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Biochemical Properties and Air Pollution Tolerance Indices of Plants in Port Harcourt City, Nigeria

F. B. G. Tanee[1*], E. Albert[1] and Becky R. Amadi[1]

[1]*Department of Plant Science and Biotechnology, University of Port Harcourt, Port Harcourt, Nigeria.*

Authors' contributions

This work was carried out in collaboration between all authors. Author FBGT designed the study, supervised the field and laboratory work, performed the statistical analysis and wrote the protocol. Authors EA and BRA wrote the first draft of the manuscript and managed literature searches; participated in the field and laboratory analyses of the study. All authors read and approved the final manuscript.

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ABSTRACT

Aims: The impact of air pollution on biochemical properties and air pollution tolerance indices of ten plants growing at Trans-Amadi Industrial Lay-out and along East-West Road, Port Harcourt alongside Umuokiri-Aluu as control site were studied.
Study Design: The leaves of the plants were collected and used to determine fresh weight, turgid weight, dry weight, relative water content, leaf extract pH, ascorbic acid content and total chlorophyll content. Air pollution tolerance indices were calculated from data obtained for each plant species.
Results: Results showed that relative water content of leaf samples were of the order

**Corresponding author: E-mail: franklin.tanee@uniport.edu.ng;*

Trans-Amadi Industrial Lay-out > East-West Road compared with the control. Leaf extract pH was higher at Trans-Amadi Industrial Lay-out and East-West Road than the control while Ascorbic acid was lower at Trans-Amadi and East-West Road. Percentage increase in air pollution tolerance index of seven plants of Trans-Amadi followed the order: *Terminalia catappa* (7.70%), *Eluesine indica* (22.24%), *Musa sapientum* (25.54%), *Panicum maximum* (26.56%), *Psidium guajava* (37.10%), *Mangifera indica* (44.18%), *Delonix regia* (181.90%) while that of East-West Road were of the order: *Musa paradisiaca* (4.84%), *Chromolaena odorata* (13.19%), *Panicum maximum* (20.17%), *Musa sapientum* (23.95%), *Carica papaya* (25.04%), *Psidium guajava* (25.32%), *Mangifera indica* (33.63%).

Conclusion: Air pollution tolerance indices of the plants were of the sensitive category and hence they can be used to monitor air quality of Niger Delta.

Keywords: Air pollution; biochemical properties; Port Harcourt; pollution tolerance.

1. INTRODUCTION

Air pollution which can simply be defined as the alteration of the natural composition of the atmosphere especially due to human activities is one of the severe problems the world is facing today [1]. This condition results out of some anthropogenic activities such as urbanization, industrialization, vehicular exhaust gas emissions, power generation and some domestic activities. These processes release particulate matter, radioactive materials and gases such as carbon monoxide (CO), carbon dioxide (CO_2), sulphur dioxide (SO_2), nitrogen oxide (NO), hydrogen sulphide (H_2S), hydrogen chloride (HCl) and ammonia (NH_3) into the atmosphere and therefore give rise to pollution. The presence and at certain concentrations of these substances in the atmosphere deteriorates air quality.

Air pollution directly affects plants through direct uptake of pollutants from it by the leaves as respiratory organs or indirectly from soil acidification through root absorption. Most plants experience physiological changes before exhibiting visible damage on their leaves when exposed to air pollutants [2,3]. Some visible signs of air pollution impacts on plants include bleached spots, chlorosis, necrotic spots, lesions, premature senescence, reduced growth and yield in sensitive plant species [4-6]. Although, vegetation which serves as sink of air pollutants is an effective indicator of overall impact of air pollution have long been used as biomonitors of air pollution [7]. The effects of air pollution on plants are time-averaged results that are more reliable than those obtained from direct determination of pollutants in air over a short period. This is because plants provide an enormous leaf area for impingement, absorption and accumulation of air pollutants and so they reduce the pollution level in air [2]. This capability varies to some extents in different plant species. The use of Ascorbic acid content [8], chlorophyll content [9], leaf extract pH [10] and relative water content [11] have been used to determine the sensitivity and tolerance of plants to air pollution. Singh and Rao [12] classified Air Pollution Tolerance Indices (APTI) value of plants as follows:

Categories of plants based on APTI

S/No	APTI value	Class
1	>17	Tolerant
2	>10 and <16	Intermediate
3	<10	Sensitive

In Niger Delta of Nigeria, air pollution has been on the increase since the commencement of oil and gas exploration in the region. The underlying factors responsible for air pollution in the area are industrialization and a general high rate of urbanization [13]. Ana [14] highlighted gas flaring, refinery, petrochemical and fertilizer plants gaseous effluents emission into atmosphere, burning of fossil fuels and oil facilities fires as some sources of air pollution in the area. In addition to the above sources, agricultural practice (bush burning), refuse burning and automobile emission are other sources of air pollution in the area. With all the above sources still operational in the area, there is no question about air pollution in the area. However, no major attempt has been undertaken to assess atmospheric pollution tolerance indices of plants in Port Harcourt metropolis. Hence, this research work has its thrust on the study of air pollution tolerance indices of plants growing in the city.

2. MATERIALS AND METHODS

2.1 Study Area

This study was carried out in Port Harcourt, the capital city of Rivers State. Port-Harcourt is located between latitudes 4º43' - 4º54' N and longitudes 6º56' - 7º03' E. The city lies along the Bonny River in the Niger Delta of southern Nigeria. The city covers an area of 186 km^2: 170 km^2 land and 16 km^2 Water (http://en.wikipedia.org/wiki/Port-Harcourt). The population of Port-Harcourt is estimated at 1,620,214 in the year 2007 (http://en.wikipedia.org/wiki/PortHarcourt). The main industrial area of the city is the Trans-Amadi Industrial Lay-out.

Port Harcourt features a tropical climate with lengthy and heavy rainy season and very short dry season. Temperature throughout the year in the city is relatively constant with mean annual temperature of about 29ºC (http://en.wikipedia.org/wiki/PortHarcourt). It has double maxima rainfall peaks with first peak usually around June/July and the second in September before the onset of dry season [15]. Mean annual rainfall of the city is over 2000 mm. The heaviest precipitation in the city occurs during September with an average of 370 mm. Only the months of December and January are the actual dry season months of the city. Harmattan which climatically influences many cities in the middle belt and northern Nigeria is less experienced in Port Harcourt.

2.2 Sampling Locations

Specifically, this study was carried out at three locations: Trans-Amadi Industrial Layout, East-West Road (Kilometre 10 -16) and Umuokiri, Aluu Fig. 1. Trans-Amadi Industrial Lay-out is at the heart of the city of Port Harcourt. It host many industries and also in proximity with Eleme, another industrial axis in boundary with Port Harcourt. Trans-Amadi is an area of high atmospheric pollution and wastes generation due to the various industrial operations undertaken by the different manufacturing companies in the area. For the purpose of this study, this area was taken as study site 1 (SS 1). Kilometre 10-16 of the East-West Road (which is a component of the trunk road of the the East-West Road that links Rivers State with Bayelsa and Akwa Ibom States) experiences high vehicular traffic. This second site was taken as study site 2 (SS 2) while Omuokiri, Aluu which is about 27.7 km away from Port Harcourt city is free from high vehicular traffic and does not host any industrial activity. As a result of this ecological condition air pollution may be minimal in the area. This site was used as control site (CS) for the study.

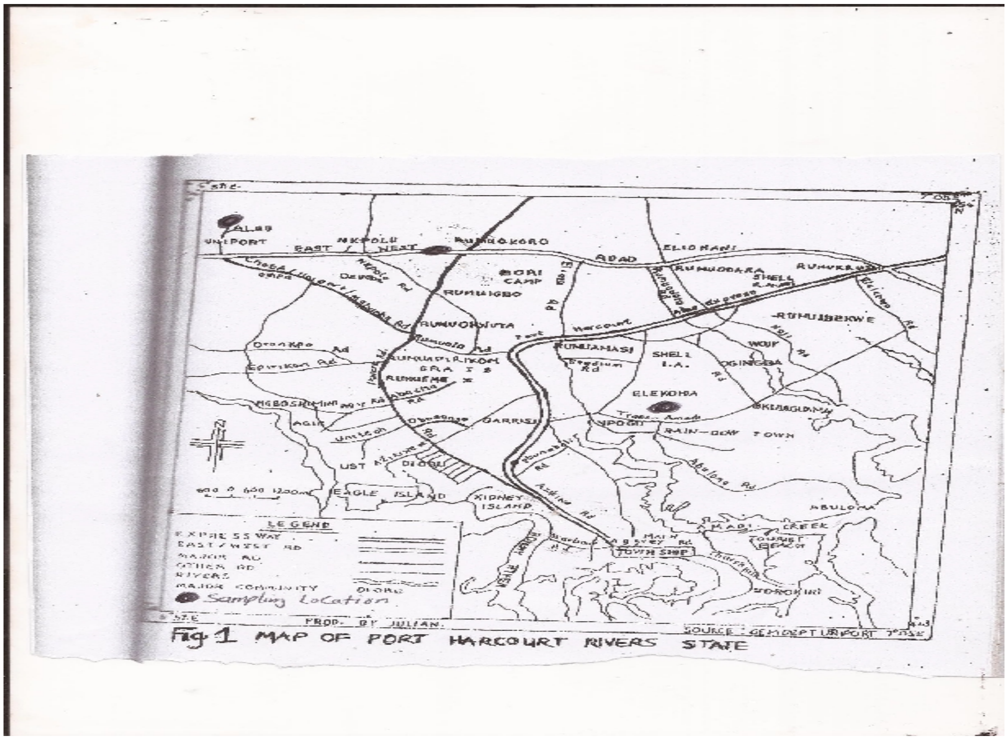

Fig. 1. Map showing sampling locations

2.3 Samples Collection and Analysis

Ten (10) common plants species (*Mangifera indica, Musa sapientum, Terminalia catapa, Panicum maximum, Chromolaena odorata*, *Psidium guajava, Eleusine indica*, *Carica papaya*, *Delonix regia* and *Musa paradiasica*) were selected and used for this study. For each species, five (5) mature leaves which were directly exposed to sun and rain were randomly collected from five (5) plants of same species in each study location. The leaves immediately collected were placed in polythene bags to minimize loss of moisture content, labeled with the aid of masking tape and marker pen. Collections were made in the month of September, 2010, the peak of rainfall in the region. The leaves of same plant species from same study location were bulked together to form composite sample which were used for analysis.

Leaf relative water content (RWC) was obtained through the method and formula of Singh [16]. The fresh leaf samples were immediately weighed by means of digital balance (satorius II 623S) on arrival at laboratory. The samples after fresh weight measurement were placed in water for 24 hours, blotted dry with absorbent paper and reweighed to obtain turgid weight. The turgid leaves were dried in oven (Gallenkamp model) for seven days at 78ºC to dry and weighed to obtain dry weight. Leaf relative water content was then calculated using the relationship:

$$RWC = \frac{FW - DW}{TW - DW} \times \frac{100}{1}$$

Where

FW = fresh weight
DW = dry weight
TW = turgid weight

Leaf total chlorophyll content (LT_{chl}) was determined by weighing 0.1 g of each leaf sample soaked in 20 ml of 50% acetone and allowed for five (5) days interval to form solution whose absorbance was taken at 645 nm and 660 nm using spectrophotometer [17].

Leaf total chlorophyll content,

$$LT_{chl}\ (\text{mg/l}) = \frac{7.12 \times \text{optical density at 660 nm} + 16.8 \times \text{optical density at 645 nm}}{10}$$

Leaf extract pH (L_{pH}) was determined by weighing and blending to powder 10 g of fresh leaf sample then homogenizing in 20 ml of deionized water. The mixture was filtered and pH of the filtrate taken after calibrating pH meter (Jennway 3015) with buffer solutions of pH 3 and 9 while leaf ascorbic acid content, L_{aa} (mg/g) content was measured using indophenol acetic acid (IAA) method by weighing and crushing 0.1 g of fresh leaf sample. The crushed leaf was homogenized in a mixture of 50 ml distilled water and 10 ml acetic acid. The resulting mixture was titrated against 0.01% indophenol solution. Air pollution tolerance index (APTI) was calculated using the formula of Singh and Rao [12].

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

Where in the formula

A = ascorbic acid content (mg/g)
T= total chlorophyll (mg/g)
P = pH of leaf extract
R= leaf relative water content (%)

The results obtained were presented in vertical bar charts using Microsoft office Excel package 2007 version. Percentage increase in air pollution tolerance indices of the plants from the sites was also calculated using the formula:

$$\%\text{increase} = \frac{APTI\ (SS) - APTI\ (CS)}{APTI(CS)} \times \frac{100}{1}$$

3. RESULTS AND DISCUSSION

The results of the impact of air pollution on plant biochemical were presented in Figs 2–8. Fresh, turgid and dry weights results were presented in Figs. 2-4 below. *M. paradiasica* and *C. papaya* showed a higher leaf fresh weight and turgid weight in the control site than at the study site Figs. 2 and 3 while no significant differences were found in the leaf dry weight of plants between the study sites and their respective controls Fig. 4. Relative water contents, RWC (%) of leaf samples from the study sites (SS 1 and 2) were generally higher than those from the control site (CS) Fig. 5. Relative water content of study site 1 (SS 1) ranged between 57.6 - 89.9% with a mean of 73. 55% while that of study site 2 (SS 2) ranged between 65.3 - 79.9% with 63.68% as its mean. The highest RWC of 89.9% recorded for *Mangifera indica* at SS 1and the least 17.3% for *Delonix regia* from the control site. This result suggests that plants of the study sites absorbed and retained more water than the ones of control site. Higher RWC result of plants of polluted sites is in line with Kousar et al. [18]. This could be a physiological adaptive mechanism of the plants to withstand the effect of atmospheric pollution in its environment.

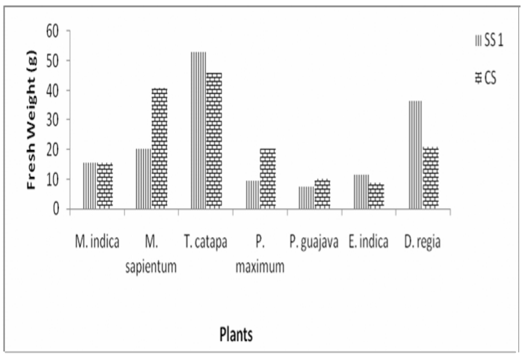

Fig. 2a. Leaf fresh weight in site 1

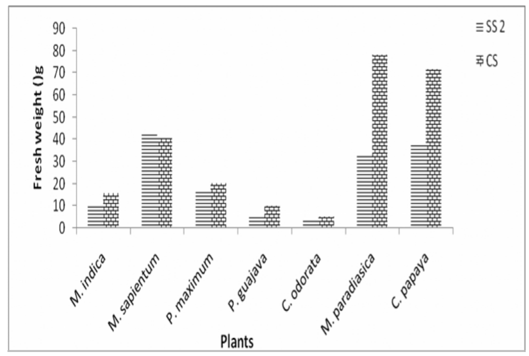

Fig. 2b. Leaf fresh weight in site 2

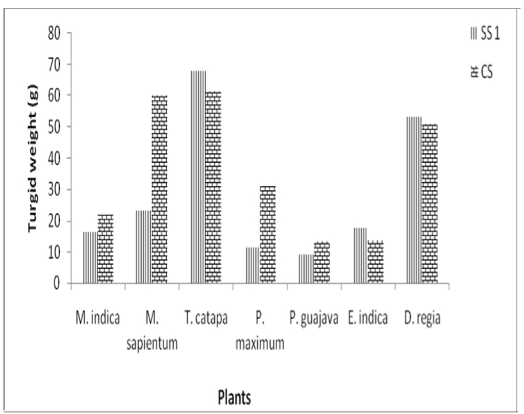

Fig. 3a. Leaf turget weight of plants in site 3

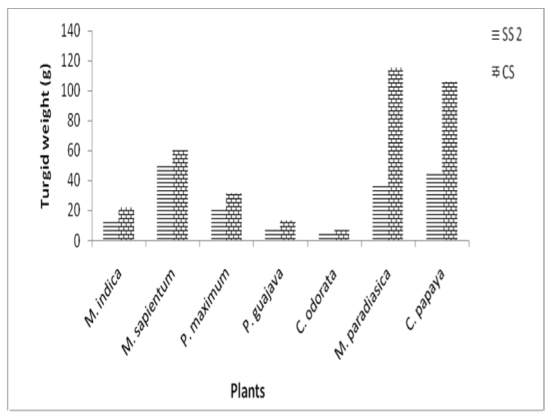

Fig. 3b. Leaf turget weight of plants in site 2

Leaf extract pH of study sites leaf samples were higher than those from control site Fig. 6. The highest recorded pH was 6.83 on *Carica papaya* study site 2 Fig. 6b and the least (4.08) was obtained on *Musa sapientum* Fig. 6a. This result follows the trend of RWC in which the plants at the study sites have high RWC than the control site. This could be explained to be due to the higher amount of water absorbed and retained by plants of the study sites. The high amount of water could have diluted the chemical effect of air pollutants in order to maintain optimum physiological pH for metabolism [19]. Ascorbic acid as a natural detoxicant help prevent the damaging effects of air pollutants on plant tissues [20] and so high amount of the substance favours air pollution tolerance. Ascorbic acid content (AAC) was found to occur at low level in the plant samples of the study sites compared with the control site Fig. 7. Keller and Schwager [21] observed that air pollution decreases the ascorbic acid level in plant. Leaf chlorophyll content did not show any consistent pattern in both study sites and control sites Fig. 8.

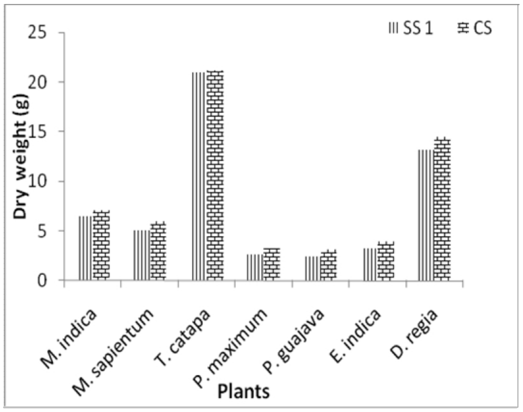

Fig. 4a. Leaf dry weight of plants in site 1

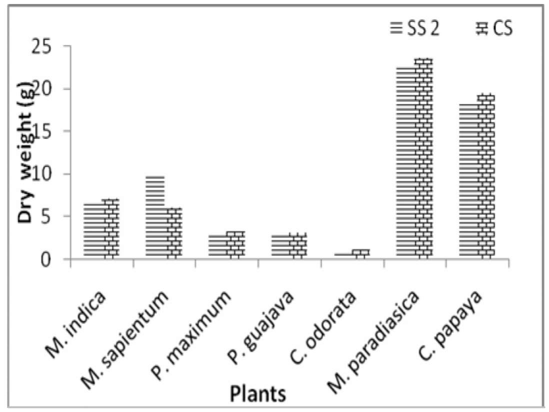

Fig. 4b. Leaf dry weight of plants in site 2

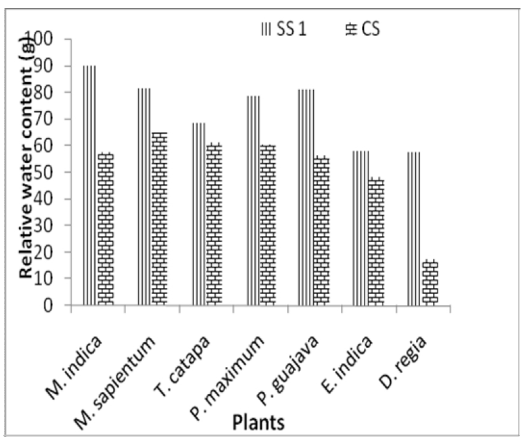

Fig. 5a. Relative water content of plants in site 1

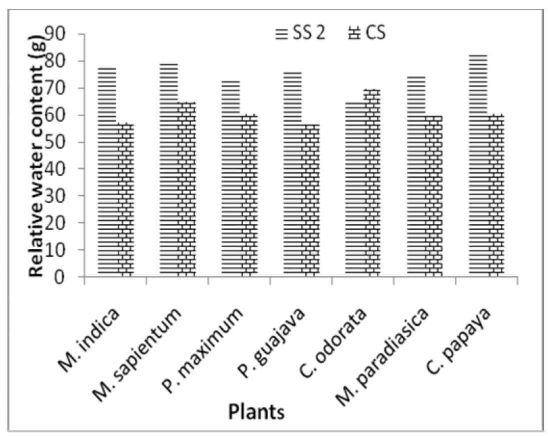

Fig. 5b. Relative water content of plants in site 2

Generally, computed APTI values showed that all plant samples had APTI values < 10 (i.e. APTI sensitive category). Values of the study sites samples were higher than those of the control site Table 1. APTI values of 9.17 (*M. indica*), 8.70 (*M. sapientum*), 8.50 (*P. guajava*) and 8.19 (*P. maximum*) of study site 1 were higher than those of same species of site 2. The highest and least values (i.e. 9.17 and 6.09) were obtained for *M. indica* and *D. regia* respectively from study site 1 while 8.59 and 6.72 for *M. sapientum* and *M. paradisiaca* of site 2.

Comparing APTI results with findings of studies of other locations in Niger Delta, the highest percentage (181.90%) change in APTI was obtained at study site 1on *Delonix regia*. Other significant changes were 45.11% on *M. sapientum* at Utorogun, Delta State [22] and 44.18% on *M. indica* at study site 1 Table 2. The least change values were 0.10% and 0.54% on *P. guajava* at Umuebulu, Rivers State [23] and Erhoike-Kokori, Delta State [24] respectively.

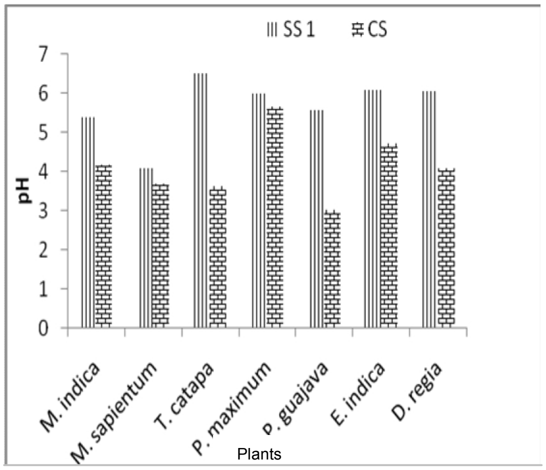

Fig. 6a. Ph of leaf extract of plants in site 1

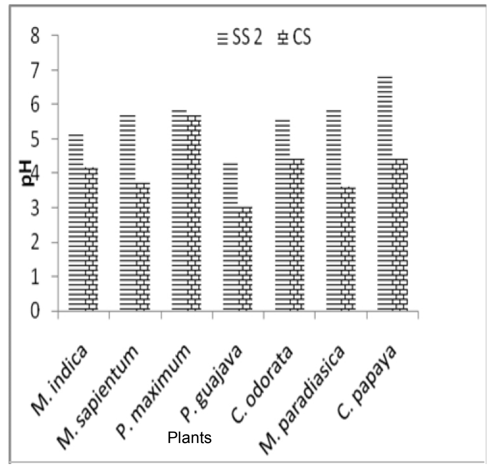

Fig. 6b. Ph of leaf extract of plants in site 2

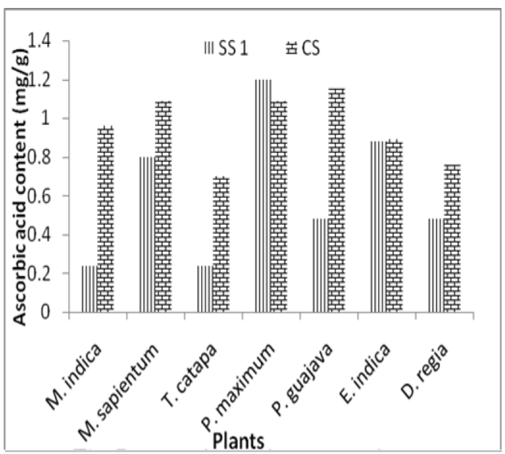

Fig. 7a. Ascorbic acid contents plant leavs of site 1

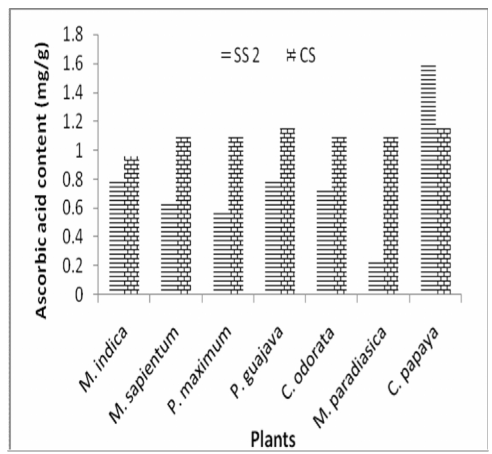

Fig. 7b. Ascorbic acid contents plant leavs of site 2

Table 1. Summary of APTI results

Plant sample	APTI (control site)	APTI (study site 1)	% Increase in APTI (study site 1)	APTI (study site 2)	% Increase in APTI (study site 2)
Mangifera indica	6.36	9.17	44.18	8.50	33.65
Musa sapientum	6.93	8.70	25.54	8.59	23.95
Terminalia catappa	6.49	6.99	7.70	-	-
Panicum maximum	7.04	8.91	26.56	8.46	25.32
Psidium guajava	5.44	8.50	37.10	7.77	20.17
Eluesine indica	2.16	6.65	22.24	-	-
Delonix regia	2.16	6.09	181.90	-	-
Musa paradisiaca	6.41	-	-	6.72	4.84
Chromolaena odorata	7.84	-	-	8.11	13.19
Carica papaya	6.79	-	-	8.49	25.04

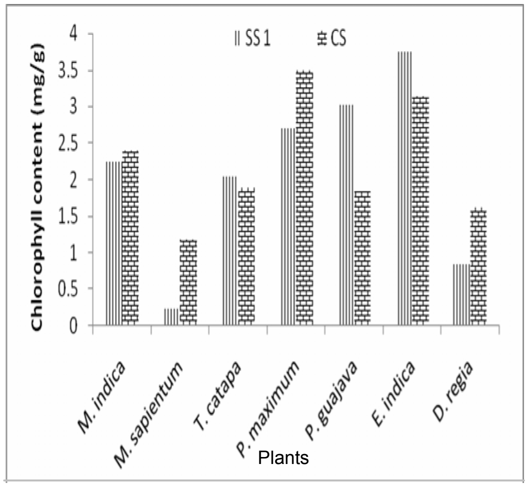

Fig. 8a. Chlorophy ll contents of plants leaves site 1

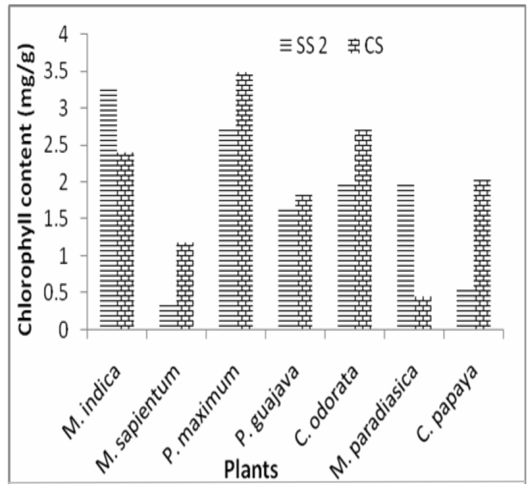

Fig. 8b. Chlorophy ll contents of plants leaves site 2

Table 2. Comparison of APTI results from other locations in Niger Delta, Nigeria

Plant sample	Percentage (%) increase in APTI				
	Study site 1	Study site 2	Erhoike-Kokori	Otorogun	Umuebulu
Mangifera indica	44.18	33.65	43.79		
Musa sapientum	24.54	23.95		45.11	
Terminalia catappa	7.7		14.02		
Panicum maximum	26.56	25. 32			
Psidium guajava	37.10	20.17	0.54		0.1
Eleusine indica	22.24				
Delonix regia	181.90		39.37		
Musa paradisiacal		4.84	6.59		6.8
Chromolaena odorata		13.19	39.37		

4. CONCLUSION

Based on the results of this study, it can be stated that air pollution tolerance index obtained using the four leaf biochemical status can serve in predicting air quality condition of an area. These biochemical parameters are important in the study of plant-environment interactions as they can serve as bioindicators of air pollution. From this study, it can also be stated that plants such *as Mangifera indica, Musa sapientum, Musa paradisiaca, Terminalia catappa, Panicum maximum, Psiduim guajava, Eluesine indica, Delonix regia, Chromolaena odorata and Carica papaya* with APTI values less 10 (APTI sensitive) can be used to monitor air quality of Niger Delta where these plants grow naturally considering air pollution activities going on in the area. The results of this and similar studies will be useful for air pollution monitoring, control measures and future planning.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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