Determination of Tolerance and Sensitivity of Some Selected Plants to Air Pollution along Major Roads in Obio-Akpor (Port Harcourt) Nigeria Using Air Pollution Tolerance Indices

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Abstract

Air pollution is among the most challenging problem in today's world. In this study, Air Pollution Tolerance Index (APTI) was calculated for four different plants (*Panicum maximum*,*Eleusineindica*,*Xanthosomamafafa*and*Amaranthusspinosus*) found growing along four busy roads (Aba road, East/West road , Ikwerre road and NTA road) in Obio/Akpor local government area and control (IkwerreNgwo) in Etche local government area in Rivers State, Nigeria. The computed APTI results obtained from four biochemical parameters(relative water content, ascorbic acid, leaf extract pH and chlorophyll) showed that the APTI of the test plants recorded remarkable changes as the values obtained in the experimental sites were higher than the control site. The APTI values in the experimental sites (4 roads) were in the range of *P. maximum* (7.4 – 8.04); *E. indica* (7.3 – 8.2); *X. mafafa* (7.2 – 7.9); and *A. spinosus* (7.2 – 8.0) as against the control (< 6.2) showing that all the test plants studied were sensitive to pollution. Thus, these plants can be used as a better indicator of air pollution in an environment.

Key words: Air Pollution, Relative water content, leaf chlorophyll, Ascorbic acid content, pH

Introduction

One of the most challenging problems that deteriorate the world today is air pollution. It can be defined as the fluctuation in the values of atmospheric constituent that could have existed without anthropogenic activities (Tripathi and Gautam, 2007). There has been severe increase in the concentration of particulate and gaseous pollutants due to continuous increase in population growth, vehicular traffic, industries and road transportation over the years (Joshi*et al.*, 2009) which posses serious threat to the health of inhabitants due to the adverse effects on the air quality arising from both mobile and stationary combustion sources. These pollutants are classified as either primary (pollutants that pollute the atmosphere directly once introduced into the environment) or secondary (pollutants that are formed as a result of the reactions or interactions of primary pollutants in the atmosphere) pollutants (Agbaire and Esiefarienrhe, 2009). Particulate (aerosols, dust, smoke, fumes etc) and gaseous (carbon monoxides, sulphurdioxide, hydrocarbons, etc) pollutants have negative impacts on humans, plants, animals and the ecosystem at large. Air pollution has been proven to be a contributing factor to increase in mortality rate (Gupta *et al.*, 2004). Epidemiological studies has shown that about 4.6 million people die yearly

due to exposure to particulate and gaseous pollutants which results to diseases such as cardiopulmonary mortality, cardiovascular diseases and respiratory infections among the habitation (WHO, 2002; Gupta *et al.*, 2004).

In Africa, the risks of exposure to air pollution is high in developing cities, research conducted in Republic of Benin, Ethiopia, Kenya and Mozambique revealed high level of DNA damage in residents in urban areas and higher prevalence of asthma in school children that are exposed to air pollution in urban areas as compared to school children in rural areas (Autrup, 2006). Plants provide some ecosystem functions like temperature amelioration, drainage and water storage filtration, air filtering etc (Bolund and Hunhammers, 1999).

Plants serve as integral basis for our ecosystems and could be affected by air pollution. They have been identified as the most potential organisms that aremostly affected by ambient air pollution because they are stationary and are continuously exposed to pollutants from the atmosphere. Hence; injuries caused by air pollution to plants is proportional to the intensity of pollution. Plants are important tools used to evaluate the impact of air pollution. Sensitive plant species act as biological indicators of air pollution (Lakshmi *et al.,* 2009).Plants response to air pollution can be understood by determining the air pollution tolerance index (APTI) which is species dependent plant attribute that expresses the ability of plant to encounter stress that arise due to pollution. APTI is obtained by using four biochemical parameters which are; relative water content of leaf, ascorbic acid, pH of the leaf and chlorophyll of the leaf(Singh and Verma,2007). Dileswar*et al.* (2015) studied the APTI of *Tectonagrandis, Sarocaasaca, Terminalia catappa, Syzygiumcumini,* and *Cassia fistula,* and they observed that *Cassia fistula* (14.34%) had the highest results followed by *Syzygiumcumini*(10.87%), *Sarocaasaca*(10.77%), *Tectonagrandis*(8.72%) and *Terminalia catappa* (7.41%).

Thus; this study was designed to determine the air pollution tolerance level of the test plants as well as the sensitivity of the test plants with respect to air pollution.The result obtained will assist in environmental biomonitoring of air polluted areas.

Materials and Methods

Description of the Study Area

The study was carried out along four roadsides (i.e Aba road, East/West road, Ikwerre road and NTA road) in parts of Obio/Akpor local government and the control (in IkwerreNgwo) inEtche local government areas in Rivers State in the Southern region of Nigeria.Two seasons are experienced in this area; the dry and rainy seasons which ranges from the month of November – March and April-October respectively.

Aba road and East-West road are among major roads in Obio/Akpor local government area linking parts of the eastern, western and northern states to Rivers State which results to a lot of anthropogenic activities in the area.These areas experience a lot of vehicular

traffic and exhaust fumes emanating from smaller and heavy duty vehicles while Ikwerre and NTA roads are roads where commercial activities take place. These roads link to some residential areas and local roads in the city. The control site (IkwerreNgwo) is a rural area. Residents here are mostly peasant farmers.

Table 1: GPS of Sample Locations

Locations	Northings	Eastings	Elevations (m)
Obio/Akpor			
Aba Road	04^0 53’ 12.3”	007^0 08’ 36.4”	5
	04^0 52’ 45.8”	007^0 07’ 37.1”	20
	04^0 52’ 05”	007^0 06’ 21.0”	18
	04^0 51’ 30.2”	007^0 4’ 28.7”	25
East/West Road	04^0 51’ 14.7”	007^0 04’0 6.6’’	26
	04^0 51’ 53.1”	007^0 02’ 46.9”	20
	04^0 52’ 13.4”	006^0 54’ 47.4”	12
	04^0 53’ 41.0”	006^0 54’ 47.4”	12
Ikwerre Road	04^0 55’ 08.2”	006^0 59’ 50.0”	25
	04^0 54’ 51.2”	006^0 59’ 52.3”	25
	04^0 53’ 40.8”	007^0 00’ 06.8”	24
	04^0 53’ 15.3”	007^0 00’ 08.0”	22
NTA Road	04^0 53’ 49.0”	006^0 54’ 25.5”	19
	04^0 52’ 44.3”	006^0 54’ 39.7”	22
	04^0 52’ 06.1”	006^0 57’ 28.5”	8

	04^0 52’ 06.1”	006^0 57’ 28.5”	16
Etche IkwerreNgwo	4^0 54’ 28.8” 4^0 55’ 8.4” 4^0 56’ 2.4” 4^0 55’ 55.2”	7^0 6’ 57.6” 7^0 5’ 49.2” 7^0 5’ 49.2” 7^0 4’ 37.2”	21 19 20 20

Sampling Procedures

Sampling was done in the months of August (wet season) and December (dry season), 2014. Four sample points along each of these roads located within a minimum of one kilometer between sample points. Four plant species(*Panicum maximum* (Jacq.),*Eleusineindica*(L.),*Xanthosomamafafa*(Schott.)*andAmaranthusspinosus*(L.))found flourishing in both the experimental and the control sites were selected for the experimental study. The leaves of the test plants used for this investigation were collected before noon between the hours of 6.30am and 11am. Replicates of fresh leaves were harvested at a distance of 1 metre away from the roadside in the experimental and control sites. They were put in well labeled sterile cellophane bags and were hurriedly transported to an analytical laboratory for analysis. It was ensured that the selected plant species were under the same ecological condition with regard to soil, light and rainfall.

Analysis of Leaf for Biochemical parameters

*R*elative water content, total chlorophyll content, pH and ascorbic acid content of leaf extract were analyzed. Thevalues obtained were used to compute the APTI values.

TheRelative Water Content (RWC) was determined by weighing the fresh leaf samples of the test plants on a digital balance (Setra model number: BL-410S) to obtain the fresh weight (FW). The fresh leaves were then immersed in water for twenty four hours, blotted dry with the aid of whatman filter paper and reweighed to obtain the turgid weight (T W). They were finally oven dried (Gallenkamp plus II oven) for 48 hours at a temperature of 70^0C and reweighed again to determine their dry weight (DW). Then RWC was computed using the formula described by Singh (1977) and Taneeet *al.*, (2014) as stated below:

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

Total Chlorophyll Content (TLC) was obtained according to the method of Stewart*et al.* (1974) in which 0.1gram of each of the leaf samples was soaked in 10ml of 50% acetone; and then allowed to stand for two days to extract the available chlorophyll using a spectrophotometer.

The pH of the leaf was obtained by homogenizing 2 gram of fresh leaves in 20 ml of deionized water and leaf pH determined using a pH meter (HI8314).TheAscorbic Acid Content (AAC) was obtained using the indophenols acetic acid method (AOAC, 1984).

Air Pollution Tolerance Index (APTI) was calculated using the standard method as described by Singh and Rao (1983). Thus;

$$APTI = \frac{AAC\ (TLC + pH) + RWC}{10}$$

Statistical Analysis

Data was statistically analyzed using Standard Error Mean (SEM) using Microsoft excel package version 2007. Least significant difference (LSD) ($p < 0.05$) was used to separate means.

Results

The average values of the biochemical parameters and percentage increase/decrease in total chlorophyll, leaf pH, ascorbic acid, relative water content for the four plant species at boththe experimental and control sites are represented in Tables 2-5 below. The APTI for the test plants at both the experimental and control sites are shown in table 6.

The relative water content of the test plants was higher in the experimental sites than the control site for both seasons. That is; plants in experimental sites retains more water than the ones in control site (Table 2a and b).The highest was recorded in *X. mafafa* in all the roads in the wet season.

Table 2a: Relative Water Content (wet season)

Location	Species	Control	Experimental Site	% Increase/Decrease

Aba Road	*P. maximum*	56.45±1.4	80.59±3.0	+30
	E. indica	51.9±1.1	76.36±1.5	+32
	X. mafafa	48.15±1.4	78.34±3.3	+38.5
	A. spinosus	58.66±1.1	76.94±0.6	+23.8
East/West Road	*P. maximum*	56.45±1.4	83.24±1.1	+32.2
	E. indica	51.9±1.1	78.3±0.6	+33.7
	X. mafafa	48.15±1.4	79.7±3.3	+39.6
	A. spinosus	58.66±1.1	74.0±0.5	+20.7
Ikwerre Road	*P. maximum*	56.45±1.4	76.53±2.1	+26.2
	E. indica	51.9±1.1	83.94±0.7	+38.2
	X. mafafa	48.15±1.4	82.24±2.4	+41.5
	A. spinosus	58.66±1.1	76.66±2.6	+23.5
NTA Road	*P. maximum*	56.45±1.4	78.68±1.2	+28.3
	E. indica	51.9±1.1	82.8±1.0	+37.3
	X. mafafa	48.15±1.4	84.43±0.6	+43.0
	A. spinosus	58.66±1.1	77.0±2.0	+23.8

Where; + = % increase, - = % decrease

Table 2b. Relative Water Content (dry season**)**

Location	Species	Control	Experimental Site	% Increase/Decrease
Aba Road	*P. maximum*	63.0±0.9	74.9±0.1	+15.9
	E. indica	62.6±1.3	77.1±1.5	+18.8
	X. mafafa	63.7±1.1	74.8±1.8	+14.8
	A. spinosus	60.6±1.9	75.2±1.5	+19.4
East/West Road	*P. maximum*	63.0±0.9	71.8±2.2	+12.3
	E. indica	62.6±1.3	70.4±2	+11.1
	X. mafafa	63.7±1.1	70.3±1.5	+9.4
	A. spinosus	60.6±1.9	69.6±1.7	+12.9

Ikwerre Road	*P. maximum*	63.0±0.9	71.3±2.8	+11.6
	E. indica	62.6±1.3	70.2±2.3	+10.5
	X. mafafa	63.7±1.1	72.0±2.6	+11.5
	A. spinosus	60.6±1.9	72.5±3.7	+16.4
NTA Road	*P. maximum*	63.0±0.9	76.1±1.1	+17.2
	E. indica	62.6±1.3	72.9±2.4	+14.1
	X. mafafa	63.7±1.1	75.9±2	+16.1
	A. spinosus	60.6±1.9	76.5±2.7	+20.8

Where; + = % increase, - = % decrease

The pH of the leaf extract was found to be lower in the experimental site than the control site (Table 3a and b). The highest pH was recorded in *Xanthosomamafafa*on Aba road while the least was recorded in *Amaranthusspinosus*on East/West road for both seasons.

Table 3a:pH of the Leaf Extracts (Wet Season)

Location	Species	Control	Experimental Site	% increase/decrease
Aba Road	*P. maximum*	4.12±0.1	2.31±0.1	-52.1
	E. indica	3.52±0.2	2.36±0.04	-43.4
	X. mafafa	4.22±0.2	2.4±0.1	-50.1
	A. spinosus	3.49±0.2	2.12±0.07	-27.4
East/West Road	*P. maximum*	4.12±0.1	1.3±0.1	-47.9
	E. indica	3.52±0.2	2.02±0.1	-49.5
	X. mafafa	4.22±0.2	1.08±0.03	-38.6
	A. spinosus	3.49±0.2	0.98±0.04	-43.9
Ikwerre Road	*P. maximum*	4.12±0.1	2.11±0.1	-56.6
	E. indica	3.52±0.2	2.11±0.1	-39
	X. mafafa	4.22±0.2	1.80±0.03	-53.8
	A. spinosus	3.49±0.2	1.5±0.1	-50.1
NTA Road	*P. maximum*	4.12±0.1	2.23±0.1	-43.3
	E. indica	3.52±0.2	1.84±0.1	-49.9
	X. mafafa	4.22±0.2	0.65±0.3	-35.6

	A. spinosus	3.49±0.2	2.12±0.1	-27.8

Where; + = % increase, - = % decrease

Table 3b:pH of the Leaf Extracts (Dry Season)

Location	Species	Control	Experimental Site	% increase/decrease
Aba Road	*P. maximum*	6.5±0.2	5.3±0.2	-22.6
	E. indica	6.3±0.2	5.4±0.2	-16.7
	X. mafafa	6.3±0.1	5.6±0.2	-12.5
	A. spinosus	6.5±0.1	5.4±0.1	-20.4
East/West	*P. maximum*	6.5±0.2	5.37±0.2	-21
Road	*E. indica*	6.3±0.2	5.13±0.2	-22.8
	X. mafafa	6.3±0.1	5.13±0.1	-22.8
	A. spinosus	6.5±0.1	5.05±0.2	-28.7
Ikwerre Road	*P. maximum*	6.5±0.2	5.2±0.2	-25
	E. indica	6.3±0.2	5.5±0.2	-14.6
	X. mafafa	6.3±0.1	5.1±0.2	-23.5
	A. spinosus	6.5±0.1	5.4±0.2	-20.4
NTA Road	*P. maximum*	6.5±0.2	5.4±0.1	-20.4
	E. indica	6.3±0.2	5.4±0.1	-16.7
	X. mafafa	6.3±0.1	5.6±0.1	-12.5
	A. spinosus	6.5±0.1	5.6±0.1	-16.1

Where; + = % increase, - = % decrease

During rainy season, the ascorbic acid content of the test plants in the experimental sites were lower in all plants except for *P. maximum* in NTA road (Table 4a). While in dry season, it varied among locations with *E. indica*in NTA road having the highest value and *P. maximum* in Aba road with the least value (Table 4b).

Table 4a: Ascorbic Acid Content (AAC) at Wet Season

Location	Species	Control	Experimental Site	% Increase/Decrease
Aba Road	*P. maximum*	0.52±0.01	0.38±0.01	-36.8
	E. indica	0.54±0.01	0.45±0.02	-20
	X. mafafa	0.52±0.01	0.4±0.02	-30
	A. spinosus	0.56±0.01	0.46±0.02	-21.7
East/West Road	*P. maximum*	0.52±0.01	0.43±0.01	-20.9
	E. indica	0.54±0.01	0.52±0.01	-3.9
	X. mafafa	0.52±0.01	0.32±0.003	-62.5
	A. spinosus	0.56±0.01	0.53±0.01	-5.7
Ikwerre Road	*P. maximum*	0.52±0.01	0.42±0.01	-23.8
	E. indica	0.54±0.01	0.47±0.01	-14.9
	X. mafafa	0.52±0.01	0.43±0.003	-20.9
	A. spinosus	0.56±0.01	0.50±0.01	-12
NTA Road	*P. maximum*	0.52±0.01	0.55±0.02	5.5
	E. indica	0.54±0.01	0.5±0.01	-8
	X. mafafa	0.52±0.01	0.33±0.01	-57.6
	A. spinosus	0.56±0.01	0.44±0.004	-27.3

Where; + = % increase, - = % decrease

Table 4b: Ascorbic Acid Content (AAC) for Dry Season

Location	Species	Control	Experimental Site	% Increase/Decrease
Aba Road	*P. maximum*	0.24±0.01	0.13±0	-84.6
	E. indica	0.23±0	0.4±0.01	+42.5
	X. mafafa	0.3±0.01	0.41±0.01	+24.4
	A. spinosus	0.26±0.01	0.46±0.02	+43.5
East/West Road	*P. maximum*	0.24±0.01	0.15±0	-60
	E. indica	0.23±0	0.26±0.01	+11.5
	X. mafafa	0.3±0.01	0.25±0.01	-24
	A. spinosus	0.26±0.01	0.18±0	-44.4

Ikwerre Road	*P. maximum*	0.24±0.01	0.23±0.01	-4.4
	E. indica	0.23±0	0.17±0.01	-35.3
	X. mafafa	0.3±0.01	0.22±0.01	-40.9
	A. spinosus	0.26±0.01	0.29±0.02	+10.4
NTA Road	*P. maximum*	0.24±0.01	0.36±0.01	+33.3
	E. indica	0.23±0	0.74±0.1	+68.9
	X. mafafa	0.3±0.01	0.34±0.01	+8.8
	A. spinosus	0.26±0.01	0.2±0.01	-8.3

Where; + = % increase, - = % decrease

Results from this study showed that the test plants in the experimental sites had lower total chlorophyll content than in the control site (Table 5a and b).

Table 5a. Total leaf chlorophyll (wet season)

Location	Species	Control	Experimental Site	% Increase/Decrease
Aba Road	*P. maximum*	4.12±0.1	2.31±0.1	-78.4
	E. indica	3.52±0.2	2.36±0.04	-49.2
	X. mafafa	4.22±0.2	2.4±0.1	-75.8
	A. spinosus	3.49±0.2	2.12±0.07	-64.6
East/West Road	*P. maximum*	4.12±0.1	1.3±0.1	-216.9
	E. indica	3.52±0.2	2.02±0.1	-74.3
	X. mafafa	4.22±0.2	1.08±0.03	-290.7
	A. spinosus	3.49±0.2	0.98±0.04	-256.1
Ikwerre Road	*P. maximum*	4.12±0.1	2.11±0.1	-95.3
	E. indica	3.52±0.2	2.11±0.1	-66.8
	X. mafafa	4.22±0.2	1.80±0.03	-134.4
	A. spinosus	3.49±0.2	1.5±0.1	-132.7
NTA Road	*P. maximum*	4.12±0.1	2.23±0.1	-84.8
	E. indica	3.52±0.2	1.84±0.1	-91.3
	X. mafafa	4.22±0.2	0.65±0.3	-549.2

	A. spinosus	3.49±0.2	2.12±0.1	-64.6

Where; + = % increase, - = % decrease

Table 5b. Total Leaf Chlorophyll (dry season)

Location	Species	Control	Experimental Site	% Increase/Decrease
Aba Road	*P. maximum*	3.4±0.1	1.65±0.2	-107.3
	E. indica	3.2±0.04	2.0±0.1	-57.5
	X. mafafa	3.9±0.1	2.2±0.1	-76.4
	A. spinosus	3.2±0.1	1.9±0.1	-66.9
East/West	*P. maximum*	3.4±0.1	3.16±0.1	-7.6
Road	*E. indica*	3.2±0.04	3.0±0.2	-6.7
	X. mafafa	3.9±0.1	2.0±0.1	-95
	A. spinosus	3.2±0.1	2.13±0.1	-50.2
Ikwerre Road	*P. maximum*	3.4±0.1	2.57±0.1	-32.3
	E. indica	3.2±0.04	1.21±0.1	-164.5
	X. mafafa	3.9±0.1	2.0±0.1	-95.0
	A. spinosus	3.2±0.1	1.3±0.1	-146.2
NTA Road	*P. maximum*	3.4±0.1	2.9±0.1	-17.2
	E. indica	3.2±0.04	1.2±0.01	-166.7
	X. mafafa	3.9±0.1	2.6±0.1	-50
	A. spinosus	3.2±0.1	2.3±0.1	-39.1

Where; + = % increase, - = % decrease

The test plants in this study had APTI values of less than 16 for both seasons. It was observed that the APTI for both seasons were higher in the experimental sites than the control site. The maximum APTI values for rainy season was recorded in *Panicum maximum* on NTA road while the least was recorded in *X. mafafa*and *A. spinosus* on East/West road while the highest values for dry season was recorded in *Elusineindica*on NTA road and the least was recorded in *Amarathusspinosus*in Ikwerre road (Tables 6a & b).

Table 6a*:* Air pollution Tolerance indices (APTI) of the Test Plants (Wet Season)

Location	Species	Control	Experimental Site	% Increase/Decrease
Aba Road	*P. maximum*	5.6±0.3	7.74±0.1	+27.6
	E. indica	5.8±0.4	8.02±0.2	+27.7
	X. mafafa	5.6±0.3	7.75±0.2	+27.7
	A. spinosus	5.7±0.5	7.82±0.2	+27.1
East/West	*P. maximum*	5.6±0.3	7.4±0.2	+24.3
Road	*E. indica*	5.8±0.4	7.4±0.2	+21.6
	X. mafafa	5.6±0.3	7.2±0.2	+22.2
	A. spinosus	5.7±0.5	7.2±0.2	+20.8
Ikwerre Road	*P. maximum*	5.6±0.3	7.4±0.3	+24.3
	E. indica	5.8±0.4	7.3±0.2	+20.6
	X. mafafa	5.6±0.3	7.5±0.3	+25.3
	A. spinosus	5.7±0.5	7.5±0.4	+24
NTA Road	*P. maximum*	5.6±0.3	8.04±0.1	+30.4
	E. indica	5.8±0.4	7.6±0.3	+23.7
	X. mafafa	5.6±0.3	7.8±0.2	+28.2
	A. spinosus	5.7±0.5	8.0±0.3	+28.8

Where; + = % increase, - = % decrease

Table 6b: Air pollution Tolerance indices (APTI) of the Test Plants (Dry Season)

Location	Species	Control	Experimental Site	% Increase/Decrease
Aba Road	*P. maximum*	6.2±0.1	7.5±0.1	+18.4
	E. indica	6.0±0.03	7.7±0.2	+21.7
	X. mafafa	6.1±0.02	7.8±0.2	+21.6
	A. spinosus	6.2±0.2	7.8±0.1	+20.8
East/West	*P. maximum*	6.2±0.1	7.9±0.2	+22.1
Road	*E. indica*	6.0±0.03	7.8±0.2	+22.3
	X. mafafa	6.1±0.02	7.7±0.2	+20.6
	A. spinosus	6.2±0.2	7.6±0.1	+17.8

Ikwerre Road	*P. maximum*	6.2±0.1	7.7±0.1	+19.9
	E. indica	6.0±0.03	7.5±0.2	+20.2
	X. mafafa	6.1±0.02	7.9±0.2	+22.2
	A. spinosus	6.2±0.2	7.4±0.2	+16.3
NTA Road	*P. maximum*	6.2±0.1	7.8±0.1	+20.8
	E. indica	6.0±0.03	8.2±0.2	+26.2
	X. mafafa	6.1±0.02	7.7±0.1	+20.3
	A. spinosus	6.2±0.2	7.7±0.1	+19.8

Where; + = % increase, - = % decrease

Discussion

When there is reduction in the rate of leaf transpiration, as a result of air pollution, plants lose its engine that pulls water from the roots to supply photosynthesis. The plants will either cool the leaf or bring minerals from roots to leaf where biosynthesis occur (Seyyednjad*et al.,* 2011).Plants at the experimental sites were found to have more relative water content than the control. Similar result has been reported by Bhattacharya *etal.* (2013) where they observed higher relative water content in the monsoon seasonwhile Das and Prasad (2010) observed high leaf RWC during rainy season, low inwinter and least in summer season.This retained water acts as an adaptive feature that helps in the maintenance of plants physiological balance against pollution stress condition (Verma, 2003). This shows that the ability to retain and accumulate water is an adaptive feature of plant to tolerate pollution stress.

pH plays very vital role in the modification of the toxicity of air pollution such as SO_2. Singh and Verma (2007) reported that plants with lower pH are more susceptible while those with pH of about 7 are more tolerant to pollution. High pH could increase the efficiency of the conversion from hexose sugar to ascorbic acid (Escobedo *et al.,* 2008). The decrease in pH in the leaves of plant at the experimental sites could be explained that the exposure of plant to air pollutant causes an appreciable acidification of the cytoplasm to occur (Veljovic-Jovanovic*et al*., 1993) leading to low photosynthesis.

Ascorbic acid activates some defense and physiological mechanisms (Arora *et al*.,2002) and serves as a tool acceptable to biomonitor pollutants. Its reducing power is proportional to its concentrations (Raza and Murthy, 1988). It also plays very significant role in light reaction during photosynthesis (Singh and Verma, 2007) but when subjected to stress, it has the ability to replace water from light reaction II (Singh and Verma, 2007). Ascorbic acid is a strong reducer that has significant function in photosynthetic fixation of carbon with its reducing power proportional to its concentration. So it reductions in the experimental site is an indicator of air pollution.

Some 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). The reductions in the pH and ascorbic acid also have a direct effect on chlorophyll synthesis as observed in the result. Similar results had been reported by Joshi and Swami (2007) who observed that one of the most common impacts of air pollution is the gradual disappearance of chlorophyll. Decrease in values of pH of leaf extract and total chlorophyll content of leaf as observed also agrees with the findings of Jyothi and Jaya (2010) who proposed that high concentration of automobile pollution results in reduction in chlorophyll content of leaf in higher plants near roadsides. This shows that there is a correlation between leaf pH, ascorbic acid content and chlorophyll synthesis. Though, this varies from plant species to species, leaf age, pollution level as well as abiotic and biotic conditions (Katiyar and Dubey, 2001). Reduction in the chlorophyll content of plants results in poor productivity in plants.Thus; plants that maintain their chlorophyll in a polluted environment are referred to as tolerant (Singh and Verma, 2007).

APTI plays important role in determining the susceptibility and resistivity of plant species against levels of pollution. The resultsshowed that various plants respond differently to air pollution. Differences in the values obtained from the four biochemical parameters (pH, ascorbic acid, chlorophyll and relative water content) resulted in variation in APTI values. In this study, the result of the APTI values of all the test plants fell within the range of sensitive for plant in the experimental site (Table 7). The increase in the APTI of the test plants may be due to increase in the RWC of the test plants that aid in plant physiological balance against pollution.Agbaire and Esiefarienrhe (2009); Tanee and Albert (2013); Tanee*et al*. (2014) and Dilesware*t al.* (2015) have also reported some plants with varying level of sensitivity and tolerance to pollution using APTI.

Table 7: Grouping of plants based on APTI

APTI Value	Response
30 – 100	Tolerant
29 – 17	Intermediate
16 – 1	Sensitive
<1	Very Sensitive

Source; Lakshmi *et al.*, (2009)

Conclusion

All the test plants showed increased values at the experimental site for relative water content and ascorbic acid except for *E. indica*and *X. mafafa* in Aba road and *E. indica*in NTA road. Also, the test plants in the control site had higher values of pH and total chlorophyll

but the values of APTI for the test plants were higher in the experimental sites than the control site. Hence, plants found growing along busy roads are exposed to pollutants to their own system which alter the biochemical nature of the leaf. All the plants in this study fell within the range of sensitive category to air pollution. Therefore, these plants can be explored as biomonitors in air pollution prone environment.

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