NJB, Volume 32(1), June, 2019

COMPARATIVE STUDIES OF AIR POLLUTION TOLERANCE INDICES (APTI) OF SOME ECONOMIC PLANTS AROUND UMUEBULU GAS FLARE STATION IN RIVERS STATE, NIGERIA

Obidiegwu P. Chinyere
Department of Biology, Federal College of Education (Technical), Asaba, Delta State, Nigeria

Received 31st January, 2019; Accepted 30th June, 2019

ABSTRACT.

The study examined the air pollution tolerance indices (APTI) of ten (10) economic plants around the gas flare station in Umuebulu community in Etche Local Government Area of Rivers State, Nigeria. Four physiological and biochemical parameters: relative water content, ascorbic acid, total chlorophyll and pH of the leaf extracts were used to compute the APTI values. Plants were classified into three categories of sensitivity: APTI < 8.11 below = sensitive, APTI 8.12 to 8.14 = intermediate and APTI > 8.15 above = tolerant. The APTI values ranged between 10. 47 for *Elaeis guineensis* Jacq. and 6.82 for *Mangifera indica* L. Six plant species had significantly ($P < 0.05$) higher APTI values than the other four. The results showed that combining a variety of these parameters gave a more reliable result than that of individual parameters. The order of tolerance is as follows: *Elaeis guineensis* < *Manihot esculenta* Crantz < *Ocimum gratissimum* Mint < *Carica papaya* L. < *Solanum incanum* L. < *Vernonia amygdalina* Del. < *Musa sapientum* Ktze < *Newbouldia laevis* (P. Beauv.) < *Psidium guajava* L. < *Mangifera indica*. The order of tolerance showed *Elaeis guineensis* as the most tolerant species, while *Mangifera indica* was the most sensitive species to air pollution stress in the station. T-test between experimental and control plants showed that the APTI values of most of the control plants were significantly ($p < 0.05$) higher than those of the experimental plants. The physiological parameters showed higher ascorbic acid content, lower total chlorophyll content, lower relative water content and variable pH leaf extract of the experimental plant to those of the control. The economic plants with high APTI (tolerant) are recommended for use in domestic, industrial and urban landscaping, both for their economic values and phytoremediation potentials of air polluted environment, while the plants with low APTI (sensitive) can used as bio-indicators of environmental air quality.

Keywords: Economic plants, air pollution tolerance index, landscaping, phytoremediation, ascorbic acid content, chlorophyll content, pH, sensitive species

INTRODUCTION

Air pollution is a major problem arising from industrialisation, mobile sources, area sources and natural sources (Odilara *et al*., 2006). Air pollution is the introduction of chemicals, particulate matter or biological materials that cause harm or discomfort to human and other living things or damage the environment. Pollutants could be classified as either primary or secondary. Pollutants that are emitted into the atmosphere and directly pollute the air are called primary pollutants while those that are formed in the air when primary pollutants react are known as secondary pollutants (Seyyednjad *et al.,* 2011). All combustion releases gases and particulate matter into the air and these include SO_2, NO_2, CO, H_2S, NH_3, CH_4 and soot particles as well as smaller quantities of toxic metals, organic molecules and radioactive isotopes (Mahecha *et al*., 2013).

Most plants experience physiological changes when exposed to air pollutants before exhibiting visible damages to leaves (Liu and Ding, 2008). Pollutants can cause leaf injury, stomata damage, premature senescence, decreased 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 condition (Dineva, 2004; Tiwari *et al*., 2006). Certain air pollutants have been reported to reduce chlorophyll content (Tiwari *et al*., 2006; Joshi and Swami, 2007, 2009) while others increased it (Tripathi and Gautam, 2007; Agbaire and Esiefarienrhe, 2009; Tanee and Albert, 2013).

The impact of gas flaring on plants and vegetation was studied by Isichei and Sanford (1976). They observed that air, soil and leaf temperatures increased and relative humidity of the air decreased within 110 metres from the flare site. Gas flaring does not only result in the destruction of vegetation, wild life and ecological change in the ecosystem, but it also significantly affects the microclimate, biological and physico-chemical properties of soils in close proximity to the flare site (Dung *et al*., 2008).

Singh *et al*. (1991) used ascorbic acid (Vitamin C), chlorophyll content, relative water content and pH of leaf extract to evaluate the susceptibility of some plants to air pollutants by computing these four 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 lower APTI values. Those with low APTI values are regarded as sensitive plant species (Shannigrahi *et al*., 2004) and may act as bio-indictors of pollution. On the basis of their indices, different plant groups were categorized into sensitive intermediate and tolerant classes (Shannigrahi *et al*., 2004).

Ordinarily, tolerance of plants to air pollution can be measured by simple symptoms such as visible injury on the plants, but it can be correctly evaluated by calculating the tolerance index of plants to air pollutants. Plants are classified into three categories of sensitivity: APTI ≤ 10 below = sensitive; APTI 10-16 = intermediate; APTI ≥ 17 above = tolerant (Agarwal *et al*., 1991). The APTI determination provides a reliable method for screening sensitive/tolerant plants under field condition where air is contaminated by a variety of pollutants (Nwadinigwe, 2009).

Air pollution tolerance index is used by landscapers to select plant species tolerant to air pollution (Yan-ju and Hui, 2008). Air pollution tolerance index has also been used to rank plant species in their order of tolerance to air pollution (Agbaire and Esiefarienrhe, 2009).

The aim of this study, therefore, was to determine the APTI values of some economic plant species so as to identify those that may be planted around polluted areas in order to mitigate the adverse effects of pollutants on man and other organisms. The screening of plants globally or in Nigeria for their APTI values has not been exhausted, so there is the need to carry out more work on numerous plants in order to mitigate the effects of air pollution globally since air pollution has no political boundaries.

This work attempted to determine the air pollution tolerance indices (APTI) of some economic plants around Umuebulu gas flare station in River State, Nigeria to enable farmers, landscapers and environmental scientists select air pollution-tolerant plants that can be planted in air pollution- prone areas. These plants can also act as bio-monitors in the management and control of air pollution in our environment.

MATERIAL AND METHODS

Description of study sites

The area of study was the vicinity of Umuebulu gas flare station. It was built by Shell Petroleum Development Company (SPDC) located at Etche Local Government Area of Rivers State, Nigeria (Figure 1). The area lies within the coastal plains of Eastern Niger Delta characterised by two seasons (rainy and dry). Rainfall in the area is variable and heavy all-year-round, ranging between 2,500 to 3,500 mm/annually. Mean maximum monthly temperature ranges from 28 to 33°C, while the mean minimum monthly temperature is between 17°C and 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 brown loamy and sandy.

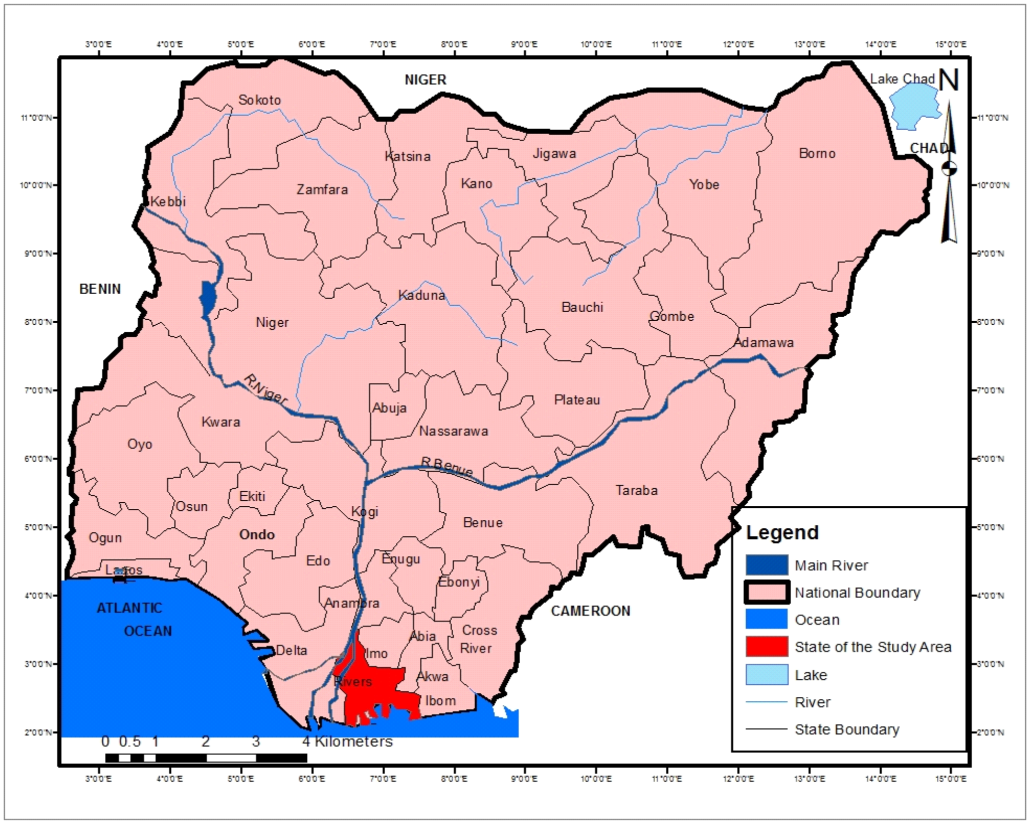

FIGURE 1: Map of Nigeria showing Rivers State

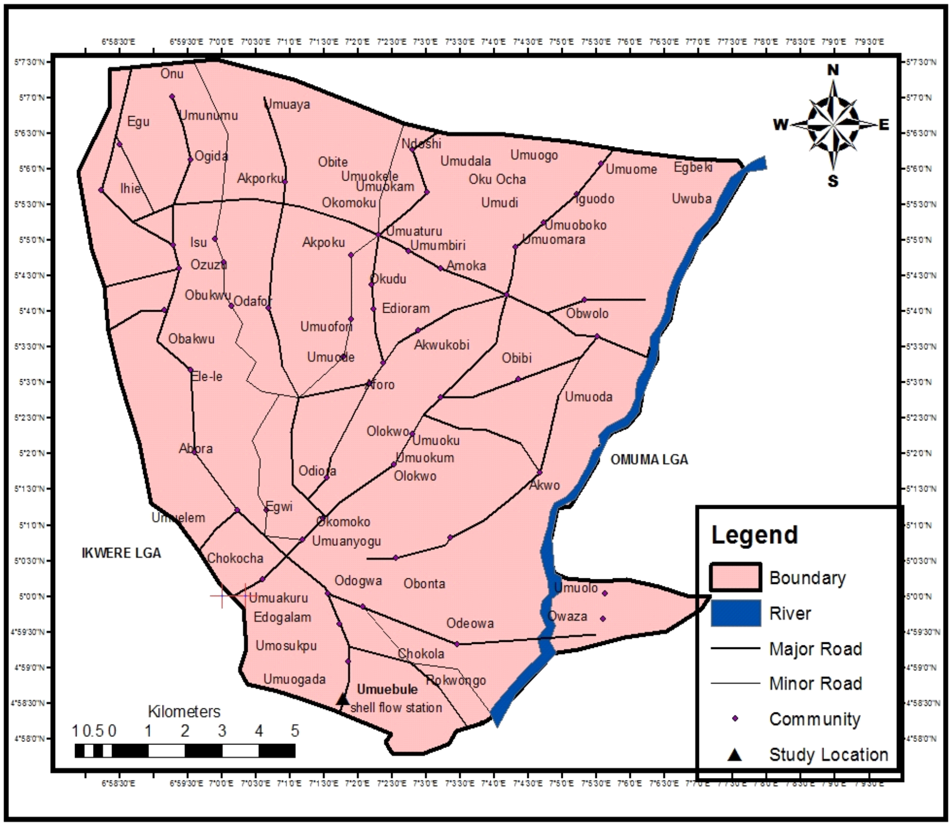

FIGURE 2: Map of Etche Local Government Area showing Umuebulu (the study site)

Sample collections

A procedure adopted by Nwadinigwe (2014) was used for both collection and analysis of samples with minor modifications. Plant sampling was carried out and plants from the immediate vicinity designated as experimental site (ES) of the station were randomly collected. The plants selected for the study were those available at the experimental site. A site with similar ecological conditions was chosen as the control site (CS) namely, Biological Garden in Nekede Zoo, Imo State. Replicates of fully mature leaf samples of various plants were collected, put in polyethylene bags and marked with masking tape. The plants were identified by a taxonomist, Mr. Alfred Ozioko, in the Department of Plant Science and Biotechnology, after which the samples were transported to the laboratory and the fresh weights of the leaves were taken immediately. Some were dried, pulverized and preserved at 40^{o}C for further analysis.

Analysis of samples

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

Determination of pH

pH determination was carried out according to the method of Shannigrahi *et al.* (2004) using the Direct Reading Engineering Method (DREM).

Determination of ascorbic acid

Spectrophotometric method was used to determine the ascorbic acid content of the leaves (Abida and Harikrishna 2010). One gram of ground fresh leaves was homogenized in 4 ml oxalic acid-ethylene-di-amine-tetra-acetic acid (EDTA) extracting solution for 30 sec. One millilitre of ortho-phosphoric acid and 1 ml 5% tetraoxosulphate (vi) acid were added. Two (2) ml of ammonium molybdate and 3 ml of water were also added. The solution was left to stand for 15 mins. The absorbance was read off with a CE 234 31D digital spectrophotometer at 760 nm. The concentration of the ascorbic acid was determined from a standard ascorbic acid regression curve.

Determination of total chlorophyll

Three grams of fresh leaves was blended and then extracted with 10 ml of 80% acetone, left to stand for 15 min, filtered and centrifuged at 2,500 rpm for 3 min. The absorbance of the supernatant was read at 645 nm (D_{646}) and 663 nm (D_{663}) using a CE 234 31D digital spectrophotometer. The optical density of the total chlorophyll (OT) was taken as the sum of chlorophyll a (D_{646}) density and chlorophyll b (D_{663}) density, thus:

$OT = 20.2\ (_{D646}) + 8.02\ (_{D663})$.

Total chlorophyll (mg/g DW) = 0.1 OT x (Leaf DW + Leaf fresh weight) (Liu and Ding, 2008).

Relative leaf water content

The relative water content was obtained by the method of Liu and Ding (2008) and Gharge and Menon (2012). Fresh leaf samples were weighed and recorded as fresh weight (FW). It was floated in distilled water inside a closed dish at a room temperature for 24 hrs. At the end of the incubation period, leaf sample was wiped dry to obtain the turgid weight (TW). It was placed in a preheated oven at 80^{o}C for 48 hrs. Thereafter, the leaf was weighed to obtain the dry weight (DW). The relative water content (RWC) was then calculated using the formula:

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

Where,

FW = Fresh Weight
DW = Dry Weight
TW = Turgid Weight

Determination of air pollution tolerance index (APTI)

Using these four parameters, the air pollution tolerance index (APTI) for each of the plant species was determined using the following mathematical formula:

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

Where,

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

The entire computation was divided by 10 to obtain a small appreciable result (Rai *et al*., 2013).

Statistical Analysis

The data were subjected to analysis of variance (ANOVA). Multiple comparisons were made between treatments using the Duncan's multiple range tests at $p \leq 0.05$ confidence level. T-tests were carried out between APTI of experimental and control sites (Edafiogho, 2006).

RESULTS

Table 1: Air pollution tolerance indices of plants collected from Umuebulu flare station and the control station

PLANTS		pH	RWC %	AA mg/g	TCC mg/g	APTI
Carica papaya	**Cont.**	$6.17\pm0.67^{I,j,k,l}$	93.63 ± 0.18^{w}	0.22 ± 0.01^{a}	$4.32\pm0.02^{n,o}$	$9.60\pm0.01^{p,q,r}$
	Exp.	$4.29\pm0.01^{q,r}$	87.51 ± 0.01^{s}	0.29 ± 0.00^{bc}	4.19 ± 0.01^{m}	$9.11\pm0.00^{m,n}$
Elaeis guineensis	**Cont.**	$5.45\pm0.23^{c,d}$	$80.35\pm0.17^{l,n}$	1.57 ± 0.03^{r}	9.17 ± 0.08^{w}	10.46 ± 0.02^{w}
	Exp.	6.63 ± 0.01^{n}	77.26 ± 0.26^{k}	$1.68\pm0.00^{s,t}$	9.24 ± 0.01^{w}	10.47 ± 0.02^{w}
Manihot esculenta	**Cont.**	$5.98\pm0.01^{f,g,h}$	$90.95\pm0.02^{u,v}$	1.65 ± 0.01^{s}	5.90 ± 0.05^{v}	11.04 ± 0.02^{x}
	Exp.	8.38 ± 0.01^{R}	$77.85\pm0.07^{l,m}$	1.72 ± 0.02^{t}	5.11 ± 0.01^{j}	$10.05\pm0.02^{v,v}$
Mangifera indica	**Cont.**	$5.43\pm0.34\ ^{c}$	55.26 ± 0.13^{b}	1.26 ± 0.00^{q}	5.07 ± 0.03^{m}	6.57 ± 0.29^{e}
	Exp.	$5.94\pm0.02^{e,f,g,h}$	54.53 ± 0.24^{a}	$1.30\pm0.00^{q,r}$	4.85 ± 0.00^{l}	6.82 ± 0.01^{d}
Musa sapientum	**Cont.**	$6.02\pm0.01^{g,h}$	95.34 ± 0.17^{x}	0.70 ± 0.06^{k}	$3.00\pm0.02^{I,j}$	10.15 ± 0.03^{v}
	Exp.	$8.29\pm0.00^{q,r}$	75.33 ± 0.33^{u}	0.74 ± 0.00^{k}	2.51 ± 0.00^{f}	3.33 ± 0.03^{g}

Newbouldia	**Cont.**	5.62±0.31^{c,d,e}	81.58±0.30^{q}	0.50±0.00^{e,f}	2.97±0.02^{i,j}	8.55±0.08^{l,j}
laevis	**Exp.**	7.94±0.02$^{\backslash\backslash q}$	70.03±0.03^{g}	0.59±0.00^{h,i}	2.17±0.01^{e}	7.55±0.01^{e}
Ocimum	**Cont.**	5.81±0.93^{d,e,f,g,h}	93.16±0.08^{w}	0.33±0.03^{c}	3.17±0.02^{k,l}	9.70±0.10^{r,s,t}
gratissimum	**Exp.**	6.33±0.03^{k,l,m,n}	91.33±0.03^{v}	0.32±0.00^{c}	3.16±0.01^{k,l}	9.44±0.01^{o,p,q}
Pisdium guajava	**Cont.**	5.65±0.32^{c,de,f,g}	90.92±0.04^{u,v}	1.28±0.00^{q,r}	3.00±0.00^{j}	10.12±0.06^{v}
	Exp.	7.23±0.03^{o}	61.08±0.10^{d}	1.31±0.00^{r}	3.01±0.00^{j}	7.54±0.03^{e}
Solanum	**Cont.**	6.38±0.01^{l,m,n}	83.44±0.30^{P}	0.72±0.01^{k}	2.87±0.02^{i}	8.99±0.00^{l,m}
incanum	**Exp.**	8.03±0.03^{p,q,r}	75.33±0.03^{i}	0.75±0.00^{k}	2.52±0.01^{f,g}	8.30±0.00^{g,h}
Vernonia	Cont.	5.59±0.30^{c,d,e}	93.14±0.57^{w}	0.61±0.00^{h,l,j}	0.93±0.04^{c,d}	9.86±0.07^{t,u}
amygdalina	Exp.	8.25±0.02^{q,r}	76.95±0.03^{k}	0.61±0.00^{h,I,J}	0.81±0.00^{c}	8.25±0.01^{g,h}

Values represent means ± standard error. Means followed by the same letters in the same column are not significantly different at $p < 0.05$.

RWC =Relative Water Content. TCC=Total Chlorophyll Content. AA = Ascorbic Acid. pH = pH of the leaf Extract. APTI = Air Pollution Tolerance Index. CONT. = Control site. EXP = Experimental site.

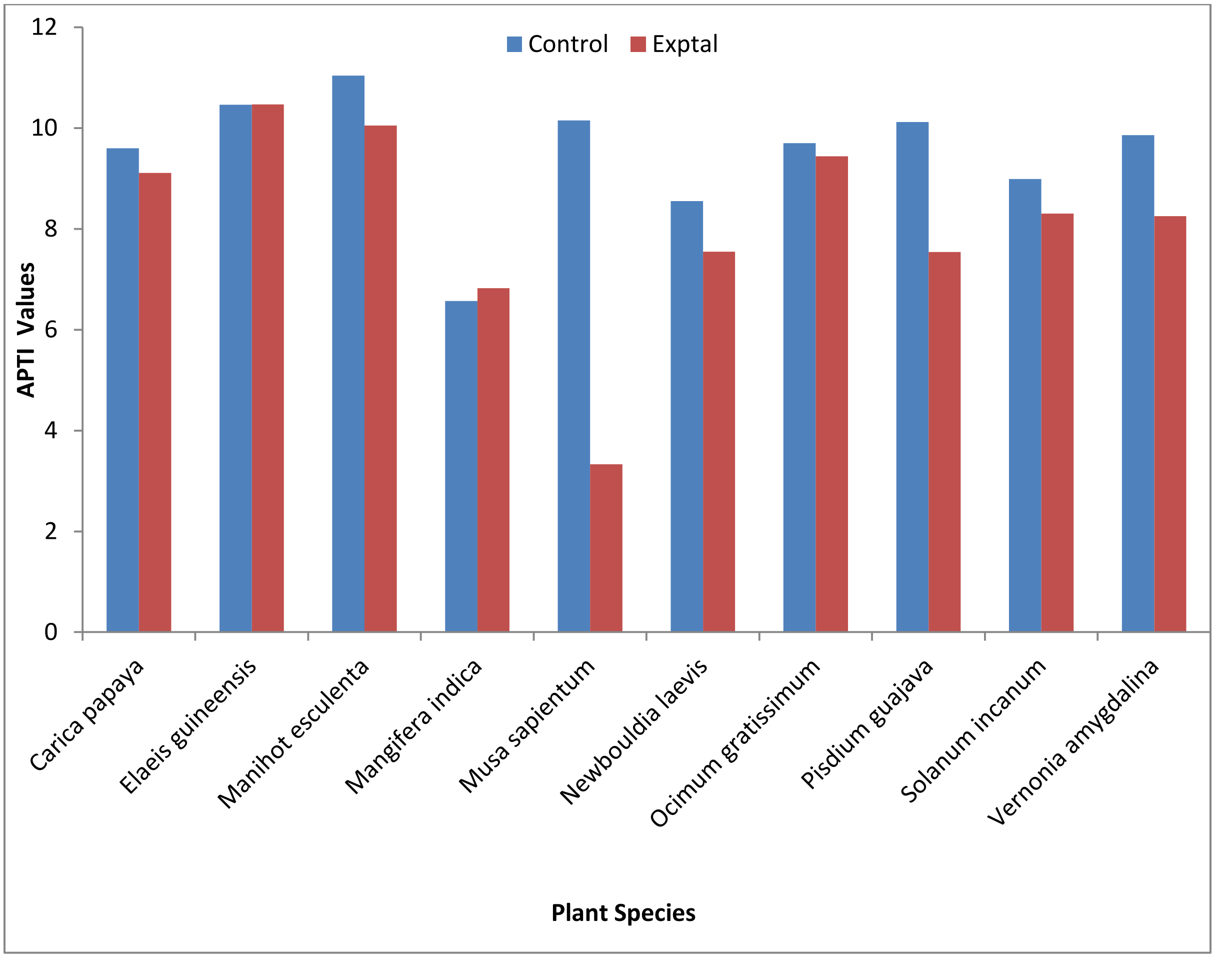

Fig 3: Plants collected from control and experimental site

Table 2: Tolerance index of plants at the experimental site

Index value	Remark
1-8.11	Sensitive
8.12 - 8.14	Intermediate
8.15 - above	Tolerant

The tolerant plant species were those with APTI more than the mean APTI + SD (standard deviation). The sensitive plants were those with APTI less than mean APTI –SD, while the moderately tolerant plants had intermediate values between those of the tolerant and sensitive plant species (Liu and Ding, 2008).

DISCUSSION

The results from Table 1 and Fig. 3 demonstrated that different plant species respond in different ways to air pollution and that the same plant species growing in different environments may respond differently, depending on the level of air pollutants in the habitat. Plants possess different pollution tolerance capabilities depending on the species and the environmental factors affecting them. In the present work, the variation in the APTI values could be attributed to the different responses of the plants to the four physiological factors, namely ascorbic acid, total chlorophyll, pH of the leaf extract and the relative water content of the leaf. These physiological factors, in turn, are affected by variation in the level of air pollution in the environment.

Elaeis guineensis, *Manihot esculenta*, *Ocimum gratissimum*, *Carica papaya*, *Solanum incanum* and *Vernonia amygdalina* are the most tolerant plants. No moderately tolerant plants were observed. The sensitive plant species were *Psidium guajava, Musa sapientum, Mangifera indica and Newbouldia laevis*. It was observed that all the tolerant plant species were tolerant at both industrial and non-industrial sites in line with Rai *et al*. (2013), who reported that *Mangifera indica* and *Bougainvillea spectabilis* were tolerant at both industrial and non- industrial sites. Tanee and Albert (2013) reported a decreasing order of tolerance to air pollution as *Psidum guajava* > *Puerenia phaseoloides* (Roxb.) Benth. > *Mallotus oppositifolius* (Geisel.) Mull - Arg. > *Musa paradisiaca* L. > *Telfairia occidentialis* Hook.f. > *Cymbopogon citratus* (DC.) Stapf. > *Talinum triangulare* (Jacq.) Willd. > *Vernonia amygdalina*> *Manihot esculenta*> *Ocimum gratissimum*. Nwadinigwe (2014) reported that *Delonix regia* (Bojer ex Hook.) had the highest APTI followed by *Bougainvillea spectabilis* and *Duranta erecta* L. in Ama industrial complex in Enugu State, Nigeria. They concluded that plants with high APTI could serve as tolerant plants, while those with low APTI could serve as sensitive ones. Agbaire and Esiefarienrhe (2009) reported that *Emilia sonchifolia* (L.) DC., *Manihot esculenta* and *Elaeis guineensis* were the more tolerant species around Otorogun gas plant in Delta State. Liu and Ding (2008) reported a number of tolerant to moderately tolerant plants near a Beijing steel factory in China which include *Cotinus coggygria* Rhus, *Periploca sepium* Bunge, *Lespedeza floribunda* Bunge and *Grewia biloba* (Bunge.) Hand.-Mazz. The comparatively high APTI values recorded for the tolerant plants in this work is in agreement with the report of Shanningrahi *et al*. (2004) who observed high APTI values in *Mangifera indica, Moringa pterydosperma* Gaertn, *Cassia renigera* Benth. and *Ailanthus excelsa* Roxb.

Plants with higher APTI (tolerant plants) can trap and contain dust particles or smog, absorb pollutant heat, other gaseous emissions and improve the ambient air quality. Such plant species should be grown in polluted cities, along roads and around industrial areas to create a sort of "curtain" that will absorb pollutants and screen the environment from their harmful effects. The plant species from Umuebulu flare station at Etche Local Government Area of Rivers State showed significantly ($p \leq 0.05$) lower APTI values than those from comparatively less polluted area (control). Nwadinigwe (2014), Gharge and Menon (2012) and Rai *et al*. (2013) reported an increase in APTI values of plants at the experimental site when compared with those at the control site. This may be due to constant exposure of these plants to emissions of gaseous and particulate matter from gas flaring.

The plant species from the polluted site had higher values of ascorbic acid, lower total chlorophyll, lower relative water content and variable pH values of the leaf extract compared with the control. Perhaps, the plants exposed to air pollution are naturally adjusting to these gaseous pollutants by increasing these physiological parameters in an attempt to contend with the environmental pollution.

The ascorbic acid from plants in the polluted site was higher than that from control plants in the present study. This agrees with the reports of Chandawat *et al*. (2011), Meerabal *et al*. (2012) and Rai *et al*. (2013) who reported higher levels of ascorbic acid in the leaves of the most tolerant plants than those at the control sites, an indication of their tolerance to the air pollutants. The lower ascorbic acid in the leaves of the sensitive plants indicates the sensitive nature of the plants to the pollutants. Ascorbic acid is important in cell wall synthesis, defense and cell division (Conklin, 2001). It is a strong reductant as it activates many physiological and defense mechanisms which play an important role in photosynthetic carbon fixation (Pasqualini *et al*., 2001). Due to its importance, it is used as a multiplication factor in the formula used in deriving APTI (Liu and Ding, 2008).

In the present work, the total chlorophyll of the test plants showed lower chlorophyll content of plants from experimental site when compared with those from the control. On the other hand, Agbaire and Esierfarienrhe (2009) reported a higher chlorophyll content of plants from experimental site compared with those of the control site. Certain pollutants increase the total chlorophyll content while others decrease it. Chandawat *et al*. (2011) observed that the chlorophyll content of all plants when tested varied with the pollution status of the area as well as the tolerance and sensitivity of the plant species. The total chlorophyll is related to ascorbic acid productivity since the ascorbic acid is concentrated mainly in the chloroplasts (Liu and Ding, 2008).

In the present investigation, the relative water content of the leaves from the polluted area was lower than those of the control. This is similar to the report of Seyyednjad *et al*. (2011) who observed lower relative water content in the experimental plants than in the control plants. Water is very important for plants, the shortage of which may cause severe stress to terrestrial plants. A high water content in the plant's body helps to maintain its physiological balance in stress conditions such as exposure to air pollution (Verma, 2003), when the transpiration rates are usually high. High relative water content contributes to the normal functioning of biological processes (Meerabal *et al*., 2012) and favours drought and pollution resistance in plants.

The result of pH of the leaf extract was variable in the present investigation. High pH may increase the efficiency of conversion from hexose sugar to ascorbic acid (Nwadinigwe, 2014), while a low pH shows a good correlation with sensitivity to air pollution (Yan-ju and Hui, 2008). Rai *et al*. (2013) observed that plants from the industrial site had a low pH (acidic) whereas those from the non-industrial site showed neutral to slightly alkaline range.

Combining a number of physiological parameters in the determination of APTI gives a more reliable result than depending on a single biochemical or physiological factors (Liu and Ding, 2008). Air pollution tolerance is affected by natural climate conditions such as rainfall, temperature, soil type and relative humidity, which were taken into consideration in this work since all the experimental plants were collected from the same climatic environment. The same applied to the control.

The variation in the APTI values could therefore be attributed to the different responses of the plants to the physiological factors and these receive most impact from the pollution load in the environment. APTI is an inherent quality of plants to encounter air pollution stress (Rai *et al*., 2013). These physiological factors help plants to adjust to stresses in the environment, such as pollution, drought and fire.

CONCLUSION

Tolerance of plants to air pollution may be specific to the site depending on the level of pollution. Majority of plants growing in the polluted site have lower APTI values compared to those of non-polluted site. The APTI values of the plants in the experimental site is less than that in the control site due to the response of the plants to air pollution at physiological and biochemical levels. All economic plants with high APTI values at the experimental site showed higher APTI values at the control site.

Air pollution tolerance index determinations are important in the choice of plants for cultivation for ornamental and economic purposes and given the increased urbanization and industrialization with attendant traffic pollution and gas flaring in Rivers State and other major cities in Nigeria, the possibility of increased air pollution cannot be ruled out. The results of the present study became very useful in landscaping, for phyto-remediation of industrial polluted air environment, and micro-climate modification. Tolerant species of plants should be considered in advance for use, where air pollution is high, while sensitive species should be used as bio-indicators of urban and rural air quality.

RECOMMENDATIONS

It is, therefore, recommended that APTI determinations of plants be made prior to the use of such plants for economic purposes since the life span of plants is determined by its air pollution tolerance ability. Cultivation and use of *Elaeis guineensis, Manihot esculenta, Ocimum gratisimum, Carica papaya, Vernonia amygdalina* and *Solanum incanum,* that are tolerant to air pollution, can absorb air pollutants, particulate matter and other emissions, thereby improving the air quality which man and other organisms are exposed to. Such plants should be grown on sites exposed to air pollutants, gas flare site, industrial areas, cities and along the road sides, but should not be consumed because of the quantity of pollutants absorbed.

Sensitive plants such as *Psidium guajava, Musa sapientum, Magnifera indica and Newbouldia laevis* are more useful as bio-indicators of air pollution in urban and industrial areas (Agarwal *et al*., 1991). Therefore, more work should be carried out on the APTI determination of many more economic plants globally, since air pollution is a global menace. It is, therefore, advised that Government should release more funds to researchers to work on the APTI values of more economic plants in order to determine those that are tolerant and sensitive to air pollutants. The gaseous profile, soil nature, nutrient levels of the soil and atmospheric parameters should be put into consideration in future studies.

ACKNOWLEDGMENT

The authors are grateful to Dr. Alfreda Nwadinigwe for her great contributions and Mr. Ozioko Alfred, both of the Department Plant Science and Biotechnology, University of Nigeria, Nsukka for collecting and analysing the plant materials.

REFERENCES

Abida, B. and Harikrishna, S. (2010). Evaluation of some tree species to absorb air pollutants in three industrial locations of south Bengaluru, India. *Journal of Chemistry*, 7:51-56.

Agarwal, M., Narayan, D., Singh, S. K. and Rao, D. N. (1991). Air Pollution tolerance index of plants. *Journal of Environmental Management*, 32: 45 – 55.

Agbaire, P.O. and Esiefarienrhe, E. (2009). Air pollution tolerance indices of some plants around Otorogun Gas plant in Delta State, Nigeria. *Journal of Applied Sciences and Environmental Management*, 13:11-14.

Chandawart, D. K., Verma, P.U. and Solanki, H.A. (2011). Air pollution tolerance index (APTI) of three species at cross roads of Ahmedabad city. *Life Science Leaflets*, 20: 935-943.

Conklin, P. (2001). Recent advances in the role and biosynthesis of ascorbic acid in plants. Plant *Cell Environment*, 24: 348- 394.

Dineva, S.B. (2004). Comparative Studies of the leaf morphology and structure of white ash *Fraxinus americana* and London plane tree, *Platanus acerifolia* Wild growing in polluted area. *Dendrobiology*, 230p.

Dung, E. J., Bombom, L. S. and Agusomu, T. D. (2008). The effect of gas flaring on crops in the Niger-Delta, Nigeria. *Geojournal*, 73: 292-305.

Edafiogho, D. O. C. (2006). *Computer Graphics. Spreadsheet (excel) and SPSS.* University of Nigeria Press Ltd., Nigeria. 237p.

Gharge, S. and Menon, G. S. (2012). Air pollution tolerance index (APTI) of certain herbs from the site around Ambernath MIDC. *Asian Journal of Experimental Biology Science, 3* (3): 543-547.

Isichei, A. O. and Sanford, W. W. (1976). The effect of waste gas flares on the surrounding vegetation in South-Eastern Nigeria. *Journal of Applied Ecology*, 13 (1): 177-187.

Joshi, P.C. and Swami, A. (2007). Physiological responses of some tree species under roadside automobile pollution stress around the city of Haridwar, India. *Environmentalist*, 27: 365-374.

Joshi, P. C. and Swami, A. (2009). Air pollution-induced changes in the photosynthetic pigment of selected plant species. *Environmental Journal of Science,* 30: 295-298.

Liu, Y. J. and Ding, H. (2008). Variation in air pollution tolerance index of plants near a steel factory: Implication for landscape plant species selection for industrial areas. *Wseas Trans. Environmental Development,* 4: 24-32.

Mahecha, M. D., Reichstein, M., Carvalhais., Lasslop, G., Lange, H., Seneviratne, S.I., Vargas, R., Amman, C., Arain, M. A., Cescatti, A., Janssens, I. A., Migliavacca, M., Montagnani, L. and Richardson, A.D. (2013). Global Convergence in the Temperature Sensitivity of Respiration at the Ecosystem Levels. *Science*, 329: 838 – 840.

Meerabal, G., Venkata, R.C. and Rasheed, M. (2012). Effect of industrial pollutants on physiology of *Cajanus cajan* (L.) Fabaceae. *International Journal of Environmental Science*, 2 (4):1889-1894.

Nwadinigwe, A.O. (2009). Air pollution tolerance index of some plant species in Udeagbala industrial area, Aba, Abia State, Nigeria. In: Anyadike, R.N.C., Madu, I.A., Ajaero, C.K. (eds). *Climate Change and the Nigerian Environment*. *Proceedings of a National conference held at the University of Nigeria, Nsukka Nigeria,* Pp 375-382.

Nwadinigwe, A.O. (2014). Air pollution tolerance indices of some plants around Ama industrial complex in Enugu State, Nigeria. *African Journal of Biotechnology,* 13 (11): 1231-1236.

Odilara, C. A., Egwaikhide, A., Esekheigbe, A. and Emua, S.A. (2006). Air pollution tolerance indices (APTI) of some plant species around Ilupeju industrial area, Lagos. *Journal of Engineering Sciences Applied,* 4: 97-101.

Pasqualini, S.P., Batini, L., Ederlis, A., Porceddu, C., Piccioni, F., Marchis, D.E. and Anthonielli, M. (2001). Effect of short-term Ozone fumigation on tobacco plants: Response of scavenging system and expression of glutathione reductase. *Plant Cell Environment*, 24: 245-252.

Rai, P. K., Panda, L. L. S., Chulia, B. M. and Singh, M. M. (2013). Comparative assessment of air pollution tolerance index (APTI) in the industrial (Rourkela) and non-industrial (Alzarol) areas of India: An eco-management approach. *African Journal of Environmental Science Technology,* 7 (10): 944-948.

Seyyednjad, S.M., Majdian, K., Koochak, H. and Niknejad, M. (2011). Air pollution tolerance indices of some plants around industrial zone in south of Iran. *Asian Journal of Biological Sciences*, 4: 300-305.

Shannigrahi, A. S., Fukustraima, T. and Sharma, R.C. (2004). Anticipated air pollution tolerance of some Plant species considered for green belt development in and around an industrial urban area in India: An overview. *International Journal of Environmental Studies,* 61 (2): 125-137.

Singh, S.K., Rao, M., Agarwal, J. and Narayan, D. (1991). Air Pollution Tolerance Index of Plants. *Journal of Environmental Management*, 32 (1): 45-55.

Tanee, F. B. G. and Albert, E. (2012). Air pollution tolerance indices of plants growing around Umuebulu gas flare station in Rivers State, Nigeria. *African Journal of Environmental Science and Technology,* 7(1): 1-8.

Tiwari, S., Agarwal, M. and Marwill, F. M. (2006). Evaluation of ambient air pollution impact on carrot plants at a sub-urban site using open top chambers. *Environmental Impact Management Assessment,* 119: 15-30.

Tripathi, A.K. and Gautam, M .(2007). Biochemical parameters of plants as indicators of air pollution. *Journal of Environmental Biology*, 28: 127-132.

Verma, M., Bhat, P.J. and Venkatesh, K.V.(2003). Quantitative analysis of Gal genetic switch of *Saccharomyces cerevisiae* reveals nucleocytoplasmic shuttling of Gal 80, resulting in a highly sensitive response to galactose. *Journal of Biological Chemistry*, 278 (49): 48764-48769.

Yan-Ju, L. and Hui, D. (2008). Variation in air pollution tolerance index of plants near a steel factory: Implications for landscape-plant species selection for industrial areas. *Environment and Development*, 1(4): 24-30.