around Enugu urban area. Four physiological and biological parameters including leaf relative water content (RWC), ascorbic acid (AA) content, total leaf chlorophyll (TCh), and leaf extract pH were used to develop an APTI. The vegetation monitoring in terms of its APTI acts as a 'Bioindicator' of air pollution and can be incorporated into assessment studies for selecting trees for urban heat island (UHI) mitigation strategy. The result of the APTI showed order of tolerance as Anacarduim occidentale (22.20), Pinus spp (22.35), Catalpa burgei (22.57), Mangifera indica (23.37), and Psiduim guajava (24.15). A comparative analysis was also done between the shedding ability of these trees and their APTI. The result showed that the best tree that provides both shed and high air pollution tolerance appeared in that order: Psiduim guajava, Magifera indica, Catalpa burgei, Pinus spp and Anacarduim occidentale. The results of such studies are therefore handy for future planning, and as well provide tolerant species for landscape and urban heat island mitigation.

Key words: *Pollution, Trees, Tolerance, Bioindicator, Enugu, APTI, UHI*

Introduction

In recent years a substantial research effort has focused on the links between particulate air pollution and poor health (QUARG, 1996). As a result the PM_{10} value has been set as a measure of such pollutants which can directly cause illness (Beckett *et al.,* 1997). Plants play an important role in monitoring and maintaining the ecological balance by actively participating in the cycling of nutrients and gases like carbon dioxide, oxygen and also provide enormous leaf area for impingement, absorption and accumulation of air pollutants to reduce the pollution level in the air environment (Escobedo *et al.,* 2008). Air pollution has been reported to have adverse affects on plant growth adversely (Rao, 2006; Bhatia, 2006). Air pollutants can directly affect plants through their aerial parts (leaves and stem) or indirectly through the soil by acidification (stubbing *et al.,* 1989). When exposed to airborne pollutants, most plants experienced physiological changes before exhibiting visible damage to leaves (Dohmen *et al.,* 1990). Sensitivity and response of plants to air pollutants is variable. The plant species which are more sensitive act as biological indicators of air pollution. The response of plants to air pollution at physiological and biochemical levels can be understood by analyzing the factors that determine resistance and susceptibility.

It is possible to estimate the overall effect of a large number of pollutants as total pollution by measuring changes in the plants (Agbaire, 2009). Studies have shown the impacts of air pollution on ascorbic acid content (Hoque *et al.,* 2007), Chlorophyll content (Flowers *et al.,* 2007), leaf extract pH (Klumpp *et al.,* 2000) and relative water content (Rao, 1979). However, these Separate parameters gave conflicting results for some species (Han *et al.,* 1995); for example, *Ailanthus altissima* identified as sensitive to pollution using one parameter (Han *et al.,* 1995) but as tolerant using another parameter (Zhou, 1996). For the reason that single parameter may not provide a clear picture of the pollution-induced changes, air pollution tolerance index (APTI) based on all four parameters has been used for identifying tolerance levels of plants species (Singh and Rao, 1983; Liu and Ding, 2008).

Using plants as indicator of air pollution gives the possibility of synergistic action of pollutants (Lakshmi *et al.,* 2008). The ambient environment of an urban area may be contaminated with several pollutants such as SO_2, CO, NO_x and heavy metals and the plants growing there would be exposed not only to one but too many pollutants and their different conditions. Air pollution tolerance index is used by landscapers to select plant species tolerance to air pollution (Agbaire, 2009). Singh

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and Verma (2007) by using the data obtained from detailed biochemical estimations of plants samples (including chlorophyll, ascorbic acid contents, and pH and relative water content) calculated the APTI.

Vegetation in Enugu City has been exposed to a variety of pollutions arising from increased traffic population, industrial activities and increased human population. The ability of plants species to remove pollutants has been evaluated (Lui *et al.,* 2007). In this study our aim is to evaluate pollution tolerance of 5 plant species currently growing in Enugu city by using APTI method. The goal of this study was also to develop a scale of air pollution tolerance that can be applied broadly in the selection of species in Urban planting for urban heat Island reduction in Enugu Urban City.

Materials and Methods

Sampling Procedure

Plants were selected from one of the major roads within Enugu Urban area - Agbani Road. The criterion for the selection of these plants was mainly on their availability in other parts of Enugu urban area. Also, the choice of this route was based on its high traffic population. Six replicates of fully matured leaves were taken and immediately taken to the laboratory in a heatproof container for analysis. The leaf fresh weight was taken immediately upon getting to the laboratory.

Air pollution Tolerance Index Technique.

To obtain the four parameters in APTI formula, Samples were treated as follows:

Relative Leaf Water Content (RWC)

The method described by Singh (1977) and Agbaire and Esiefarenrhe (2009) was applied to determine and calculate relative leaf water content as follows:

$$RWC = \frac{FW - DW}{TW - DW} \times 100$$

FW = Fresh weight

DW = Dry weight

TW =Turgid weight

Fresh weight was obtained by weighing the fresh leaves. The leaves were then immersed in water over night at 70°C and reweighed to obtain the dry weight.

Total Chlorophyll Content (TCh)

Following the method described by Agbaire and Esiefarienrhe (2009), TCh analysis was obtained as follows: 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 (C_T) is the sum of chlorophyll a (D645) density and chlorophyll a (D663) density as follows:

C_T = 20.2 (D645) + 8.02 (D663)

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

TCh = 0.1 C_T x (leaf DW/leaf FW)

Ascorbic Acid (AA) Content Analysis

Ascorbic acid content (expressed in Mg/g) was measured using spectrophotometric method (Bajaj and Kaur, 1981). Ig of the fresh foliage was put in a text-tube, 4 ml oxalic acid EDTA extracting solution was added, them 1 ml of Orthophospheric acid and then 1 ml 5% tetraoxosulphate (vi) acid added to this mixture, 2 ml of ammonium molybdate was added and then 3ml of water. The solution was then allowed to stand for 15 minutes after which the absorbance at 760nm was measured with a spectrophotometer. The concentrations of ascorbic acid in the sample were then extrapolated from a standard ascorbic.

Leaf Extract pH

This was done following the method adapted by Agbarie and Esiefarenrhe (2009). 5g of the fresh leaves was homogenized in 10ml demonized water. This was filtered and the pH of the leaf extract determined after calibrating pH water with buffer solution of pH 4 and 9

Air Pollution Tolerance Index (APTI) Determination

This was done following the method of Singh and Rao (1983). The fornular of APTI is given as:

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

A = Ascorbic acid content (mg/g)

T = Total Chlorophyll (mg/g)

P = pH of leaf extract

R = Relative water content of leaf (%)

Urban heat Island measurement

Selected trees represented by trees of different canopy and different species. The mean temperature data were used to determine the contributions of selected street trees to urban heat Island reduction. Urban heat island magnitude (UHIM) is typically defined as the temperature difference (T) between the urban (u) and reference (r) locations or Tu-r (Hinkel *et al.,* 2003; Enete *et al*).

Results

Plants growing in polluted environment often respond and show significant changes in their morphology, physiology and biochemistry. Lakshmi *et al.,* (2008) reported that plants that are constantly exposed to environmental pollutants absorb, accumulate and integrate these pollutants into their systems. The analysis value of the calculated APTI for the five tree species is given in Table 1.

Table 1 Air Pollution Tolerance Index (APTI) of Selected Plants.

Plant Species	Ascorbic Acid	Relative water Content (%)	pH	Total Chlorophyll (mg/g)	APTI
Catalpa burgei	8.50	87.12	4.70	11.60	22.57
Mango (*Mangifera indica)*	7.56	89.32	5.0	14.10	23.37
Guava (*Psiduim guajava*)	8.99	80.89	5.20	12.65	24.15
Pine (*Pinus spp*)	8.46	74.75	5.20	11.98	22. 35
Cashew (*Anacarduim occidentale*)	9.06	84.85	4.60	13.85	22.20

From table 1, it was evident that the plants showed varied degree of tolerance index to air pollution. The APTI of the plant ranged from 22.20 to 24.15 with Guava (*Psiduim guajava*) having the highest value and cashew (*Anacarduim occidentale*) having lowest values. Based on the previous studies (Lakshmi *et al*., 2008; Agbarie and Esiefarienrhe, 2009), APTI values can be utilized as bio-indicators of the air quality, while those species in the tolerant group can be used for development of streetscape greening.

Table 2 showed contributions of different species to temperature reduction. All temperature measurements were reported as monthly average. The highest were recorded under *Psiduim guajava* (guava) 17^{o}C and lowest temperature under *Catalpa bungei* and *Anacarduim occidentale* (cashew) 12^{o}C each.

Table 2 Mean Temperature Under different Trees.

S/No	Plant Species	Temperature
1	*Anacarduim occidentale* (cashew)	12^{o}C
2	*Mangifera indica* (mango)	14^{o}C
3	*Psiduim guajava* (Guava)	17^{o}C
4	*Pinus spp* (pine)	25^{o}C
5	*Catalpa bungei*	12^{o}C

Discussion

The ability of each plant species to absorb pollutants by their foliar surface varies greatly and depends on several biochemicals, physiological and morphological characteristics (Singh and Verma, 2007). The sensitive species help to indicate air pollution and tolerant ones help in abatement of air pollution. The tolerant species of plants function as pollution sink and therefore a number of environmental benefits can be obtained by planting tolerant species in polluted areas. There are many factors controlling tolerance in plants. For example, the importance of pH in modifying the toxicity of SO_2 has been shown. Singh and Verma (2007) reported that plants with lower pH are more susceptible, while those with pH around 7 are more tolerant.

Ascorbic acid content is another parameter that may be used to decide the tolerance of plant to air pollution. It plays a significant role in light reaction of photosynthesis (Singh and Verma, 2007), activates defense mechanism (Arora *et al.,* 2002), and under stress condition, it can replace water from light reaction (Singh and Verma, 2007). Joshi and Swami (2007) also reported that ascorbic acid is a natural antioxidant in plants that play an important role in pollution tolerance. It is also a factor in cell wall synthesis, defense and cell division. It is also a strong reducer and plays important roles in photosynthetic carbon fixation, with the reducing power directly proportional to its concentration. So it has been given top priority and used as a multiplication factor in the formula. High pH may increase the efficiency of conversion from hexose sugar to AA, while Low leaf extract pH has also showed good correlation with sensitivity to air pollution (Escobedo et al., 2008; Pasqualini *et al.,* 2001; Conklin, 2001; Lui and Ding; 2008).

Total chlorophyll (TCh) is another parameter in APTI that is so important. Depletion in Chlorophyll immediately causes a decrease in productivity of plant and subsequently plant exhibits poor vigor. Photosynthetic efficiency was noted to be strongly dependent on leaf pH is low (Singh and Verma, 2007).

Water is a necessity for plant life. Shortage of water may cause severe stress to terrestrial plants (Singh and Verma, 2007); High water content within the plants body will help to maintain its physiological balance under stress conditions such as exposure to air pollution when the transpiration rates are usually high.

Based on the APTI values, and in line with the report of Lakshmi *et al.,* (2009) the plants were conveniently grouped as follows:

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

In the current study, the five species showed APTI values of 22.20 to 24.15 which fall within the classification range of 17 to 29 and are designated as intermediate. Plants are recommended for pollution abatement in urban areas, for aesthetic improvement or for microclimate modification. The sensitive species help in indicating air pollution (Lakshmi *et al.,* 2008). One the other hand, APTI is a handy tool for selecting tolerant species for urban heat Island reduction. For example, comparing the contributions of some selected trees to urban temperature reduction shown in table 2 and the APTI to the trees in table 1. It was evident that *Psiduim guajava* third place in temperature reduction but has the highest tolerance rate among all the selected trees. *Catalpa bungei* and *Anacarduim occidentale* ranked first in temperature reduction but have lowest APTI rates of 22.57 and 22.20 respectively. The implication of this is that street trees should be selected not only based on their ability to provide shed but also on their tolerance index. This becomes necessary following the alarming rate of air pollution in Enugu city, evidently seen on the high vehicular population in the city. This singular factor (traffic pollution sources), combined with other sources have predisposed Enugu urban vegetation and street trees to serious air pollution. Thus, the need to find a viable option for selecting street trees that provide shed and at the same time withstand stress from the increasing air pollution in the city.

In the current study, tolerant and intermediate species are recommended for planting in Enugu City. They will not only abate air pollution but also provide shed, thus modifying the urban microclimate. In this study, all the species examined are intermediate. The implication is that under high stress and heavy pollution they may not function properly.

Conclusion

Air pollution tolerance Index determinations are of importance because with increased urbanization, industrialization and traffic population increase in Enugu Urban City, there will be more air pollution. The results of such studies are therefore handy for future planning. This study also provides useful information for selecting tolerant species for landscape and urban heat Island mitigation. Species ranked as tolerant and intermediate tolerant should be considered first.

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