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Determination of Air Pollution Tolerance Index of Selected Trees in Selected Locations in Maiduguri

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ABSTRACT

In an attempt to contribute to environmental pollution control measures, relative tolerance of six selected tree species namely; *Anacardium occidentale, Azadiracta indica, Cassia angustifolia, Eucalyptus spp, Khaya senegalensis, Mangifera indica* from three selected locations of high, moderate, and low pollution rate in Maiduguri City was determined. The plants were selected based on their relative abundance in the locations. The Ascorbic acid content (AAC), pH, Relative water content (RWC), Total chlorophyll content and Air Pollution Tolerance Index (APTI) was evaluated based on the measured physiological and biochemical parameters. The study revealed that *Mangifera indica* (30.02) and *Anacardium occidentale* (29.65) are tolerant species, *Khaya senegalensis*(28.61) Azadiracta indica(28.23) and *Eucalyptus spp*(24.10) are intermediate and *Cassia angustifolia*(25.129) is sensitive. Therefore these tree species could be used as bio indicators in pollution monitoring.
Keywords: Air pollution, relative water content, total chlorophyll content, ascorbic acid, pH,

I. INTRODUCTION

Emission of green house gases is one of the major problems arising from human population explosion and industrialization. The use of fossil fuels such as petroleum hydrocarbons and coal for transport, electricity generation for industries and households; land clearing, deforestation, agriculture and land use, produce large quantities of oxides of carbon, nitrogen and sulphur, as well as methane, aerosol particulates, etc. These pollute the environment; destroy the atmospheric ozone shield that protects organisms from high levels of ultraviolet radiation, resulting in global warming and climate change [1]. Hence, the study focuses on the determination of air pollution tolerance index of six selected tree species *(Anacardium occidentale, Azadiracta indica, Cassia angustifolia, Eucalyptus spp, Khaya senegalensis, Mangifera indica)* commonly found in selected locations of different pollution concentration in Maiduguri city.

The relative leaf water content (RWC), total chlorophyll content (Tch), pH of leaf extract, and ascorbic acid content (AAC) were determined to calculate the air pollution tolerance index of the selected tree species in automobile repair garage, road sides, commercial areas, as highly polluted areas (HP) where most pollutants are emitted into the atmosphere, residential areas as moderately polluted areas (MP) and city outskirts as low polluted areas (LP). Pollutants that are pumped into the atmosphere and directly pollute the air are primary pollutants while those that are formed in the air when primary pollutants react or interact are known as secondary pollutants [2]. Also the effects are most often apparent on the leaves which are usually the most abundant and most obvious primary receptors of large number of air pollution [3]. Studies show that air pollution has an impact on the ascorbic acid content, total chlorophyll content, leaf extract pH, and relative water content of plants. Therefore, air pollution tolerance index (APTI) was computed base on all four parameters that has been used to identify the tolerance of plant species [4].

Many workers like [5, 6 and 7] used ascorbic acid, chlorophyll, relative water content and leaf extract pH to evaluate the susceptibility of some plants to air pollutants by computing these four physiological parameters together in a formation signifying their air pollution tolerance index (APTI). Plants with higher

APTI values are more tolerant to air pollution than those with low APTI values. Those with low APTI values are sensitive plants and may act as bio-indicators of pollution [8, 9]. Hence, on the basis of their indices, different plants may be categorized into tolerant, moderately tolerant, intermediate and sensitive plants [8]. Ascorbic acid is an antioxidant, which contributes in protecting the plants against oxidative damage resulting from aerobic metabolism, photo-synthesis and a range of pollutants [10]. Reactive oxygen species are produced in plants after exposure to environmental conditions like drought, cold or air pollution by building up reactive oxygen species and then respond by reducing the amount of water that escapes from leaves [11]. The water content of the plant tissues helps to maintain the physiological balance of the plant when subjected to the stress of air pollution. Hence, the water content is related to the degree of pollution. The pH of the plant tissue is also related to the degree of air pollution since air pollutants interact with rainwater to form mixtures and solutions with pH, depending on the type of pollutant. Chlorophyll is involving in the productivity of the plants and its level is a direct measure of leaf damage by pollution [12, 13]. Its measurement is an important tool for evaluating the effects of air pollutants on plants since it plays an essential role in plant metabolism and any reduction in chlorophyll content corresponds directly to plant growth [14].

II. METHODS AND MATERIAL

STUDY AREA

Maiduguri is situated at 11.85^{o} North Latitude, 13.16^{o} East and 300 meters elevation above the sea level. The climate of Maiduguri is characterized by a long dry season with high evaporation rate from October to May and a short wet season for the remaining part of the year. Generally the mean monthly temperature is always above 20^{o}C, but the daily extremes vary in a wide range reaching up to 47^{o}C in April. The blowing of the North East winds and the south West are the determinants of the climatic pattern of the city [15].

Maiduguri is a very large town in Nigeria, having between 1,089,185 to 2,722,986 inhabitants [16]. Maiduguri is the heart of the Sudan savannah and Luxuriant canopies of neem trees are commonly found lined up along most streets of the city. Flowers and exotic species of trees are commonly used in landscaping in many institutions and homes. On the outskirts of the city, mango, and cashew gardens are dominant. The soil of Maiduguri and environs may be classified into groups. These are aerosol or sands of Aeolian origin and the beach ridge sediment, vertisol or lagoonal clay and fluvisol and clay soil of alluvial deposit [15].

SAMPLING PROCEDURE

Plants were selected from one of the major roads within Maiduguri Urban area – Lagos Street Road, Automobile garages, University of Maiduguri commercial area, and university gardens. The criterion for the selection of these plants was mainly on their availability in the selected locations and other parts of Maiduguri urban area. Also, the choice of this route was based on its high traffic population. These tree species include; *(Anacardium occidentale, Azadiracta indica, Cassia angustifolia, Eucalyptus spp, Khaya senegalensis, Mangifera indica)*. Six replicates of fully matured leaves were taken and immediately taken to the laboratory in a heat proof container for analysis. The leaf analysis was done immediately upon getting to the laboratory.

Air pollution Tolerance Index Technique.
To obtain the four biochemical parameters in APTI formula, Samples were treated as follows:

Relative Leaf Water Content (RWC)
The method described by [6] and [2] was applied to determine and calculate relative leaf water content as follows: Fresh weight was obtained by weighing the leaves. The leaf samples were then immersed in water over night blotted dry and then weighed to get the turgid weight. The leaves were then dried overnight in a hot air oven at 70^{o}C and reweighed to obtain the dry weight.

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

FW = Fresh weight
DW = Dry weight
TW =Turgid weight

Total Chlorophyll Content (Tch)
Following the method described by [17] the acetone extraction method, to determine total chlorophyll

content **(**TCh) in the leaves; 3 g of fresh leaves were blended and then extracted with 10 ml of 80% acetone and left for 15 minutes for thorough extraction. The liquid portion was decanted into another test-tube and centrifuged at 2,500 rpm for 3 minutes. The supernatant liquid was then collected and the absorbance taken using a spectrophotometer at 670 nm and 690 nm. Calculations were done according to the formula given below.

$$\text{Chlorophyll 'a'} = \frac{12.7\,Dy \times 670 - 2.69\,Dy \times 690V}{1000W}\ \text{mg/g}$$

$$\text{Chlorophyll 'b'} = \frac{22.9\,Dy \times 670 - 4.68\,Dy \times 690V}{1000W}\ \text{mg/g}$$

Where:
TCh = Chlorophyll a + b mg/g,
Dy = Absorbance of the extract at the wavelength y nm.
V = Total volume of the chlorophyll solution (ml) and
W = Weight of the tissue extracted (g).

Ascorbic Acid (AA) Content Analysis
The AAC was measured using the indophenols acetic acid method. 1 g of the leaf sample was crushed and made up to 50 ml using distilled water and 10 ml of acetic acid. A solution of 0.01% 2,6-Dichlorophenol indo phenol was made and then titrated with the sample alternatively until pink colour develops.

Leaf Extract pH
This was done following the method adapted by [2]. 5g of the fresh leaves was homogenized in 10ml deionized water. This was filtered and the pH of the leaf extract determined using a digital pH meter.

Air Pollution Tolerance Index (APTI) Evaluation
This was done following the method of [18]. The fornular for APTI is given as:

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

A = Ascorbic acid content (mg/g)
T = Total Chlorophyll (mg/g)
P = pH of leaf extract
R = Relative water content of leaf (%)

III. RESULT AND DISCUSSION

Table: 1 APTI of selected tree species in selected areas

S/N	Specie	Site	AAC	pH	Tch	RWC	APTI
1	Anacardium Occidentale	HP	9.80	6.20	16.01	80.82	29.65
		MP	6.53	5.92	16.86	79.20	22.80
		LP	5.09	5.13	16.92	75.74	18.80
2	Azadiracta Indica	HP	8.29	5.47	18.43	84.14	28.23
		MP	5.33	6.03	18.72	83.69	21.56
		LP	4.61	6.32	19.50	82.13	20.12
3	Cassia Angustifolia	HP	7.92	4.90	16.53	81.33	25.12
		MP	3.30	4.32	16.55	81.20	15.01
		LP	2.89	4.01	18.01	78.78	14.24
4	Eucalyptus Spp	HP	8.52	5.00	14.55	74.42	24.10
		MP	8.40	5.55	15.61	71.95	24.97
		LP	6.34	5.67	16.00	70.36	20.78
5	Khaya Senegalensis	HP	9.17	5.20	16.72	85.07	28.61
		MP	5.06	5.88	17.11	77.90	19.42
		LP	3.41	6.12	17.82	74.53	15.62
6	Mangifera Indica	HP	8.70	4.85	19.60	87.44	30.02
		MP	4.77	5.68	19.80	82.45	20.40
		LP	4.11	6.00	20.30	81.14	18.92

Plant leaves were dried in an oven and another sample was dried under the sun. It took 2 days (48 hours) to sundry the first sample at a mean temperature of 40^{o}C while the second sample took a day (24 hours) to dry in an oven at 70^{o}C.There was colour change from dark green to light green for samples dried under the sun, while colour changes to greenish yellow, and dark green when dried in an oven.

In this study *Mangifera indica* has the maximum relative water content of 87.44% in highly polluted areas and minimum in *Eucalyptus spp* of 70.36% in low polluted areas. Relative water content is associated with protoplasmic permeability in cells which causes loss of water and dissolved nutrients, resulting in early senescence of leaves [19]. More water in a leaf will help to maintain its physiological balance under stress condition of air pollution when the transportation rates are usually high. Higher relative water content favours drought resistance in plants [20].
Ascorbic acid is a strong reductant and it activates many physiological and defense mechanism in the plants. Its reducing power is directly proportional to its concentration [21, 2]. However it's reducing activity is pH dependent, being more at higher pH levels because

high Ph may increase the efficiency of conversion of hexose sugar to ascorbic acid and is related to the tolerance to pollution [22]. The result of the study revealed that *Anarcardium ocidentale* has highest ascorbic acid content of 9.80 and *Cassia angustifolia* has the lowest ascorbic acid content of 7.92 both in high pollution areas.

Chlorophyll is an index of productivity of plant [21] Chlorophyll content of plants varies from speices to species, age of leaf and also with the pollution level as well as with other biotic and abiotic condition [23]. Whereas certain pollutants increase the total chlorophyll content [24], other decreases it. It is revealed from the study that *Eucalyptus spp has* least total chlorophyll content of 14.55 in high pollution area due to air pollution and *Mangifera indica* has the highest total chlorophyll content of 20.30 in low pollution area.

Plants with lower pH are more susceptible while those with pH around 7 are tolerant [25, 26]. The change in leaf extract pH might influence the stomatal sensitivity due to air pollution. The pH ranges between 4.6 and 6.7. The pH of leaf extract was slightly acidic.

Table: 2 APTI Ranges of Sensitivity

APTI VALUE	RESPONSE
< 1	Very sensitive
1 – 16	Sensitive
17 –29	Intermediate
30 -100	Tolerant

APTI DISCUSSION

The parameters studied provide a clear picture of pollution induced changes. The variation in biochemical parameter of the tree species considered could be used as indicators of air pollution for early diagnosis of stress or as a marker for physiological damage prior to the onset of visible injury symptoms as agreed by [27, 28, & 29]

APTI of six different plants species at roadsides and automobile garages in Maiduguri City (high pollution area), University of Maiduguri campus (moderate pollution area) and University of Maiduguri Agricultural garden (low pollution area) are presented in table 1. Analysis shows that *Mangifera indica* and *Anacardium occidentale* have much more high APTI values of 30.02 and 29.65 respectively in high pollution areas and are termed as tolerant trees. However, plant species such as *Azadiracta indica, khaya senegalensis,* and *Eucalyptus spp* have APTI values of 28.23, 28.61 and 24.10 respectively in high pollution areas and are termed intermediate. Finally, *Cassia angustifolia* with APTI value of 25.123 in high pollution, 15.01 in moderate pollution and 14.24 in low pollution fall in sensitive plant range and are termed sensitive plant that can be used as bio indicators of pollution. Sensitive species are those either not found in the polluted area or occur only in low abundance [30]. Moreover the tolerant species *Mangifera indica* and *Anacardium occidentale* found in this study are also valuable economic trees whose fruits are edible and have commercial value aside their performance as air pollution sinks.

Variation in Order of Tolerance of Trees under This Study:

Order of Tolerance of Selected Plants on Roadsides and Automobile Garages in Maiduguri (High Pollution Area)

Mangifera indica>Anacardium occidentale>Khaya senegalensis>Azadiracta indica>Cassia angustifolia>Eucalyptus spp

Order of Tolerance of Selected Plants in University Of Maiduguri Agricultural Garden (Moderate Pollution Area)

Eucalyptus spp>Anacardium occidentale>Azadiracta indica>Mangifera indica>Khaya senegalensis>Cassia angustifolia

Order of Tolerance of Selected Plants in University Of Maiduguri Campus (Low Pollution Area)

Eucalyptus spp>Azadiracta indica>Mangifera indica>Anacardium occidentale>Khaya senegalensis>Cassia angustifolia.

The variation in tolerance position of each plant species shown in different location of varied pollution rate is as a result of the difference in biochemical parameters content of the selected plant leaves and their ability to tolerate pollution.

IV. CONCLUSION

The study has identified various tree species growing in all the three areas of Maiduguri with different pollution level. An overview of the entire result obtained from this study reveals that different plants respond differently to air pollution; hence the different indices show that plants growing in apparently polluted environment have higher APTI values as could be seen in the results of all the six species; *Mangifera indica* (30.02) *Anacardium occidentale* (29.65), *Khaya senegalensis*(28.61) Azadiracta indica(28.23) *Eucalyptus spp*(24.10) *Cassia angustifolia*(25.129) respectively. In highly polluted areas, the pattern is as listed *Mangifera indica* (20.40) *Anacardium occidentale* (22.80), *Khaya senegalensis*(19.42) Azadiracta indica(21.56) *Eucalyptus spp*(24.92) *Cassia angustifolia*(15.01) while in moderately polluted areas,nthe pattern thus reads: *Mangifera indica* (18.92) and *Anacardium occidentale* (18.80), *Khaya senegalensis*(15.62) Azadiracta indica(20.12) *Eucalyptus spp*(20.78) *Cassia angustifolia*(14.24) in low polluted areas. Hence the selected trees have potential to serve as indicators of pollution rate and air pollution sinks.

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