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Assessment of pollution tolerance index of selected plant species in abakaliki metropolis, south –eastern, Nigeria

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ABSTRACT

In the recent years, Abakaliki Metropolis witnessed increase in urbanization and industrialization, which lead to increase in air pollution resulting from dusts, smokes and domestic wastes. The roads are adorned with plants that are used in landscaping. It is therefore necessary to find out the role of these plants in mitigating pollution. This study was carried out to assess the air pollution tolerance indices of four plant species that are widespread in Abakaliki Metropolis with the goal of determining their suitability for urban plantation and development. The leaves of the four plant species were collected at three different sites. Standard methods were adopted for ascorbic acid, pH, chlorophyll and relative water content analysis of these plants. The values were used to compute the air pollution tolerance index (APTI) of each plant species as well as the assessment of its tolerance and sensitivity. In the present study, APTI values of less than 16 were recorded for *Gmelina aborea* (8.87) in site 3 and *Terminalia catappa* (6.22) in site 2 and (8.98) in site 3, thus they can be used as indicators of air pollution in these sites. *Mangifera indica* and *Carica papaya* had APTI values ranging from 89.6 – 98.1 and 91.1 – 106.67 respectively in the studied sites, thus it can be deduced that these plants are tolerant to air pollution.

KEYWORDS

APTI;
Indicator species;
Tolerant and sensitive.

INTRODUCTION

Plants are central for ascertaining, preserving and maintaining the ecological balance of the ecosystem by taking part in the cycling of nutrient and gases. Escorbedo *et. al.* (2008) reported that plants provide massive leaf areas for impact, concentration and build up of air pollution which will invariably bring about reduction of pollution level in the air environment. Plants physioecological activities are greatly affected by air pollution[27,5,30,15]. Plants biomonitoring is an important tool for the evaluation of air pollution. Plant response towards air pollution can be monitored using Air Pollution Tolerance Index (APTI). Several scholars have investigated the usefulness of evaluating air pollution tolerance index for the determination as well as sensitiveness of plant species[2,10,22,11]. Experiments have revealed that air pollution impacted negatively on Ascorbic acid content[14], leaf extract and pH[19] and Relative water content of plants[27]. APTI is a conditional plant trait that conveys its intrinsic capability to confront stress originating from pollution. Mashita and Pise (2001) described APTI value between 30 – 100 in species as tolerant; 17 – 29 as occasionally tolerant; 1 – 16 are considered sensitive, while values less than 1 are highly sensitive. Studies on Air Pollution Tolerance Index of some plants in urban areas of Bhopal carried out by Tiwari *et. al.* (1993) revealed that plants having higher APTI values are more tolerant to air pollution than those having lower values. Abakaliki Metropolis in the recent years has witnessed increase in urbanization. It is expected that air pollutants will be on the increase. The roads are adorned with plants that are used as ornaments. It is therefore necessary to find out the role of these plants in mitigating pollution. According to Palit *et. al.* (2013) species having lower APTI value may act as bioindicator of air pollution. This study is aimed at determining the air pollution tolerance values of four tree species that are widespread at Abakaliki Metropolis with the goal of ascertaining the plant species that will be suitable for urban plantation and development.

MATERIALS AND METHODS

The study was carried out within Abakaliki town in Ebonyi State, Nigeria. Abakaliki has a land mass of 51 km^2. The area lies on latitude 6^{o}22'26"N and longitude 8^{o}6'6"E of the Greenwich meridian. The average atmospheric temperature is 32-35^{o}C[12].

In this study, the metropolis was divided into three sites having different anthropogenic atmospheric influence. Quarry dust pollution, industrial activities and heavy traffic highways contributed to air pollution in Site 1, 2 and 3 respectively of Abakaliki Metropolis. Mature of leaves of *Mangifera indica, Gmelina aborea, Carica papaya and Terminalia catappa* were sampled during the dry season from the three sites in Abakaliki Metropolis. The leaves from all the sites were collected in polyethylene bags and transported to the laboratory. The leaves collected from plants in each site were washed thoroughly with distilled water and filtered; and the filtrate used for the study. Three replicates for each plant and site were collected and used for the study. Estimation of pH of the filtrate was done according to Singh and Rao (1983). Leaf relative water content (RWC), ascorbic acid content (AA) (mg/g), total chlorophyll content (TChl) (mg/g) were determined according to the methods adopted by Begum and Harikrishna (2010). The Air Pollution Tolerance Index was calculated by using the following formula[29].

Air Pollution Tolerance Index= [A (T+P) + R] /10

Where A= Ascorbic acid (mg/g dry wt.), T= Total Chlorophyll (mg/g dry wt.), P = pH of leaf extract and R= Relative water content of leaf tissue (%).

Based on the Air Pollution Tolerance Index values, the plants will be grouped using the method of Kalyani and Singaracharya (1995) as follows

AIR POLLUTION TOLERANCE INDEX Value	Response
30 to100	Tolerant
17 to 29	Intermediate
1 to 16	Sensitive
<1	Very sensitive

RESULTS AND DISCUSSION

The values of the analyses carried out on the four plant species in three selected sites of Abakaliki Metropolis are as shown in TABLE 1.

pH

The results revealed that pH of the (leaf) filtrate from the studied plants are acidic in nature except for *Gmelina aborea* in site 1 and 3 (TABLE 1). The nature of the pH of the (leaf) filtrates in the sites is an indication of gaseous nature of air pollutants especially SO_2 and NO_2. These pollutants diffuse and form acid radicals in leaf matrices by reacting with cellular water thus affecting the chlorophyll molecules[24]. pH aids in physiological reactions caused by stress in plants. Change in pH stimulates stomatal sensitivity, thus leaves with low pH are more vulnerable to pollution while those having neutral pH are tolerant[20]. Site 3 recorded the highest leaf extract pH (8.14) in *Gmelina aborea*, while *Carica papaya* had the least pH (4.16) in site 1. Rao 1977 and Scholz & Rech (1997) reported that in the presence of an acidic pollutant, the leaf pH is lowered which leads to greater decline in plant species sensitive. Agrawal (1986) argued that plants with higher (leaf filtrate) pH are endowed with tolerance against pollution.

TABLE 1: Biochemical composition of the leaf samples collected from four plants species in Abakaliki Metropolis

Site	Plant species				
	Biochemical parameters	***Mangifera indica***	***Gmelina aborea***	***Carica papaya***	***Terminalia catappa***
1	pH	5.75	7.18	4.16	5.48
	RWC (%)	92.70	6.90	84.39	4.11
	Tchl.(mg/g)	25.97	30.65	7.09	0.28
	AA (mg/g)	1.06	8.86	5.96	2.46
2	pH	6.85	6.91	6.83	5.44
	RWC (%)	83.90	6.80	90.43	5.48
	Tchl.(mg/g)	30.65	23.03	17.56	0.64
	AA (mg/g)	1.52	5.65	6.66	1.22
3	pH	6.07	8.14	6.79	5.03
	RWC (%)	85.51	6.90	83.43	8.47
	Tchl.(mg/g)	35.77	7.77	24.03	0.19
	AA (mg/g)	3.01	1.24	7.47	0.98

RWC = Relative Water Content, Tchl. = Total Chlorophyll Content and AA = Ascorbic Acid.

Relative water content

Dedio (1975) reported that the relative water content in a plant body helps in maintaining its physiological balance under stress conditions such as exposure to air pollution when transpiration rates are high. Reduction in leaf evapotranspiration rate due to air pollution retard the growth of these plants, and consequently the tugor pressure that pulls water up from the roots to the leaves are affected. Thus the plants do not translocate water and or minerals effectively from the root to leaves where biosynthesis occurs to cool the leaves[22].

Relative water content varied between 4.11% to 92.7% in site 1, 5.48% to 83.9% in site 2 while in site 3 it was within 6.9% to 85.51%. *Mangifera indica* recorded the highest relative water content in site 1 and site 3 (TABLE 1), while *Carica papaya* recorded the highest value of Relative water content in Site 2. The least Relative water content was recorded by *Terminalia catappa* (TABLE 1). Plants with relatively high water content are highly resistant to pollution[1]. Based on this, *Mangifera indica* and *Carica papaya* are highly resistant to air pollution in this study.

Total chlorophyll content

The chlorophyll content of plant is an indication of its photosynthetic vigour as well as its growth and development of biomass[6]. According to Katiyar and Dubey, 2001, chlorophyll content in plants varies from species to species, and also depends on age of leaf, and pollution level along side with other biotic and abiotic factors. Plants having chlorophyll content between 4mg/g to 16mg/g are categorized as intermediate tolerant plant species[21]. The analyses of total chlorophyll content of four plant species studied are as shown in TABLE 1. The total chlorophyll content of *Mangifera indica* in the sites 1, 2 and 3 are 25.98mg/g, 30.65mg/g and 35.77mg/g respectively. It showed an increase of 8.25% at site 2 and increase of 15.85% at site 3. *Gmelina aborea* had total chlorophyll content of 30.65mg/g, 23.03mg/g and 7.7mg/g at sites 1, 2 and 3 respectively. There was a marked reduction of 14.20% at site 2 and 59.63% at site 3. The total chlorophyll content of *Carica papaya* in sites 1, 2 and 3 are 7.09mg/g, 17.56mg/g and 24.03mg/g respectively. It showed 42.48% increase at site 2 and 54.43% at site 3. *Terminalia catappa* had a total chlorophyll content of 0.28mg/g,0.64mg/g and 0.19mg/g at sites 1, 2 and 3 respectively. There was marked increase by 39.13% at site 2 and 19.15% in site 3. The higher levels of chlorophyll content in leaves of *Mangifera indica* at site 2 and 3 when compared to site 1, *Gmelina aborea* in site 1 and 2 when compared to 3, *Carica papaya* in site 2 and 3 when compared to site 1 and *Terminalia catappa* at site 1 and 2 when compared to site 3 is an indication of lower air pollution stress. The lowest total chlorophyll content in the leaves of four studied plant species in site 1 and 3 when compared to site 2 is an indication of higher air pollution stress.

Ascorbic acid

Ascorbic acid plays a role in cell wall synthesis, defence, and cell division (Conklin, 2001). The increase in ascorbic acid might act as strong reductant for defence mechanism against automobile pollutants and plays important roles in photosynthetic carbon fixation[25].

Keller and Schwager (1977) reports that Ascorbic acid induces the resistance of plants to unfavourable environment conditions including air pollution. In site 1 of this study, ascorbic acid content ranged from 1.06mg/g to 8.86mg/g, with *Gmelina aborea* having the highest value and *Mangifera indica* the least value. In all the four plant species studied in site 2, ascorbic acid ranged from 1.22mg/g to 6.66mg/g with *Carica papaya* having the highest ascorbic acid content while *Terminalia catappa* has the lowest content. The highest ascorbic acid content of 7.47mg/g was recorded in site 3 for *Carica papaya* with *Terminalia catappa* having the lowest content of 0.98mg/g. Chaudhary and Rao (1977) and Varshney & Varshney (1984) opined that higher ascorbic acid content in plant is an indication of its tolerance against sulphur dioxide. Tripathi and Gautam (2007) reported increase in the concentration of ascorbic acid in the leaves of *Mangifera indica* near roadsides due to enhanced pollution loads.

Air pollution tolerance index (APTI)

The evaluated air pollution tolerance indices for the studied plants at sites 1, 2 and 3 were in the range of 19.2 – 96.06, 6.22 –106.67 and 8.98 – 106.45 respectively (TABLE 2). The APTI of *Mangifera indica* at sites 1, 2 and 3 are 96.06, 89.6 and 98.1 respectively, while *Carica papaya* had APTI of 91.1 in site 1, 106.67 in site 2 and 106.45 in site 3. This implies that these plant species had the ability to cope with the difficulty of air pollution. *Gmelina aborea* had APTI values of 40.43, 23.72 and 8.87 in sites 1, 2 and 3 respectively. It was occasionally tolerant to air pollution in site 2 and sensitive in site 3. *Terminalia catappa* had intermediate tolerance in site 1, but sensitive to air pollution in sites 2 and 3 (TABLE 2). The APTI classification of studied plants in Abakaliki Metropolis is as shown in TABLE 3.

TABLE 2 : Relative Air Pollution Tolerance Index for the plant species at selected sites in Abakaliki Metropolis

Plant species	Air Pollution Tolerance Index values of studied plants		
	Site 1	Site 2	Site 3
Mangifera indica	96.06	89.6	98.1
Gmelina aborea	40.43	23.72	8.87
Carica papaya	91.1	106.67	106.45
Terminalia catappa	19.2	6.22	8.98

TABLE 3 : Classification of Air Pollution Tolerance Index for the plant species studied in Abakaliki Metropolis

Plant species	Classification of Studied Plants		
	Site 1	Site 2	Site 3
Mangifera indica	Tolerant	Tolerant	Tolerant
Gmelina aborea	Tolerant	Intermediate	Sensitive
Carica papaya	Tolerant	Tolerant	Tolerant
Terminalia catappa	Intermediate	Sensitive	Sensitive

The correlation between air pollution tolerance index and biochemical parameters: ascorbic acid, total chlorophyll, leaf pH and relative water content and among themselves were carried out. There exist a positive correlation between air pollution tolerance index and the biochemical parameters in most sites (TABLES 4, 5 and 6). In site 1, there was a significant correlation between air pollution tolerance index and RWC, while it correlated negatively with pH and ascorbic acid (TABLES 4, 5 and 6). In site 2, air pollution tolerance index was significantly correlated with relative water content and showed a positive correlation with pH, total chlorophyll and ascorbic acid (TABLE 5). In site 3, air pollution tolerance index was significantly correlated with relative water content but did not show any significant relation with total chlorophyll and ascorbic acid. However, there was a negative correlation between air pollution tolerance index and pH (TABLE 6).

TABLE 4 : Correlation of Air Pollution Tolerance Index and Biochemical parameter of leaf samples from site 1.

	pH	RWC	Tchl	AA	APTI
pH	1				
RWC	-0.589	1			
Tchl	0.725	0.099	1		
AA	0.344	-0.374	0.315	1	
APTI	-0.395	0.951*	0.344	-0.115	1

*** Correlation significant at 0.05 level**

TABLE 5 : Correlation of Air Pollution Tolerance Index and Biochemical parameters of leaf samples from site 2.

	pH	RWC	Tchl	AA	APTI
pH	1				
RWC	.546	1			
Tchl	.909	.540	1		
AA	.609	.185	.225	1	
APTI	.649	.987*	.589	.333	1

*** Correlation significant at 0.05 level**

TABLE 6 : Correlation of Air Pollution Tolerance Index and Biochemical parameters of leaf samples from site 3.

	pH	RWC	Tchl	AA	APTI
pH	1				
RWC	-.087	1			
Tchl	.056	.937	1		
AA	.116	.782	.568	1	
APTI	-.168	.991**	.883	.824	1

** Correlation significant at 0.01 level

In conclusion, it can be deduced from the results that *Gmelina aborea* is a bioindicator of air pollution in site 3, while *Terminalia catappa* is for all the sites.

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