COMPARATIVE AIR POLLUTION TOLERANCE INDEX (APTI) ASSESSMENT OF SELECTED PLANTS AROUND INDUSTRIAL SITES IN DELTA STATE

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Emoyan, Onoriode Onos
Environment Chemistry & Waste Management Research Group
Department of Chemistry Delta State University, PMB 1 Abraka, Nigeria
emoyanonos@gmail.com

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Abstract: Air pollution tolerance index (APTI) is used by the environmental chemist to evaluate plant species that are tolerant to air pollution. Biochemical characteristics such as plant relative water content, pH, chlorophyll content and ascorbic acid of leaf tissue was determined in four sites. *Manihot esculenta, Chromolaena odorata, Musa paradisiaca, Elias guinea, Helianthus, Psidium guajava, Imperata cylindrica, Mangifera, indica, Sida acuta* and *Centrosena pubescens* are plant species used for the study. Three composites leaf samples growing near the sites were collected between three dates from October to December 2017. The obtained APTI values in all plant species exhibited tolerant characteristics with values ranging between 38.21 and 73.59. Results show that the APTI are relatively in the order; control > Agbor-Eku road side > Platform oil > eastern metal works. Also, results revealed a significant difference ($P < 0.05$) between APTI variables in the studied sites. This study has reaffirm that dust collecting capacity of plants and that environmental conditions such as humidity and temperature could be responsible for the decrease or increase of different physiological parameters and hence APTI. This study has established that the studied plant species exhibit potential for air pollution resistance.

Keywords: Plant species, APTI, ascorbic acid, pH, water content, chlorophyll

Introduction

Atmospheric air pollution is associated with the introduction of foreign organic and inorganic materials in the form of solid, liquid and gaseous particles into the atmosphere by anthropogenic and/or natural means (Lohe *et al.*, 2015). Above normal atmospheric threshold concentration, air pollution brings about understandable change or imbalance in the physical, chemical and biological characteristics of the atmosphere. This poses danger to environment and human health (Daniel, 2014). Atmospheric pollution is caused by different sources such as fuel and diesel engine exhaust fumes, industrial, commercial and domestic combustion processes, chemical utilization and tobacco smoke through stationery, mobile, point and non point sources (Marchonoka–Wyrwal, 2011). Modern industries are the major sources of these pollutants and causes of air pollution (Daniel, 2014). Studies have shown that exposure to air pollution may be associated with different and varying human and environment health effects (Defense, 1996).

Different plant species have been recognised to have large leaf area for the absorption and accumulation of atmospheric pollutants (Escobedo *et al*., 2008). Studies have shown that some plant species exhibit high sensitivity to air pollution which serves as bio-makers of air pollution (Liu and Ding, 2007; Pratik *et al*., 2012). Air pollution can directly and indirectly affect plant leaves through soil acidification (Steubing *et al*., 1989). Plant exposed to air pollution could experience biochemical changes before exhibiting visible effects on leaves (Dohmen *et al*., 1990). Studies have also shown that biochemical properties of plants such as water content, pH, chlorophyll, ascorbic acid, leaf conductance, membrane, permeability, glutathione concentration, peroxidase activity and $\delta^{13}C$ of leaf tissue are parameters applied to estimate plant species tolerance to air pollution stress (Dohmen *et al*., 1990). However, Liu and Ding (2009) opine that individual parameter give conflicting results for some species. For example *Ailanthus altissima* is sensitive to pollution on one parameter application but tolerant to another (Han *et al*., 1995; Zhou, 1996). This may have significant implications for the study of of atmospheric pollutants on plant species.

The study sites are situated in Delta State. These sites are suspected to be point and non point sources of pollutants such as SOx, NOx, CO, CO_2, H_2S, CH_4, PM_{25} – PM_{50} and heavy metals except the control. Air pollution tolerance index is associated with the ability to exhibit physiological symptoms arising from pollution in plants (Lohe *et al*., 2015). The response of plants to air pollution at biochemical level can be understood by evaluating APTI. Air pollution tolerance index uses four (pH, water content, ascorbic acid and chlorophyll) plants biochemical parameters that provides reliable information for screening plant species for susceptibility to air pollution (Escobedo *et al*., 2008). Plant species with higher APTI are more tolerant to air pollution relative to those with low APTI value. This may however act as bio-indicator of air pollution. Review of related literature show non-existence of APTI of plant species in the study area. Therefore, the objective of this study is to evaluate the physiological responses of some plant as bio-indicator of air pollution stress using APTI approach.

Materials and Method

Study area and sampling

The study area is situated in Delta State. Delta State is located in the Niger Delta flood plain in the coast of Nigeria. The study area climate and weather conditions include high temperature and humidity, and abundant rain forest (Emoyan, 2018). The study site are: Control (Emu-Uno), Eastern Metal Ltd (Asaba-Benin Road), Platform oil (Ebede-Umutu) and Agbor- Eku road side. *Manihot esculenta, Chromolaena odorata, Musa paradisiaca, Elias guinea, Helianthus, Psidium guajava, Imperata cylindrica, Mangifera indica, Sida acuta* and *Centrosena pubescens* are ten plant species used. Leaves from top, middle and bottom plant canopy were used. Samples were collected within a distance of 1km of sample sites. Collected samples were put in polyethylene bags, coded and immediately transferred to the laboratory for analysis.

Biochemical analysis

To compute the APTI, the following biochemical parameters were analysed according to procedures adapted by Krishnaveni *et al.* (2013).

Relative water content (RWC)

The leaf samples were weighed to obtain the fresh weight (FW). The leaves were soaked in water for 24 h, blotted dry with Whartman filter paper and weighed to obtain the turgid weight (TW). The weighed leaves were dried in an oven (England, Mettler 501) at 70^{o}C for 48 h and reweighed to obtain the dry weight (DW). Relative water content was evaluated using the method described in Singh (2005).

Leaf extract pH (LEpH)

Ten grams of the fresh leaves was homogenised in 20 ml of deionised water. With the aid of Italy, Hanna pH meter, the pH of the leave extract was determined from the filtrate after allowing it to stabilize for 15 min and calibrated with buffer solution of pH 3 and 9.

Total chlorophyll content (TCC)

The TCC was obtained by weighing 1.0 g of leaf soaked in 20 ml of 50% acetone for 5 days 25 ml aliquote of leaf extract was added to 50 ml diethly ether in a separating funnel. Absorbance was taken at 645 nm on spectrophotometer USA, Spectrum Lab Model 21 with ether is a reference (Krishnaveni *et al*., 2013);

$$\text{TCC (mg/g)} = \frac{20.2\,(A_{645}) + 8.02\,(A_{663})\,x\,V}{a\,x\,100\,x\,w}$$

Where: a is the length of light path in cell (usually 1 cm); V is the volume of the extract made; w is the weight of sample

Ascorbic acid (AA)

The indophenol acetic acid method was used to analyse the AA value. Thus, 1 gram of leaf sample was crushed and made up to 50 ml using distilled water and 10 ml of acetic acid. A solution of 0.01% indophenal was made and then titrated with the sample (Lohe *et al.*, 2015).

APTI

The APTI was determined by following the method of Singh and Rao (1983), Agbaire and Esiefarienrhe (2009), Pravi and Madhumita (2013).

APTI is given as:

APTI= [A (T+P) + R]/10.

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

Quality control

To ensure viability of results, fresh leaf samples were immediately taken to the laboratory for analysis.

Data analysis

Primary data were subjected to descriptive (tables, mean, standard deviation, and (ANOVA) statistical tool using statistical program for social science (SPSS) 22.3.

Results and Discussion

In this study, leaf samples of the plant species were analysed for pH, relative water content, chlorophyll and ascorbic acid. All the biochemical indicators and APTI exhibited variations from specie to specie and site to site (Tables 1 – 4 and Figs. 1 – 6).

Variation in relative water content

Relative water content is the water present leaf relative to its whole turgidity. High water content within plant body helps to retain its physiological balance under air pollution stress condition and serves as indicator of drought resistance in plants (Raza *et al*., 1988; Pravi and Madhumita, 2013). Results of relative water content of plant species studied are shown in Table 1. Results of relative water content at the control range between 21.78-35.86% and 34.48-39.98%. M*anihot esculenta, Helianthus,* and *Imperata cylindrical* showed low relative water content while *Chromolaena odorata, Musa paradisiacal, Elias guinea, Psidium guajava, Mangifera indica, Sida acuta* and *Centrosena pubescens* showed high relative water content. For eastern metal works, the relative water content range from 38.58-50.58% to 74.27-84.17%. Results show that *Chromolaena odorata, Musa paradisiacal, Elias guinea,, Psidium guajava, Mangifera, Indica and Sida acuta* exhibit low relative water content, while *Manihot esculenta, Helianthus, Imperata cylindrical* and *Centrosena pubescens* show high relative water content. Also, the relative water content for Platform oil ranged from 34.19-37.65% to 72.56-77.27%. Results reveal that *Manihot esculenta, Helianthus, Imperata cylindrical and Centrosena pubescens* show high relative water content while *Chromolaena odorata, Musa paradisiacal, Elias guinea, Sodium guajava, Mangifera indica* and *Sida acuta* show relatively low relative water content. For the Agbor- Eku site, the relative water content range between 35.59-54.45% and 68.85-77.57%. Similarly results reveal that *Manihot esculenta, Elias guinea, Psidium guajava, Imperata cylindrical, Mangifera indica,* and *Centrosena pubescens* show high relative water content while, *Chromolaena odorata, Musa paradisiacal, Helianthus* and *Sida acuta* showed relatively low relative water content.

Table 1: Summary statistics of relative water content in the study area (%)

Sample station	Control		Eastern Metal		Platform Oil		Agbor-Eku Road	
	Range	Mean±SD	Range	Mean±SD	Range	Mean±SD	Range	Mean±SD
Manihot esculenta	23.60- 27.57	25.57±1.99	57.71 - 77.57	66.93±10.01	72.56-77.27	75.48±2.55	68.85-77.57	74.25±4.72
Chromolaena odorata	32.31- 35.81	34.62±2.00	42.38 -55.51	47.85±6.84	39.15-45.71	42.41±3.28	39.75-55.51	47.02±7.95
Musa paradisiaca	27.78- 38.65	33.35±5.44	43.67 - 48.55	46.60±2.58	37.77-39.62	38.71±0.93	37.27-48.55	42.53±5.68
Elias guinea	34.18- 41.87	38.34±3.88	44.68 -58.58	50.34±7.30	44.58-48.28	46.84±1.98	47.47-58.98	52.08±6.09
Helianthus	21.78- 35.86	30.10±7.38	62.26 - 75.36	69.11±6.57	65.85-72.26	69.28±3.28	37.65-75.36	60.98±20.38
Psidium guajava	33.56- 35.76	34.96±1.21	45.51 - 55.43	51.50±5.27	45.76-49.52	47.02±2.16	45.46-64.22	55.04±9.39
Imperata cylindrica	24.47- 25.55	24.96±0.55	64.67 -75.35	68.33±6.08	64.57-74.43	70.26±5.10	64.67-77.27	72.02±6.56
Mangifera indica	34.48- 39.98	37.74±2.89	38.56 -50.58	46.17±6.62	48.71-54.38	50.96±3.01	45.71-49.48	47.93±1.97
Sida acuta	32.15- 34.75	33.19±1.38	39.65 - 54.45	45.56±7.84	34.19-37.65	35.80±1.74	35.59-54.45	42.93±10.10
Centrosena pubescens	28.67- 41.17	34.65±6.27	74.27 - 84.17	80.03±5.14	59.16-68.63	64.00±4.74	68.28-84.87	73.83±9.56

Table 2: Summary statistics of leaf extract ph in the study area

Sample station	Control		Eastern Metal		Platform Oil		Agbor-Eku Road	
	Range	Mean±SD	Range	Mean±SD	Range	Mean±SD	Range	Mean±SD
Manihot esculenta	3.59- 4.13	3.81±0.28	2.22-3.51	2.72±0.69	2.12-2.33	2.19±0.12	1.53-3.73	2.52±1.12
Chromolaena odorata	3.54±4.72	3.96±0.66	2.54-3.22	2.79±0.37	2.54-3.22	2.83±0.35	1.22-2.72	2.19±0.84
Musa paradisiacal	2.14- 3.72	2.99±0.80	1.15-3.52	2.59±1.27	2.10-3.11	2.54±0.52	2.11-3.29	2.53±0.66
Elias guinea	2.12- 4.63	3.41±1.26	2.53-2.92	2.68±0.21	2.53-2.72	2.63±0.10	2.19-2.63	2.45±0.23
Helianthus	3.29- 4.23	3.76±0.47	2.12-3.21.	2.75±0.57	2.13-2.53	2.29±0.21	1.43-3.93	2.52±1.28
Psidium guajava	2.14- 3.72	2.99±0.80	1.15-3.52	2.59±1.27	2.10-3.11	2.54±0.52	2.11-3.19	2.50±0.60
Imperata cylindrical	3.54- 4.72	3.96±0.66	2.54-3.22	2.79±0.37	2.72-3.22	2.83±0.35	1.22-2.72	2.19±0.84
Mangifera indica	2.12- 3.67	2.97±0.78	1.25-3.12	2.50±1.08	2.17-3.12	2.67±0.48	2.17-3.29	2.75±0.56
Sida acuta	3.12- 4.13	3.60±0.51	2.12-3.81	2.75±0.92	2.42-2.93	2.69±0.26	1.73-3.13	2.42±0.70
Centrosena pubescens	3.54- 4.72	3.96±0.66	2.14-3.22	2.66±0.54	2.54-3.22	2.83±0.35	1.22-2.72	2.19±0.84

Table 3: Summary statistics of total chlorophyll in the study area (mg/g)

Sample station	Control		Eastern Metal		Platform Oil		Agbor-Eku Road	
	Range	Mean±SD	Range	Mean±SD	Range	Mean±SD	Range	Mean±SD
Manihot esculenta	35.54- 43.60	38.90±4.19	19.52-27.57	23.60±4.03	22.56-23.71	23.28±0.63	23.17-23.71	23.53±0.31
Chromolaena odorata	31.81- 35.75	34.29±2.16	12.38-18.65	15.51±3.14	15.37-19.51	17.84±2.18	15.21-18.65	17.50±1.99
Musa paradisiacal	34.65- 43.61	38.68±4.55	23.67- 28.55	26.60±2.58	22.55-30.62	26.92±4.08	27.58-28.25	27.80±0.39
Elias guinea	38.18- 41.87	39.41±2.13	18.77-38.18	22.68±5.20	17.58-18.77	18.31±0.64	18.77-38.38	25.31±11.32
Helianthus	38.66- 41.78	40.10±1.57	22.26-25.36	23.78±1.55	23.26-23.72	23.45±0.24	23.72-25.16	24.20±0.83
Psidium guajava	35.55- 38.56	36.62±1.68	15.43-24.52	21.15±4.98	21.43-24.51	22.82±1.56	15.34-25.51	21.79±5.61
Imperata cylindrical	34.47- 45.55	38.30±6.28	22.35-24.67	23.90±1.38	22.35-24.57	23.20±1.20	22.35-24.27	22.99±1.11
Mangifera indica	34.98- 39.48	37.74±2.42	19.38-22.56	20.51±1.78	21.38-24.38	22.77±1.51	19.31-22.56	21.48±1.88
Sida acuta	37.75- 38.67	38.19±0.46	19.65-24.45	22.22±2.42	22.57-24.45	23.74±1.02	22.57-24.42	23.19±1.07
Centrosena pubescens	28.67- 41.17	35.65±6.38	21.64-25.27	23.69±1.86	19.16-23.17	21.32±2.02	21.64-24.11	22.46±1.43

Table 4: Summary statistics of ascobic acid in the study area (mg/g)

Sample station	Control		Eastern Metal		Platform Oil		Agbor-Eku Road	
	Range	Mean±SD	Range	Mean±SD	Range	Mean±SD	Range	Mean±SD
Manihot esculenta	19.54- 21.60	12.23±0.55	13.71-15.52	14.60±0.91	16.62-22.56	18.82±3.26	11.37-18.85	15.51±3.80
Chromolaena odorata	21.81- 22.75	13.29±0.47	17.65-19.38	18.52±0.87	15.71-19.15	17.74±1.80	15.51-19.75	17.02±2.37
Musa paradisiacal	22.78- 24.65	13.35±0.49	18.58-23.67	21.60±2.67	21.62-22.75	22.01±0.64	21.77-23.55	22.86±0.96
Elias guinea	22.18- 23.98	12.34±1.01	19.58-21.83	21.03±1.26	19.28-21.58	20.50±1.16	18.47-21.98	20.74±1.97
Helianthus	22.66- 25.86	13.10±0.60	18.26-21.36	19.78±1.55	15.85-19.72	17.61±1.96	18.36-20.65	19.64±1.17
Psidium guajava	23.56- 25.76	13.29±0.46	16.55-20.43	18.83±2.03	16.76-19.52	17.69±1.58	15.45-17.22	16.04±1.02
Imperata cylindrical	24.57- 25.58	12.67±0.17	14.47-15.35	14.80±0.48	16.73-19.43	17.94±1.37	16.67-18.13	17.36±0.73
Mangifera indica	24.48- 26.98	12.74±0.25	17.58-20.38	18.84±1.42	18.38-19.78	18.96±0.73	18.61-19.71	19.27±0.58
Sida acuta	22.15- 24.75	12.19±0.54	18.45-19.65	18.22±1.55	17.65-19.19	18.47±0.77	18.45-19.59	18.93±0.59
Centrosena pubescens	21.17- 23.67	11.65±0.88	14.17-15.64	14.69±0.82	16.22-19.16	18.00±1.57	17.33-18.87	18.16±0.78

From the results, the relative water content in the leaf of experimental samples collected in eastern metal works, platform oil and Agbor-Eku road side with respect to the control samples (Fig. 1) increased by 61.8, 66.1 and 65.6% for *Manihot esculenta*; by 27.6, 18.4 and 26.4% for *Chromolaena odorata*; by 28.4, 13.8 and 21.6% for *Musa paradisiaca*; by 23.8, 18.1 and 26.4% for *Elias guinea*; by 56.4, 56.6 and 50.6% for *Helianthus*; by 32.1, 25.6 and 36.5% for *Psidium guajava;* by 63.5, 64.5 and 65.3% for *Imperata cylindrica*; 18.3, 25.9 and 21.3% for *Mangifera indica*; by 27.2, 7.3 and 22.7% for *Sida acuta* and by 56.7, 45.9 and 53.1% for *Centrosena pubescens*. Relative water content is a plant's biochemical characteristic that is associated with cells protoplasmic permeability. It causes loss of dissolved nutrients and water, resulting in senescence of leaves (Agrawal and Tiwari, 1997). Therefore, in air polluted environment, plants with high relative water content could exhibit tolerance to pollutants. In this study, the relative water content was found to be relatively high in other sites compared to the control. This could be associated to plant physiological response to air pollution stress in the study area. Similar results between control and experimental samples were reported by Krishnaveni *et al.* (2013), Pravin and Madhumita (2013).

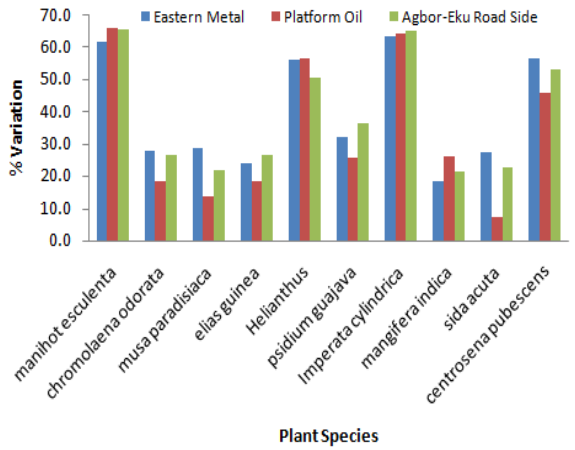

Fig. 1: Relative water content variability in experimental samples (%)

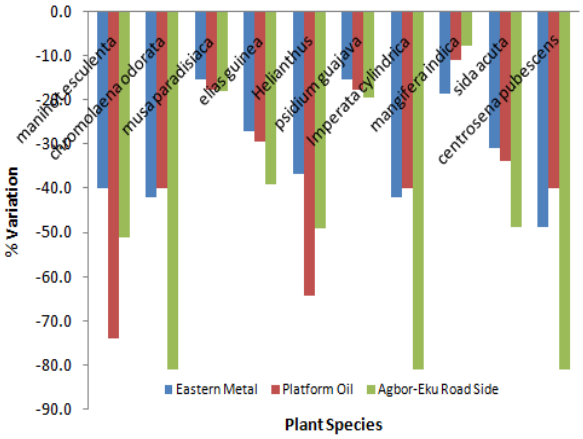

Fig. 2: Leaf extract pH variability in experimental samples

Variation in leaf extract pH

In this study, the pH in the control was found to range from 2.12-3.67 to 3.59-4. At eastern metal works, the pH ranges from 1.15-3.52 to 2.54-3.22. For platform oil, the pH ranged between 2.10-3.11 and 2.72-3.22. In the Agbor- Eku road site, the pH ranges from 1.22-2.72 to 2.19-2.63. The pH was found to be relatively acidic in the experimental samples when compared to the control samples. The results of this investigation indicate that leaf extract pH of experimental samples in eastern metal works, platform oil and Agbor-Eku road side with respect to the control samples (Fig. 2) decreased by 40.1, 74.0 and 51.2% for *Manihot esculenta*; by 41.9, 39.9 and 80.8% for *Chromolaena odorata*; by 15.4, 17.7 and 18.2 % for *Musa paradisiaca*; by 27.2, 29.7 and 39.2% for *Elias guinea*; by 36.7, 64.2 and 47.2% for *Helianthus*; by 15.4, 17.7 and 19.6% for *Psidium guajava*,; by 41.9%, 39.9% and 80.8% for *Imperata cylindrica*; 18.8, 11.2 and 8.0% for *Mangifera indica*; by 30.9, 33.8 and 48.8% for *Sida acuta* and by 48.9, 39.9 and 80.8% for *Centrosena pubescens*. The results showed that the leaf extract pH of experimental samples in eastern metal works, platform oil and Agbor-Eku road side with respect to the control samples (Fig. 2) decreased towards acidic pH in all plant species in the order: Agbor-Eku > Platform oil >eastern metal (Fig. 2). This could

be related to the emission of acidic vapour forming air pollutants such as, NOx, SOx CO_2 along with suspended particulate matter (Bhavika *et al.*, 2017). High pH increased the conversion efficiency from hexose to ascorbic acid (Escobedo *et. al.* 2008). Results from this study shows that plant species could experience photosynthetic deficiency since photosynthetic efficiency is strongly pH dependent at leaf acidic pH, photosynthesis in plant is reduced (Yan-Ju and Hui, 2008). Similar findings were reported in Krishnaveni *et al.* (2013).

Variation in chlorophyll content

Degradation of photosynthetic pigment has been widely used as bio-indicator of air pollution, (Ninave *et al.*, 2001). Results of chlorophyll content of plants studied are presented in Table 3. The chlorophyll content of leaf extract in the control range between 28.67-41.17 and 38.66-41.78 mg/g. *Chromolaena odorata* and *Centrosena pubescens* show low chlorophyll content while *Manihot esculenta, Musa paradisiacal, Elias guinea, Helianthus, Psidium guajava, Imperata cylindrical, Mangifera indica* and *Sida acuta* show high chloropyhll content. For eastern metal works, the chlorophyll content range from 12.38-18.65 to 23.67-28.55 mg/g. Results show that *Manihot esculenta, Musa paradisiacal, Elias guinea, Helianthus, Imperata cylindrical, Mangifera indica, Sida acuta* and *Centrosena pubescens* exhibit high chlorophyll content, while *Chromolaena odorata* and *Psidium guajava* show low total chlorophyll content. Also, the chlorophyll content for Platform oil range from 15.37-19.51 to 23.26-23.72 mg/g. Results reveal that *Chromolaena odorata, Musa paradisiacal* and *Elias guinea* show low total chlorophyll content while *Manihot esculenta, Musa paradisiacal, Helianthus, Psidium guajava, Imperata cylindrical, Mangifera indica, Sida acuta* and *Centrosena pubescens* exhibited relatively high chlorophyll content. For the Agbor-Eku road side, chlorophyll content range between 15.21-18.5 and 27.58-28.25 mg/g. Similarly results reveal that *Manihot esculenta, Musa paradisiacal, Elias guinea, Helianthus, Imperata cylindrical, Mangifera indica, Sida acuta* and *Centrosena pubescens* showed high chlorophyll content while, *Chromolaena odorata*, and *Psidium guajava* show low total chlorophyll content. Results of this investigation indicate that the chlorophyll content of the experimental samples collected in eastern metal works, platform oil and Agbor-Eku road side with respect to the control samples (Fig. 3) decreased by 64.8, 67.1 and 65.3% for *Manihot esculenta*; by 121.1, 92.2 and 95.9% for *Chromolaena odorata*; by 45.4, 43.7 and 39.1% for *Musa paradisiaca*; by 73.8, 115 and 55.7% for *Elias guinea*; by 68.6, 71.0 and 65.7% for *Helianthus*; by 73.1, 60.5 and 68.1% for *Psidium guajava*,; by 60.3, 65.1 and 66.6% for *Imperata cylindrica*; 84.0, 65.7 and 75.7% for *Mangifera indica*; by 71.9, 60.9 and 64.7% for *Sida acuta* and by 50.5, 67.2 and 58.7% for *Centrosena pubescens*. Chlorophyll is plant characteristics that measure the growth and development of biomass, and photosynthetic activity. It varies from one plant species to another. The age of the leaf, level of pollution, abiotic and biotic factors also determine the chlorophil content of the plant leaves, (Katiyar and Dubey, 2001). Chlorophyll varies with the tolerance and sensitivity of the plant: lower plant sensitivity translates to a higher chlorophyll content. In previous studies, Krishnaveni *et al*. (2013), Mir *et al*. (2008), Tripathi and Gautam (2007) discussed that chlorophyll content is relatively high in the control compared to other sites. The decreased chlorophyll content in this study could be ascribed to response to higher pollution levels in the form of vehicular exhausts fumes. Lower chlorophyll content also suggests that high concentrations of automobile and related pollutants decreases chlorophyll content in plants near roadsides.

Variation in ascorbic acid

Ascorbic acid is an important reducing agent. It plays an important role in cell wall synthesis and cell division in plants (Conklin, 2001). The ascorbic acid content of plants studied is presented in Table 4. The ascorbic acid content at the control range between 19.54-21.60 and 24.57-25.58 mg/g. Results in this site show that *Chromolaena odorata, Musa paradisiaca, Elias guinea, Helianthus, Psidium guajava, Imperata cylindrical, Mangifera indica, Sida acuta* and *Centrosena pubescens* exhibits high ascorbic acid content except *Manihot esculenta* that show low ascorbic acid content. In the eastern metal works, the ascorbic acid content range between 13.71-15.52 and 19.58-21.83 mg/g. Results show that *Manihot esculenta, Imperata cylindrical*, and *Centrosena pubescens* exhibit low ascorbic acid content, while *Chromolaena odorata, Musa paradisiaca, Elias guinea, Helianthus, Psidium guajava, Mangifera indica* and *Sida acuta* show high ascorbic acid content. Also, the ascorbic acid content in Platform oil site ranged from 15.71-19.15 to 21.62-22.75 mg/g. Results reveal that *Manihot esculenta, Chromolaena odorata, Elias guinea, Helianthus, Psidium guajava, Imperata cylindrica, Mangifera indica, Sida acuta* and *Centrosena pubescens* show low ascorbic acid content except *Musa paradisiaca* that show relatively high ascorbic acid content. For the Agbor- Eku road side, the ascorbic acid content ranged between 21.37-18.85 and 21.77-23.55 mg/g. Similarly results reveal that *Manihot esculenta, Chromolaena odorata, Elias guinea, Helianthus, Psidium guajava, Imperata cylindrica, Mangifera indica, Sida acuta* and *Centrosena pubescens* show low ascorbic acid content except *Musa paradisiaca* that show relatively high ascorbic acid content. The ascorbic acid content is relatively high in the control compared to other sites. Results from the present study reveal that the ascorbic acid content in the experimental samples in eastern metal works, platform oil and Agbor-Eku road side with respect to the control samples (Fig. 4) increased by 16.2, 35.0 and 21.1% for *Manihot esculenta*; by 28.2, 25.1 and 21.9% for *Chromolaena odorata*; by 38.2, 39.3 and 41.6% for *Musa paradisiaca*; by 41.3, 39.8 and 40.5% for *Elias guinea*; by 33.8, 25.6 and 33.3% for *Helianthus*; by 29.4, 24.9 and 17.1% for *Psidium guajava*,; by 14.4, 29.4 and 27% for *Imperata cylindrica*; 32.4%, 32.8% and 33.9% for *Mangifera indica*; by 33.1, 34 and 35.6% for *Sida acuta* and by 20.7, 35.3 and 35.8% for *Centrosena pubescens*. This study has shown high ascorbic acid content in all plant species; this may be related to increased rate of synthesis of reactive oxygen species during photo-oxidation of SO_2 to SO_3. Research has also shown that high ascorbic acid in plants is a measure of its tolerance against SO_2 pollution stress (Varshney and Varsney, 1984).

Air pollution tolerance index

The APTI of the studied plant species in the control, eastern metal works, platform oil, and Agbor-Eku road side are presented in Fig. 1. The APTI for *Manihot esculenta* ranges between 47.83 and 55.48. The APTI value for *Chromolaena odorata* range from 38.21 to 54.30; also, the APTI for *Musa paradisiaca* ranges between 58.95 and 73.59. The APTI for *Elias guinea* ranged between 47.61 and 62.78. Similarly, the APTI for *Helianthus* range from 52.26 to 60.47. The APTI for *Psidium guajava* range from 44.47 to 56.14, similarly, the APTI for *Imperata cylindrica* range from 46.33 to 56.05. The APTI for *Mangifera indica*, range between 47.97 and 55.64. Also, the APTI values for *Sida acuta* range between 50.05 and 54.26, similarly the APTI for *Centrosena pubescens* range from 46.71 to 52.15. Results from the present study shows APTI in the experimental samples with respect to the control samples (Fig. 6) increased by 1.2% for *Manihot esculenta in platform oil*; by 12.9, 14.2 and 19.9% for *Musa paradisiacal* in all experimental sits; by 2.9 and 9.7% for *Elias guinea* in

eastern metal and Agbor-Eku road side, respectively; and by 0.5 and 4.9% for *Centrosena pubescens* in platform oil, respectively. However, results from the present study show APTI in the experimental samples with respect to the control samples (Fig. 6) decreased by 21.4% and 14.6% for *Manihot esculenta* in eastern metal and Agbor-Eku road side respectively; by 40.4, 32.7 and 42.1% for *Chromolaena odorata* in all sites; by 19.1% for *Elias guinea* in platform oil and by 6.2% in eastern metal works. Also, results from the present study show APTI in the experimental samples with respect to the control samples (Fig. 6) decreased by 1.8, 15.7 and 3.2% for *Helianthus*; by 12.6, 13.3 and 26.2% for *Psidium guajava;* by 21, 4.3 and 10.1% for *Imperata cylindrica*; by 16, 4.3 and 8.1% for *Mangifera indica and* by 8.4, 3.5 and 2.8% for *Sida acuta* in all sites.

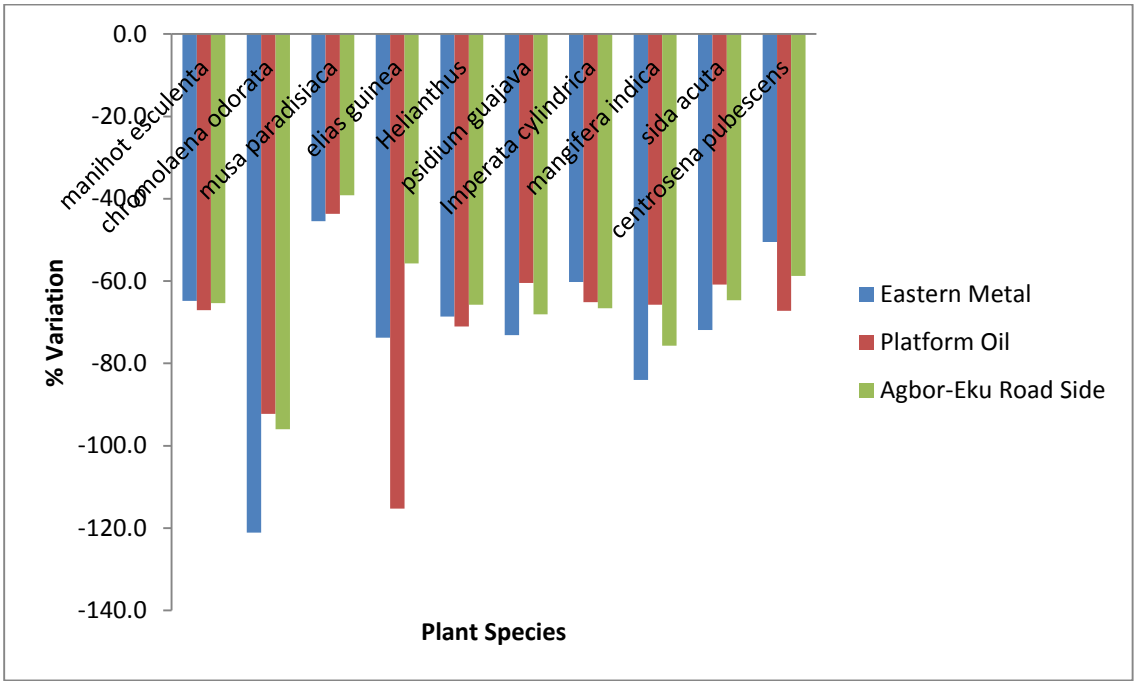

Fig. 3: Total chlorophyll variability in experimental samples

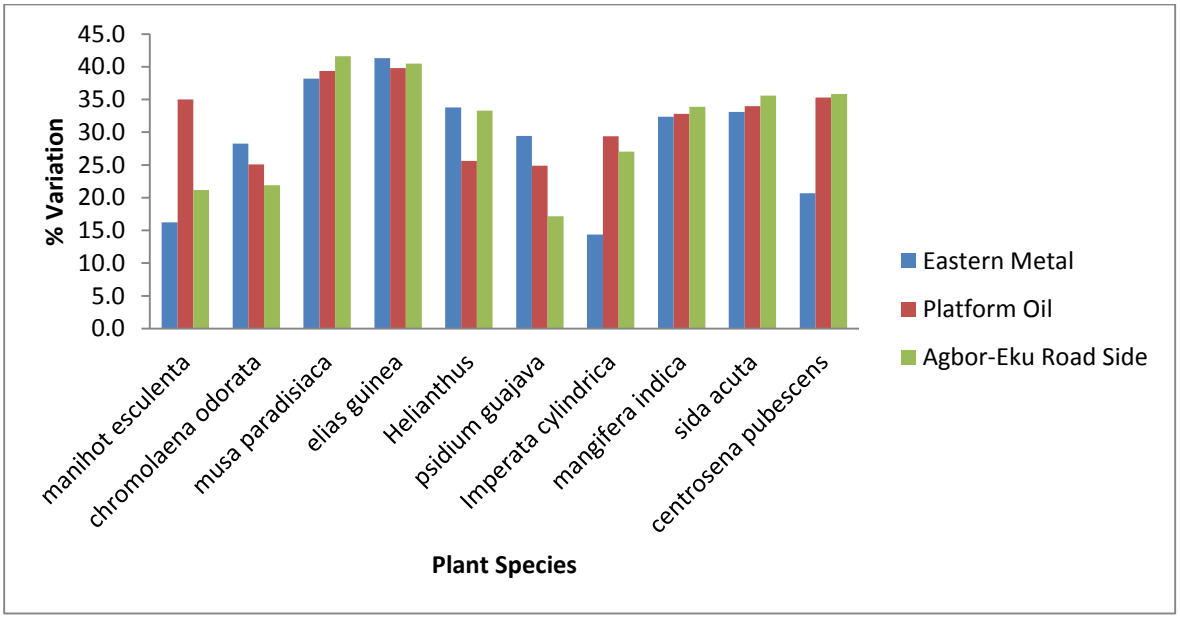

Fig. 4: Ascorbic acid variability in experimental samples

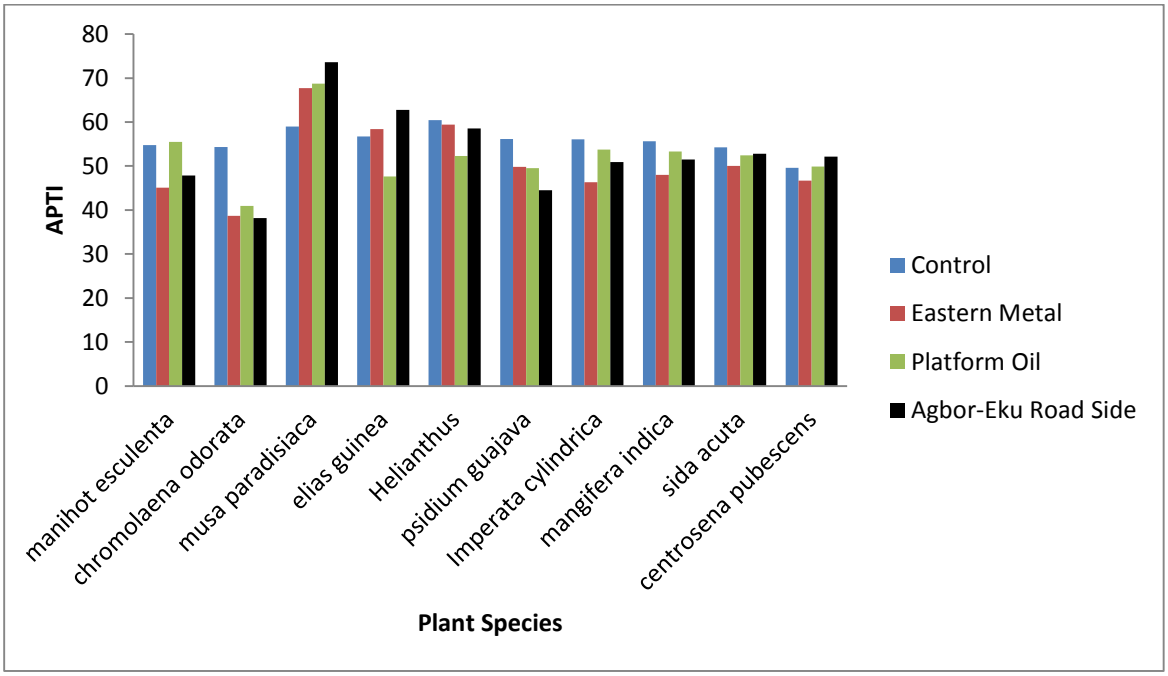

Fig. 5: Variability of APTI of selected plant species in experimental and control samples in the study area

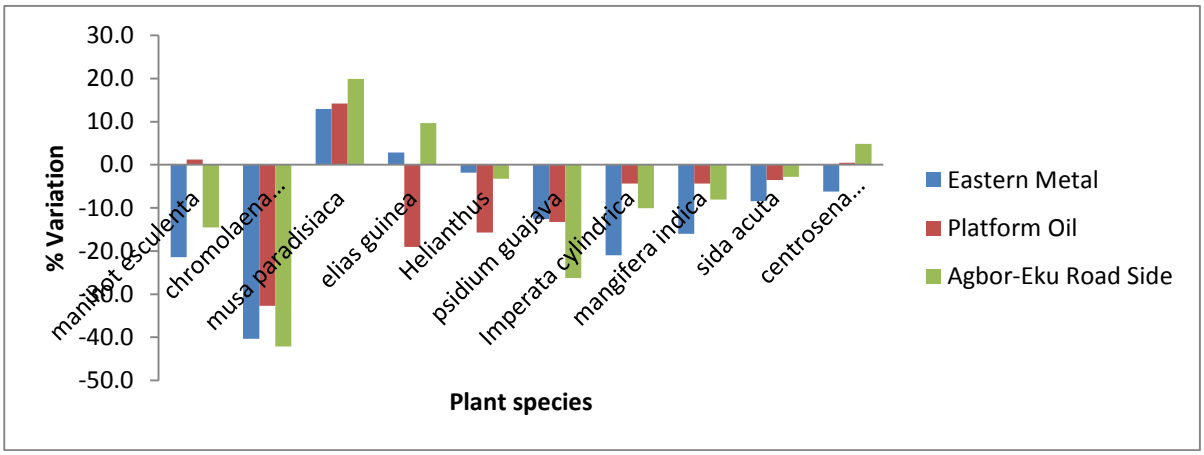

Fig. 6: APTI Variability in experimental samples

Generally, results show that APTI are relatively in the order control > Agbor-Eku road side > Platform oil > eastern metal works in plant species studied. Results show that there is significant difference ($P < 0.05$) between APTI variables in the sites studied. Observed APTI in this study revealed that eastern metal works and platform oil field contribute more to the air pollution load of the study area. Similarly, air pollutants from these sites could have affected the biochemical composition of the studied plant species hence the low APTI. In this study all 10 plant species show APTI ranging between 38.21 and 73.59. The obtained APTI in all plant species were found to be tolerant as they have APTI between 38.21 and 73.59. Similar APTI value for different plant species was reported in Lohe *et al.* (2015). The APTI variation in this study could be attributed to the changes in any of the four biochemical factors which govern the computation of the index (Pravi and Madhumita, 2013). The low in APTI of plant species in platform oil and eastern metal works reveal the extent of air pollutants and effects of environmental pollution on biochemical components of plant species in these sites. In this study, the biochemical parameters were found to be highly affected. The variability level of plant biochemical parameters in the selected sites can be viewed as a response and adaptation to environmental condition to protect plants against air pollutants. Dust collecting capacity may be responsible for plant species studied to become highly susceptible to pollutants, causing increase or reduction in biochemical variables (Singh, 2005). Furthermore, variability of APTI in this study may be due to environmental conditions such as temperature and humidity. The APTI values from this study show that the plant species are pollution tolerant. However, the extent of air pollution effects on plant species is evident in platform oil and eastern metal works relative to other sites. Mitigating the pollution potential associated with the anthropogenic activities in the study area is of priority in reducing and preventing the effects of pollution in the environment and human health within and around the study area.

Conclusion

As a measure of air pollution in the study area, relative water content, pH, chlorophyll and ascorbic acid were used to determine APTI of selected plant species. This study has shown that different plant species respond in diverse ways to air pollution and the same plant species may respond differently in different environments depending on the extent of pollution in the environmental factors. This study has established that the plant species are pollution tolerant.

However, the extent of air pollution and contamination effects on the plant species is higher in platform oil and eastern metal works compared to other sites. This study has further revealed that dust collecting capacity and natural climate conditions such as humidity and temperature could be responsible for observed variability of biochemical parameters. The study has shown that the plant species could be applied as air pollution control measure.

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Conflict of Interest
Author declares that there is no conflict of interest reported on this work.

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