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Full Length Research Paper

Air pollution tolerance indices of plants growing around Umuebulu Gas Flare Station in Rivers State, Nigeria

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The air pollution tolerance indices of 10 plants growing around the vicinity of Umuebulu Gas flare Station in Oyigbo Local Government Area of Rivers State, Nigeria were analyzed. Plant samples were randomly collected from the vicinity of the gas station. A composite sample of eight leaves for each plant was used for laboratory analysis. Four physiological and biochemical parameters: leaf relative water content (RWC), ascorbic acid content (AAC), total leaf chlorophyll (TLC) and pH of leaf extract were used to compute the Air pollution tolerance indices (APTI). Results showed order of tolerance as *Psidium guajava* (0.10%) > *Puerenia phaseoloides* (0.36%) > *Mallotus oppositifolus* (3.23%) > *Musa paradisiaca* (6.80%) > *Telfairia occidentalis* (7.01%) > *Cymbopogon citratus* (9.18%) > *Talinum triangulare* (9.36%) > *Vernonia amygdalina* (12.34%) > *Manihot esculenta* (14.61%) > *Ocimum gratissimum* (36.53%); showing *Psidium guajava* as the most tolerant species while *Ocimum gratissimum* as the most sensitive species to air pollution stress. Therefore, plants with high and low APTI can serve as tolerant and sensitive species for air pollution biomonitor, respectively.

Key words: Air pollution, relative water content, chlorophyll content, ascorbic acid, pH, tolerance, sensitivity.

INTRODUCTION

Air pollution is one of the severe problems facing the world today due to the continual change in concentration levels of some gaseous and trace metals in the environment resulting from man's activities such as road transportation, vehicular traffic and industries (Johan and Iqbal, 1992; Joshi et al., 2009). Air pollution can directly affect plant via leaves or indirectly via soil acidification. Most plant experienced physiological changes before exhibiting visible damage to leaves when exposed to air pollutants (Liu and Ding, 2008). Pollutants can cause leaf injury, stomatal damage, premature senescence, decrease photosynthetic activities, disturb membrane permeability and reduce growth and yield in sensitive plant species (Tiwari et al., 2006). Reduction in leaf area and petiole length was observed under pollution stress conditions (Dineva, 2004; Tiwari et al., 2006). Certain air pollutants have been reported to reduce chlorophyll content (Tiwari et al., 2006; Joshi and Swami, 2007 and 2009, Joshi and Swami, 2009) while others increase it (Tripathi and Gautam, 2007, Agbaire and Esiefarienrhe, 2009).

Vegetation is an effective indicator of the overall impact of air pollution and the effect observed is a time-averaged result that is more reliable than the one obtained from direct determination of the pollutants in air over a short period. A large number of trees and shrubs have been identified as dust filters to check the rising urban dust pollution level (Rai et al., 2010). Plants provide an enormous leaf area for impingement, absorption and accumulation of air pollutants to reduce the pollution level in the air environment with various extents for different species (Liu and Ding, 2008). The use of plants as biomonitors of air pollution has long been established because these are the initial acceptors of air pollutants due to having scavenging property for many air pollutants (Joshi and Swami, 2009). Plants show varying degree of

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Abbreviations: ES, Experimental; **CS,** control site; **RWC,** relative water content; **AAC,** ascorbic acid content; **TLC,** total leaf chlorophyll; **APTI,** air pollution tolerance indices.

sensitivity and tolerance to air pollution stress. Chlorophyll content (Flower et al., 2007); ascorbic acid content (Hoque et al., 2007); leaf pH (Klumpp et al., 2000) and relative water content (Rao, 2006) have been used in the evaluation of the impact of air pollution on plants. Although, Han et al. (1995) observed that separate parameters gave conflicting result for a particular plant. Air pollution tolerance index based on the four aforementioned parameters has been used to identify tolerance levels of plant species (Sing and Rao, 1993; Sing et al., 1991).

This work attempts to determine the air pollution tolerance indices (APTI) of some plants growing around Umuebulu Gas Flare Station in Rivers state, Nigeria. It is expected that results obtained will widen the knowledge of the tolerance and sensitivity of some plants to air pollution. This will assist horticulturists, landscapers and environmental scientists in the selection of air pollution tolerance plants that can be planted in air pollution prone areas. These plants will also act as biomonitors in the management and control of air pollution in our environment.

MATERIALS AND METHODS

Description of study site

The area of study is the vicinity of Umuebulu Gas Flare Station (built by Shell Petroleum Development Company [SPDC]) located at Oyigbo Local Government Area of Rivers State, Nigeria (Figure 1). The area lies within the coastal plain of eastern Niger Delta characterized by two seasons (rainy and dry seasons).

Rainfall in the area is variable, heavy and adequate for all year round crop cultivation; ranging between 2500 to 3500 mm/yr. Mean maximum monthly temperature ranges from 28 to 33°C while the mean minimum monthly temperature between 17 to 24°C. The mean annual temperature is 26°C. Relative humidity is high throughout the year and decreases slightly in the dry season. The soil in the area is the brown loams and sandy loams.

Sample collection

The procedure adopted by Agbaire and Esiefarienrhe (2009) was used for both collection and analysis of samples with minor modifications. Plant sampling was done in September, 2010. Plants from the immediate vicinity of the station were randomly collected designated as experimental site (ES). The plants selected for the study were those available at the experimental site. Identification of the plant samples were done at the University of Port Harcourt Herbarium. A nearby site with similar ecological conditions was chosen as the control site (CS). Replicates of fully mature leaf samples of the various plants were collected, put in polyethene bags and marked with masking tape. These were immediately taken to the laboratory for analysis. Composite sample of eight leaves for each species were used for the analysis.

Analysis of samples

The following physiological and biochemical parameters were analyzed: leaf relative water content (RWC), ascorbic acid content (AAC), total leaf chlorophyll (TC) and pH of leaf extract. These were used to compute the APTI values for both the experimental site (ES) and control site (CS).

The relative leaf water content (RWC) was calculated using the formula as described by Singh (1997) below:

$$\text{RWC} = \frac{\text{Fresh Weight (FW)} - \text{Dry Weight (DW)}}{\text{Turgid Weight (TW)} - \text{Dry Weight (DW)}} \times 100$$

The fresh plants were immediately taken to the laboratory for the determination of the leaf fresh weight in order to minimize water loss. Leaf samples were weighed on a weighing balance (model PN 163) to obtain the fresh weight (FW). The leaves were then immersed in water for 24 h (overnight), blotted dry with Whatman filter paper and weighed to obtain the turgid weight (TW). The leaves were finally dried in an oven for 48 h at 70°C and reweighed on the weighing balance to obtain the dry weight (DW).

Total leaf chlorophyll content (TLC) was obtained by weighing 1.0 g of each leaf sample and soaked in 20 ml of 50% acetone, then left for five days. 25 ml aliquot of extract was added to 50 ml diethyl ether in a separating funnel. For the optical density, absorbance was taken at 645 nm and 660 nm on spectrophometer using ether as a reference. Total leaf chlorophyll was calculated thus:

Total chlorophyll in ether solution (mg/l^{-1}) = (7.12 x optical density at 660 nm + 16.8 x optical density at 645 nm) ÷ 10.

The leaf extract pH was obtained by homogenising 10 g of the fresh leaves in 20 ml of deionised water. This was filtered and the pH of leaf extract determined using a pH meter (model: Jennway 3015) after allowing it to stabilise for 15 min and calibrated with buffer solution of pH 3 and 9. The AAC was measured using the indophenol 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% indophenol was made and then titrated with the sample. The method of Sing et al. (1991) was used in the calculation of APTI. Thus:

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

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 results are presented in Tables 1 to 5. The relative water content (%) of a leaf is the water present in it relative to its full turgidity. The RWC of a leaf is associated with protoplasmic permeability in the cells. The relative leaf water content of all the plants in ES was higher than those in the control site (CS) (Table 1). *Talinum triangulare* in the experimental site had the highest RWC (%). This is an indication that plants at polluted site retain more water than those at unpolluted site. A possible explanation to this might be that the plant at the polluted site absorbed more water as an adaptive

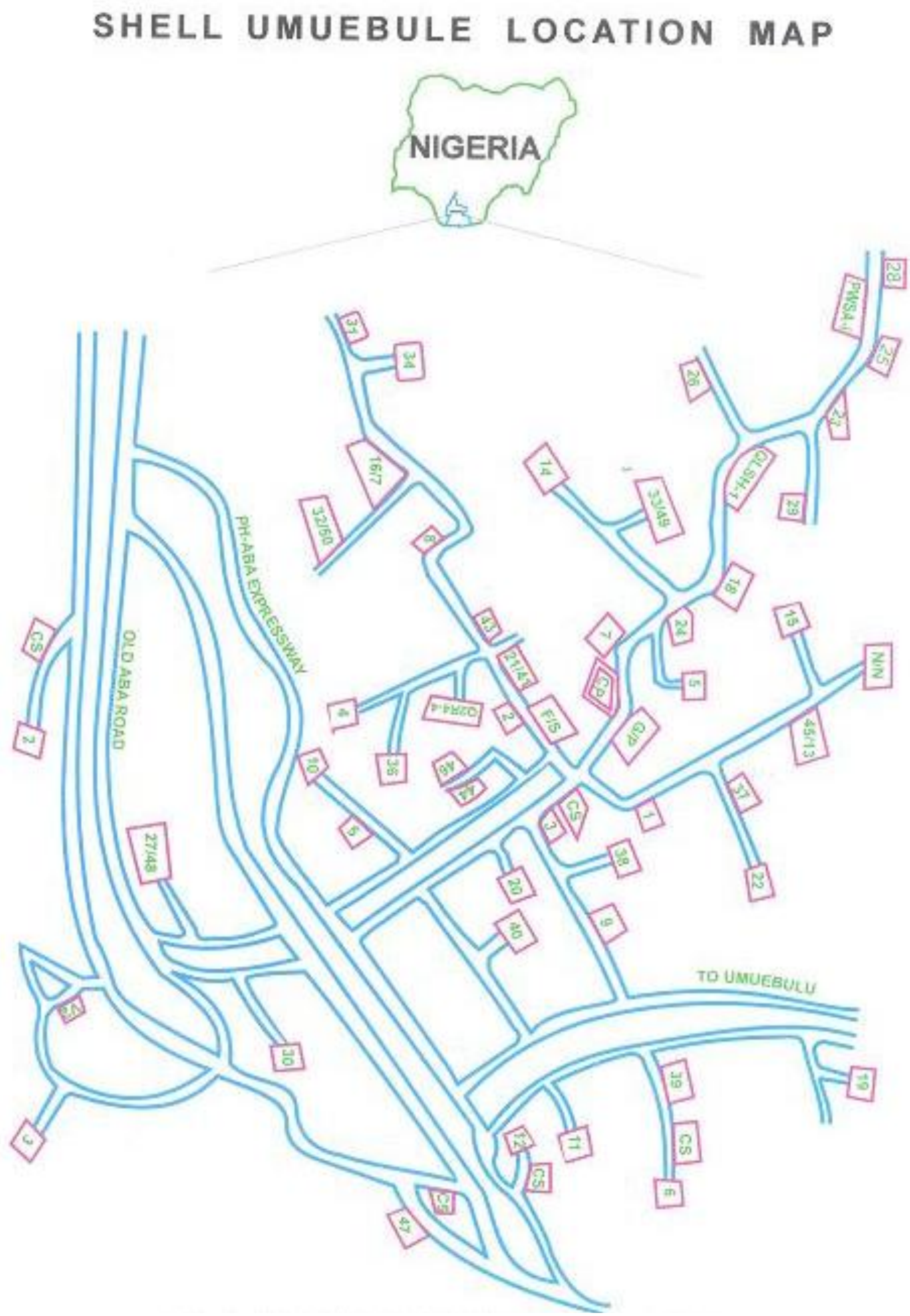

Figure 1. Umuebulu Gas Flare Station.

Table 1. Relative leaf water content.

Species	Site	Fresh weight (g)	Turgid weight (g)	Dry weight (g)	RWC (%)
Mallotus oppositifolus	ES	35.82	37.375	8.969	94.526
	CS	19.133	20.843	5.09	89.145
Puerania phaseoloides	ES	9.107	10.932	2.461	78.456
	CS	24.971	30.607	5.752	77.324
Vernonia amygdalina	ES	21.45	20.152	2.38	107.304
	CS	14.43	15.264	1.993	93.776
Psidium guajava	ES	8.049	8.41	2.84	93.519
	CS	7.722	8.173	3.229	90.896
Cymbopogon citratus	ES	12.867	13.753	2.72	91.97
	CS	10.331	12.131	2.912	80.475
Manihot esculenta	ES	19.635	18.199	3.21	109.58
	CS	19.532	21.073	4.091	90.926
Ocimum grassitisimum	ES	3.01	2.814	0.266	107.692
	CS	1.63	2.034	0.101	79.01
Telfairia occidentalis	ES	73.2	70.998	8.035	103.497
	CS	41.823	44.632	4.867	92.936
Musa paradisiaca	ES	10.165	7.16	1.972	99.405
	CS	6.5	6.741	1.38	95.505
Talinum triangulare	ES	3.459	3.031	0.155	114.882
	CS	7.357	7.16	0.439	102.931

feature which helps in maintaining its physiological balance against pollution stress. It might also be This is an indication that plants with high relative water suggested that the pollutant absorbed by the plant are hydrophilic hence enabled the plant to retain more water. content in polluted conditions may be tolerant to pollution stress. A corollary result was observed in the pH of the leaf extract which showed reduction in the plant species from the experimental site with respect to their control site except in *Puerenia phaseoloides, Psidium guajava* and *Cymbopogon citratus* in which the reverse was the case (Table 2). Similar result was also observed in the ascorbic acid content (AAC) in which seven of the selected plants showed a lower AAC in the experimental site (except in *Vernonia amygdalina, Ocimum gratissimum* and *Musa paradisiaca*) when compared to the control site (Table 3). In other words, lower ascorbic acid contents were associated with lower pH of the leaf. Ascorbic acid is a strong reductant and activates many biochemical and physiological activities of the cell such as cell wall synthesis and cell division. Raza and Murthy (1988) observed that the reducing power of the ascorbic acid depends directly on its concentration. Scholz and Reck (1977) reported that in the presence of an acidic pollutant, the leaf pH is lowered and the decline is greater in sensitive species. A shift in cell sap pH towards the acid zone in the presence of an acidic pollutant might decrease the efficiency of conversion of hexose sugar to ascorbic acid (Agrawal, 1988).

Chlorophyll is the principal photoreceptor in photosynthesis; the light-driven process in which carbon dioxide is fixed to yield carbohydrates and oxygen. It is evident that chlorophyll content of plants varies from species to species; age of leaf and also with the pollution level as well as with other biotic and abiotic conditions (Katiyar and Dubey, 2001). Certain air pollutants have been reported to reduce chlorophyll content (Tiwari et al., 2006; Joshi and Swami, 2007 and 2009, Joshi et al., 2009) while others increase it (Tripathi and Gautam, 2007, Agbaire and Esiefarienrhe, 2009).

Table 2. Leaf pH.

Species	Site	pH
Mallotus oppositifolus	ES	4.26
	CS	4.76
Puerania phaseoloides	ES	5.85
	CS	4.15
Vernonia amygdalina	ES	5.78
	CS	5.93
Psidium guajava	ES	5.65
	CS	4.15
Cymbopogon citratus	ES	5.73
	CS	5.53
Manihot esculenta	ES	5.04
	CS	5.84
Ocimum grassitisimum	ES	5.59
	CS	5.85
Telfairia occidentalis	ES	5.83
	CS	6.07
Musa paradisiaca	ES	5.73
	CS	5.75
Talinum triangulare	ES	4.83
	CS	6.05

Table 3. Ascorbic acid content (AAC).

Species	Site	Titre value	AAC (mg/kg)	% AAC
Mallotus oppositifolus	ES	0.6	0.28	0.028
	CS	1	0.43	0.043
Puerania phaseoloides	ES	1.2	0.57	0.057
	CS	1.5	0.64	0.064
Vernonia amygdalina	ES	1.25	0.59	0.059
	CS	1.25	0.53	0.053
Psidium guajava	ES	0.6	0.28	0.028
	CS	1.6	0.68	0.068
Cymbopogon citratus	ES	1.55	0.24	0.024
	CS	1.4	0.596	0.06
Manihot esculenta	ES	3.5	1.66	0.166
	CS	4.2	1.787	0.179

Table 3. Continued.

Ocimum grassitisimum	ES	0.8	0.38	0.038
	CS	0.5	0.21	0.021
Telfairia occidentalis	ES	1.3	0.62	0.062
	CS	1.75	0.74	0.074
Musa paradisiaca	ES	1.5	0.71	0.071
	CS	1	0.43	0.043
Talinum triangulare	ES	0.71	0.34	0.034
	CS	1.1	0.47	0.047

Table 4. Total leaf chlorophyll content (TLC).

Species	Site	TLC (mg/kg)
Mallotus oppositifolus	ES	0.359
	CS	3.729
Puerania phaseoloides	ES	4.294
	CS	6.278
Vernonia amygdalina	ES	0.705
	CS	3.796
Psidium guajava	ES	2.642
	CS	3.419
Cymbopogon citratus	ES	2.915
	CS	3.884
Manihot esculenta	ES	5.009
	CS	4.966
Ocimum grassitisimum	ES	3.135
	CS	4.926
Telfairia occidentalis	ES	2.153
	CS	5.297
Musa paradisiaca	ES	2.453
	CS	1.17
Talinum triangulare	ES	0.804
	CS	2.108

Result from the study shows that 80% of the plants selected for the study showed higher total TLC (%) in the control site than in the experimental site (Table 4). The reduction in total chlorophyll might be as a result of the effect on the degradation of chlorophyll synthesis. This is in line with Joshi and Swami (2007) who reported that

Table 5. Air pollution tolerance index (APTI).

Species	Site	APTI	% Increase in APTI
Mallotus oppositifolus	ES CS	9.58 9.28	3.23
Puerania phaseoloides	ES CS	8.42 8.39	0.36
Vernonia amygdalina	ES CS	11.11 9.89	12.34
Psidium guajava	ES CS	9.6 9.59	0.1
Cymbopogon citratus	ES CS	9.4 8.61	9.18
Manihot esculenta	ES CS	12.63 11.02	14.61
Ocimum grassitisimum	ES CS	11.1 8.13	36.53
Telfairia occidentalis	ES CS	10.84 10.13	7.01
Musa paradisiaca	ES CS	10.52 9.85	6.8
Talinum triangulare	ES CS	11.68 10.68	9.36

one of the most common impacts of air pollution is the gradual disappearance of chlorophyll and concomitant leaf chlorosis which may be associated with a consequent decrease in photosynthetic capacity. Degradation of photosynthetic pigment has been widely used as an indicator of air pollution (Ninave, 2001).

APTI is as shown in Table 5. Result shows that plants growing in polluted (experimental) site had higher APTI values than those in the less polluted (control) site. The percentage increase trend was in the order: *Psidium guajava* (0.10%), *Puerenia phaseoloides* (0.36%), *Mallotus oppositifolus* (3.23%), *Musa paradisiaca* (6.80%), *Telfairia occidentalis* (7.01%), *Cymbopogon citratus* (9.18%), *Talinum triangulare* (9.36%), *Vernonia amygdalina* (12.34%), *Manihot esculenta* (14.61%) and *Occimum grastissimum* (36.53%); indicating that *Psidium guajava* was the most tolerant plant while *Occimum grastissimum* was the least tolerance (most sensitive) plant in the area studied.

The plant with low and high APTI percentage values can serve as tolerant and sensitive plant, respectively. The results of this study suggest that plants have the potential to serve as excellent quantitative and qualitative indices of pollution; since biomonitoring of plant is an important tool to evaluate the impacts of air pollution on plants. In conclusion, APTI determinations are of importance because with increased industrialization, there is increasing danger of disappearance of vegetation cover due to air pollution. Therefore, only plant with air pollution tolerance should be planted in areas prone to air pollution.

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