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Assessment of Foliar Parameters and Air Pollution Tolerance of Broad Leaved Trees in Ugwuele Quarry Site, Uturu, Nigeria

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Abstract This present study assessed oxidative stress and air pollution tolerance of selected broad leaved trees in the vicinity of a quarry site at Ugwuele, Uturu by assessing some physiological and biochemical properties of their leaves. Three trees *Alchornea cordifolia*, *Nauclea latifolia* and *Newbouldia laevis* growing in the quarry site were randomly selected for this study. The result of quantitative analysis of foliar parameters shows that the epidermal cells of *A. cordifolia* and *N. laevis* were completely deformed and the guard cells became plasmolysed. The pore length, width and area had higher values at control samples and were significantly different ($P<0.05$) when compared with those from the study area. Significant differences ($P<0.05$) were observed in pH and total chlorophyll content of the evaluated plants. *N. laevis* had the highest air pollution tolerance index of 22.34, thus making *N. laevis* the most tolerant to air pollution among the studied plants. Based on the findings of this study, *N. laevis* tree is recommended for bio-mitigation of air pollution from the quarry environment.

Keywords: *quarry site, broad leaved trees, foliar parameters, air pollution tolerance, Newboudia laevis*

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1. Introduction

Quarrying is a key extractive industry segment employing large number of skilled and unskilled workers. [1] The economic benefits of this industry also come with an environmental cost mainly due to dust pollution. Suspended particulate generated in quarrying operations have been implicated as sources of environmental and health problems particularly in the vicinity of quarries. [2,3] Suspended particulate matter from quarry sites is a major source of air pollution, the severity of which depends on local climate, particle load in the ambient air and the size and chemistry of the dust particles are all important determinants of the level of particulate pollution. [4] Vegetation in and around quarry sites suffer from air pollution stress largely due to ambient particulate load which causes physiological and biochemical damage in plants. [5] Since plants are immobile, they are continually exposed to and are therefore important sinks and monitors of air pollutants. [6,7,8] Higher plants such as trees and shrubs are most affected by particulate pollution given their larger canopy of surface area for trapping pollutants. [9].

Vegetation in quarry environments have been reported to manifest wide ranging damage and changes in their physiological and biochemical constitution. Many physiological alteration and biochemical changes are observed in plants in the vicinity of stressed environments. These include distorted foliar structure and abrasion of leaves and cuticle. [1,10,11], necrosis and stunted growth, inhibition of photosynthetic activity, stomata clogging and leaf fall [12], as well as oxidative stress. [13,14] Given the various roles plants play in the ecosystems and ethnobotanical significance it is necessary to understand how they respond to or are affected by pollution.

Among vegetation types, trees and woodland appear to be most impacted by air pollutants. [9] Broad leaved trees are also reported to capture higher amount of particulate matter [7], although many of them are deciduous. In the study area, studies have been carried out on the effects of quarrying on vegetation. [3,15,16] Broad leaved trees that usually have higher biomass and canopy have so far not been assessed for their tolerance to air pollution from the quarry environment.

The aim of this study was to assess the response of broad leaved trees to air pollution from quarrying activities at Ugwuele by examining the foliar microstructure, and evaluating air pollution tolerance of selected trees.

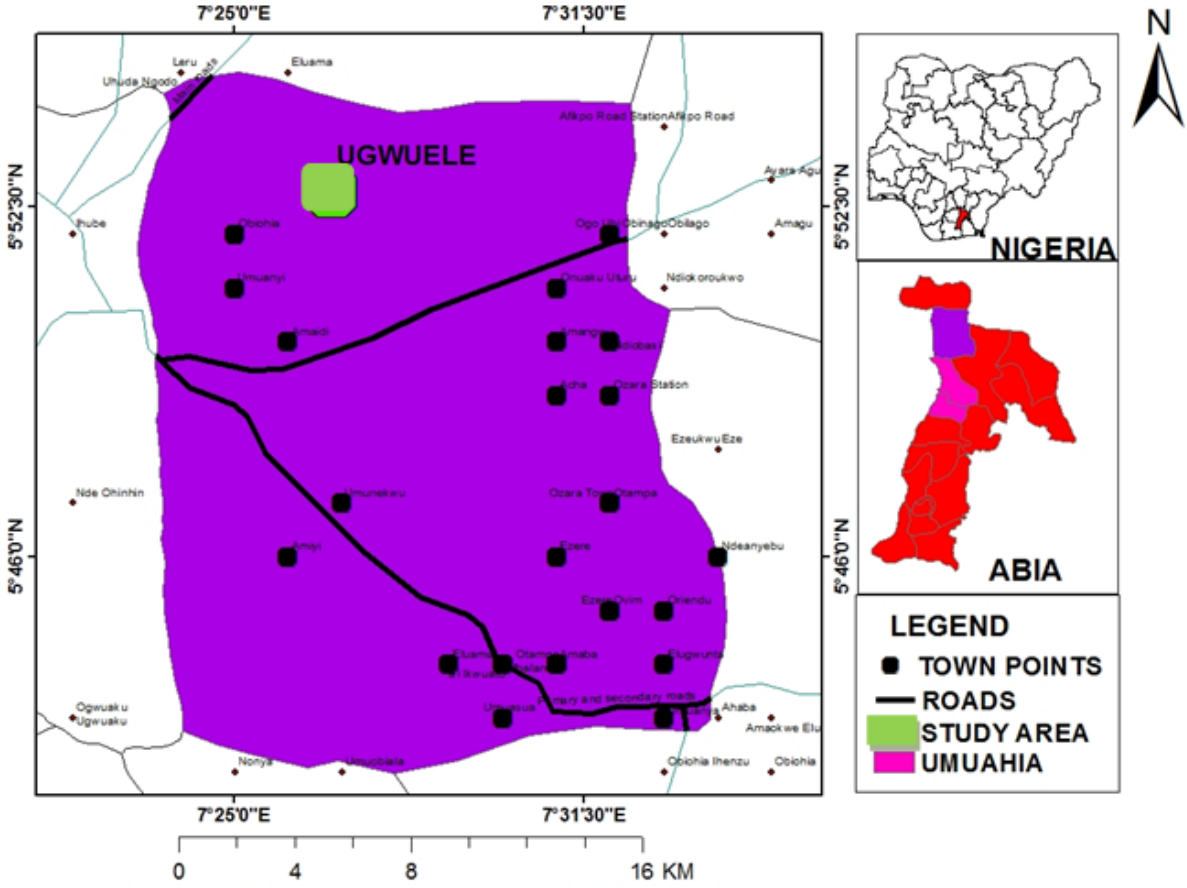

Figure 1. Map showing study area [16]

2. Methodology

2.1. Study Area

Ugwuele is located between latitude $5^{0}35$'N and $5^{0}55$'N and longitudes $7^{0}22$'E and $7^{0}30$'E. The relief is mainly undulating with elevation ranging from 100 meters to about 224metres. Soil type is false bedded sand stones (Ajali formation) of the Mastrichitan geologic era with igneous rock outcrops where rock quarrying takes place. The study area is situated in the humid tropics with annual rainfall between 1500mm and 2000mm with mean relative humidity and temperature of over 70% and 27°C respectively. [4] The vegetation of the study is the derived savanna type as a result of intensified human activities including solid mineral mining. This has been carried out in the study area for over thirty years with the associated environmental and health effects.

2.2. Plant Selection and Sample Collection

The study population consisted of all identified broad leave trees growing within the quarry site. Out of the ten identified, *Alchornea cordifolia*, *Nauclea latifolia* and *Newbouldia laevis* were randomly selected, using sampling without replacement. Control samples were collected 6 kilometers from the study site in Achara community, Uturu from trees of equal girth with those of the study area. Leaf samples were taken from the lowest branch of each selected tree facing the pollution source. Freshly collected samples were labelled, and placed in sealed poly packs and immediately sent to the laboratory for analysis.

2.3. Micromorphological Study of the Foliar Epidermis

Foliar epidermis of the adaxial (upper surface) and abaxial (lower surface) surfaces of the leaves were prepared by clearing method. The leaf samples were cleared by soaking in petri dishes containing commercial bleach (3.5% sodium hypochlorite) for 18 hrs. Then, the epidermal strips of the leaf samples were scrapped gently with the aid of forceps and placed on a clean slide, stained with Safranin and covered with a cover slip. The slides were viewed under light Olympus Tokyo (Japan No.271961) microscope at X400 magnification and photomicrographs were taken with Motic Camera 2.0.

The following parameters were observed and assessed:

1. Epidermal cells: the type of epidermal cells were observed and recorded.
2. Stomata type: the stomatal complex types were observed and recorded following the terminologies of Evert. [17]
3. Stomata size (length and width): the stomata length and width were measured using Motic microscope software in four replicates for each sample.
4. Stomatal density: the stomatal density was determined as the number of stomata per square millimetre.

Trichome parameters: trichomes were observed following the same procedures as the stomata above. [18]

2.4. Determination of Biochemical Parameters of Leaf Extracts

2.4.1. Determination of Ascorbic Acid Content (AA)

This was determined according to Bajaj and Kaur [19] method, using spectrophotometer. One gram of the leaf sample was treated with 4ml of oxalic acid – EDTA extracting solution in a test tube. Then 1 ml of orthophosphoric acid was added followed by 1 ml of 5% H_2SO_4 and 2 ml of ammonium molybdate, and then 3 ml of water. The solution was allowed to stand for 15 minutes after which the absorbance at 760 nm was measured. The concentration of ascorbic acid was extrapolated from a standard ascorbic acid curve.

2.4.2. Determination of Chlorophyll Content (TCH)

This was determined using the method of Arnon [20]. Exactly 3g of the leaf sample was blended and then extracted with 10 ml of 80% acetone, left for 15 minutes and the liquid portion decanted and centrifuged at 2,500 rpm for 3 minutes. The supernatant was collected and its absorbance measured at 663 nm using spectrophotometer.

2.4.3. Determination of Leaf pH

Leaf pH was determined by "direct reading engineering method" (DREM) using a digital pH meter. The leaf extract was made by cold maceration of the leaf with de-ionised water, filtered through an ashless filter and the filtrate used for pH determination. The pH meter was precalibrated before it was used with buffer solution of pH 4 and 9. The pH electrode was carefully dipped into the filtrate in a 10ml beaker. The value displayed on the Crystal Liquid Panel (CLD) was taken as the true pH value. The exercise was done in triplicate and the average of the three readings was used.

2.4.4. Determination of Percentage Relative Water Content (RWC)

This was determined using the method described by Singh. [21] Fresh leaf sample was weighed and recorded as Fresh Mass (FM). It was floated in distilled water inside a closed petri dish at room temperature for 24 hours. At the end of the incubation period, the leaf sample was wiped dry gently with blotted paper and re weighed to obtain the Turgid Mass (TM). It was then placed in a pre- heated oven at 80°C for 48 hours. Thereafter the leaf was weighed to obtain the Dry Mass (DM). The relative water content was calculated using the formular:

$$Rwc = \frac{FM - DM}{TM - DM} \cdot 100$$

Where;
FM = Fresh mass
DM = Dry mass
TM = Turgid mass.

2.4.5. Determination of Air Pollution Tolerance Index (APTI)

APTI is given mathematically by the equation:

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

Where;
A= Ascorbic acid content in mg/g
T= Total chlorophyll content in mg/g
P= pH of leaf sample
R= Percentage Relative water content

On the basis of APTI values, selected plants are rated as follows;

APTI 30 - 100 is considered tolerant plant species.
APTI 17 - 29 is considered intermediate plant species.
APTI 1 – 16 is considered sensitive plant species.
APTI < 1 is considered very sensitive plant species. [22]

2.5. Statistical Analyses

Analysis of variance (ANOVA) was done using statistical package for social sciences (SPSS) version 20 to check for significance (at $p \leq 0.05$) among the three samples and Duncan multiple test range was used for mean separation. Students' Independent t-test was used to check for significance (at $p \leq 0.05$) between the samples obtained from the control and study area.

3. Results

3.1. Qualitative Leaf Study

The result of the qualitative leaf study of the three species used in this study is summarised in Table 1. Some differences were observed in the leaf morphology, as well as in leaf epidermal parameters.

Table 1. Qualitative leaf parameters of the samples

Parameter	*Alchornea cordifolia*	*Nauclea latifolia*	*Newbouldia laevis*
Leaf	The leaf is ovate with acuminate apex, cordate at the base and entire margin. Simple leaf.	The leaf is broadly elliptic with shortly acuminate apex, subcordate at the base and entire margin. Simple leaf.	The leaf is elliptic with acuminate apex, acute base and entire margin. Pinnately compound leaf.
Epidermal cell	Epidermal cells are irregularly shaped with wavy anticlinal cell walls on both surfaces	Epidermal cells are polygonal in shape with straight anticlinal cell walls on both surfaces	Epidermal cells are polygonal in shape with straight anticlinal cell walls on both surfaces
Stomata type	The leaf is Amphistomatic (stomata occur on both the upper and lower surfaces, but more abundant on the lower surface) with paracytic type of stomata	The leaf is Amphistomatic (stomata occur on both the upper and lower surfaces, but more abundant on the lower surface) with paracytic type of stomata	The leaf is hypostomatic (stomata only occur on the lower surface) with anomocytic type of stomata
Trichome type	Absent.	There is presence of multicellular covering trichomes. Glandular trichomes are absent.	Absent

3.2. Foliar Parameters

Analysis of variance (ANOVA) showed that at least one of the stomata parameters tested for the three plants was significantly different at $p \leq 0.05$ for the abaxial (lower) surface. Table 2 indicates that *Nauclea latifolia* had the highest values in all the parameters except for pore width while *Alchornea cordifolia* had the lowest values in all the stomatal parameters.

The adaxial (upper) surfaces of the leaves of *Newbouldia laevis* lacked stomata. T-test showed that significant differences existed in some stomatal parameters (number per field of view, density, length, width and area) between those of *Alchornea cordifolia* and *Nauclea latifolia. A. cordifolia* had significantly higher stomata number and stomata density while *N. latifolia* had significantly higher stomata length, stomata width and stomata area. There were no significant differences in pore length, pore width and pore area (Table 3).

Quantitative analysis of stomata patterns showed that samples from the study site had higher number of stomata per unit area than those from control site while samples from control site had higher values for stomata size and pore size (Table 4 and Table 6).

Quantitative studies showed that even though the samples from control sites had higher stomata density on the abaxial surface than those collected from the control site, every other parameter: stomata size and pore size were not significantly different. However, the samples from control site had larger stomata and pores than those from the study site on the adaxial surface suggesting pollution stress (Table 5).

Table 2. Qualitative stomata parameters of lower leaf surface of the samples (control)

Parameter	*Alchornea cordifolia*	*Nauclea latifolia*	*Newbouldia laevis*
Stomata number per field of view	16.75 ± 0.25^{c}	27.25 ± 0.42^{a}	19.50 ± 0.29^{b}
Stomata density (mm^{-2})	98.53 ± 1.47^{c}	160.30 ± 2.82^{a}	114.71 ± 1.70^{b}
Stomata length (µm)	20.39 ± 0.91^{b}	26.31 ± 1.16^{a}	22.42 ± 0.55^{b}
Stomata width (µm)	12.95 ± 0.48^{b}	17.40 ± 0.99^{a}	17.15 ± 0.95^{a}
Stomata area (μm^2)	263.90 ± 13.52^{c}	455.41 ± 20.42^{a}	385.39 ± 28.89^{b}
Pore length (µm)	12.17 ± 0.41^{c}	19.31 ± 0.71^{a}	14.26 ± 0.31^{b}
Pore width (µm)	4.50 ± 0.56^{b}	5.51 ± 0.40^{ab}	6.93 ± 0.63^{a}
Pore area (μm^2)	55.14 ± 7.75^{b}	106.93 ± 10.37^{a}	98.93 ± 9.29^{a}

Mean values with different letters as superscript across the row are significantly different at $p \leq 0.05$
Mean values with same letters as superscript along the column are not significantly different at $p \leq 0.05$.

Table 3. Qualitative stomata parameters of upper leaf surface of the samples

Parameter	*Alchornea cordifolia*	*Nauclea latifolia*	*Newbouldia laevis*
Stomata number per field of view	5.75 ± 0.25*	4.25 ± 0.25	-
Stomata density (mm^{-2})	33.82 ± 1.47*	25.00 ± 1.47	-
Stomata length (µm)	26.53 ± 1.36	37.16 ± 0.63*	-
Stomata width (µm)	16.83 ± 0.84	27.38 ± 1.76*	-
Stomata area (μm^2)	449.56 ± 43.98	1018.24 ± 70.66*	-
Pore length (µm)	14.42 ± 1.87	15.42 ± 1.12^{NS}	-
Pore width (µm)	4.55 ± 0.94	3.58 ± 0.38^{NS}	-
Pore area (μm^2)	66.69 ± 19.06	55.28 ± 6.79^{NS}	-

* = Significantly different at $p \leq 0.05$
^{NS} = Not significantly different at $p \leq 0.05$.

Table 4. Stomata parameters in *Alchornea cordifolia*

Parameter	Lower surface		Upper surface	
	Control	Study area	Control	Study area
Stomata number per field of view	16.75 ± 0.25	25.75 ± 0.25*	5.75 ± 0.25	7.75 ± 0.25*
Stomata density (mm^{-2})	98.53 ± 1.47	151.47 ± 1.47*	33.82 ± 1.47	45.57 ± 1.47*
Stomata length (µm)	20.39 ± 0.91^{NS}	18.93 ± 0.81	26.53 ± 1.36^{NS}	23.24 ± 0.41
Stomata width (µm)	12.95 ± 0.48*	11.05 ± 0.05	16.83 ± 0.84^{NS}	17.02 ± 0.13
Stomata area (μm^2)	263.90 ± 13.52*	209.14 ± 8.71	449.56 ± 43.98^{NS}	395.54 ± 7.31
Pore length (µm)	12.17 ± 0.41*	9.96 ± 0.07	14.42 ± 1.87^{NS}	12.59 ± 0.38
Pore width (µm)	4.50 ± 0.56*	2.92 ± 0.08	4.55 ± 0.94^{NS}	3.50 ± 0.17
Pore area (μm^2)	55.14 ± 7.75*	29.09 ± 0.71	66.69 ± 19.06^{NS}	44.18 ± 3.42

* = Significantly different at $p \leq 0.05$
^{NS} = Not significantly different at $p \leq 0.05$.

Table 5. Stomata parameters in *Nauclea latifolia*

Parameter	Lower surface		Upper surface	
	Control	Study area	Control	Study area
Stomata number per field of view	27.25 ± 0.42*	25.50 ± 0.29	4.25 ± 0.25 ^{NS}	4.75 ± 0.25
Stomata density (mm^{-2})	160.30 ± 2.82*	150.00 ± 1.70	25.00 ± 1.47 ^{NS}	27.94 ± 1.47
Stomata length (µm)	26.31 ± 1.16^{NS}	26.70 ± 2.17	37.16 ± 0.63 ^{NS}	33.70 ± 1.68
Stomata width (µm)	17.40 ± 0.99 ^{NS}	17.68 ± 0.48	27.38 ± 1.76*	18.07 ± 0.77
Stomata area (μm^2)	455.41 ± 20.42 ^{NS}	478.46 ± 50.54	1018.24 ± 70.66*	611.86 ± 55.43
Pore length (µm)	19.31 ± 0.71*	15.66 ± 11.26	15.42 ± 1.12 ^{NS}	12.06 ± 1.28
Pore width (µm)	5.51 ± 0.40 ^{NS}	4.04 ± 0.71	3.58 ± 0.38 ^{NS}	2.59 ± 0.38
Pore area (μm^2)	106.93 ± 10.37 ^{NS}	65.45 ± 16.20	55.28 ± 6.79*	31.68 ± 6.19

* = Significantly different at $p \leq 0.05$
^{NS} = Not significantly different at $p \leq 0.05$.

Table 6. Stomata parameters in *Newbouldia laevis*

Parameter	Lower surface		Upper surface	
	Control	Study area	Control	Study area
Stomata number per field of view	19.50 ± 0.29	21.25 ± 0.25*	-	-
Stomata density (mm^{-2})	114.71 ± 1.70	125.00 ± 1.47*	-	-
Stomata length (µm)	22.42 ± 0.55^{NS}	21.37 ± 0.78	-	-
Stomata width (µm)	17.15 ± 0.95*	11.67 ± 0.21	-	-
Stomata area (μm^2)	385.39 ± 28.89*	249.13 ± 8.82	-	-
Pore length (µm)	14.26 ± 0.31^{NS}	15.10 ± 1.02	-	-
Pore width (µm)	6.93 ± 0.63*	4.37 ± 0.21	-	-
Pore area (μm^2)	98.93 ± 9.29*	65.76 ± 4.19	-	-

* = Significantly different at $p \leq 0.05$
^{NS} = Not significantly different at $p \leq 0.05$.

3.3. Foliar Micrograph Analysis

Examination of the foliar micrographs of the three plants indicated that those at the study site showed signs of damage and alterations as a result of environmental stress. The most significant changes observed were distorted epidermal cell, plasmolysed guard cells, and reduction in stomatal sizes (Plate 1, Plate 2, Plate 3, Plate 5 and Plate 6).

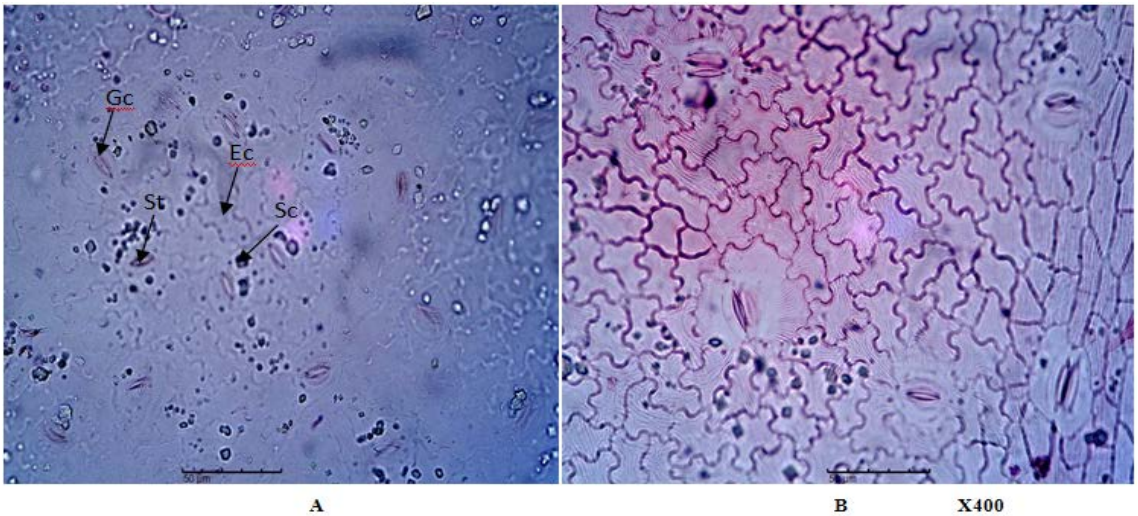

Plate 1. Leaf epidermis of *Alchornea cordifolia* for control site: A = abaxial surface; B = adaxial surface, Gc = guard cell; Ec = epidermal cell; St = stomatal pore; Sc = subsidiary cell

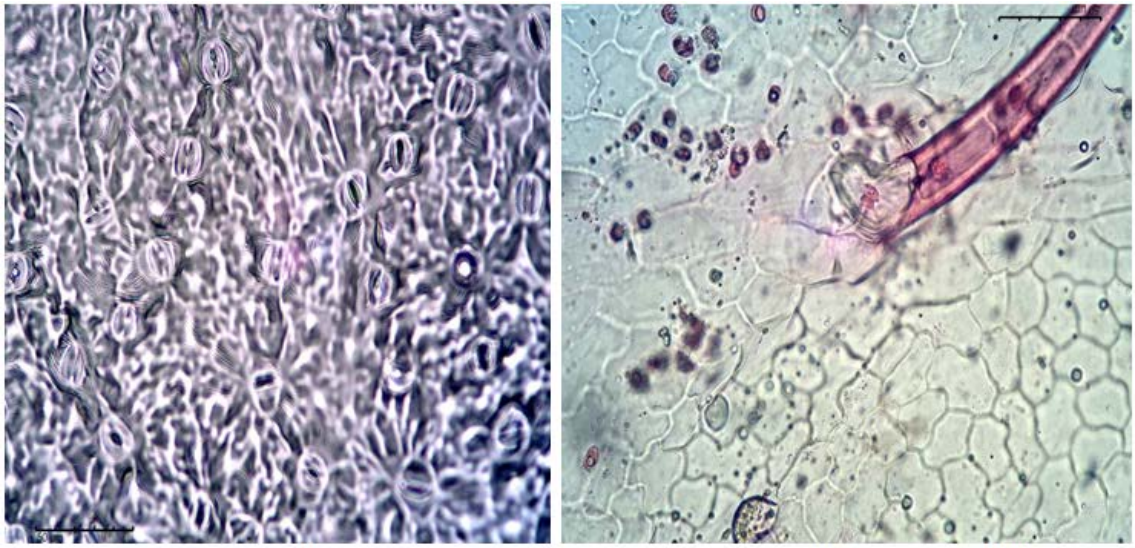

Plate 2. Leaf epidermis of *Alchornea cordifolia* for study area: A = abaxial surface; B = adaxial surface

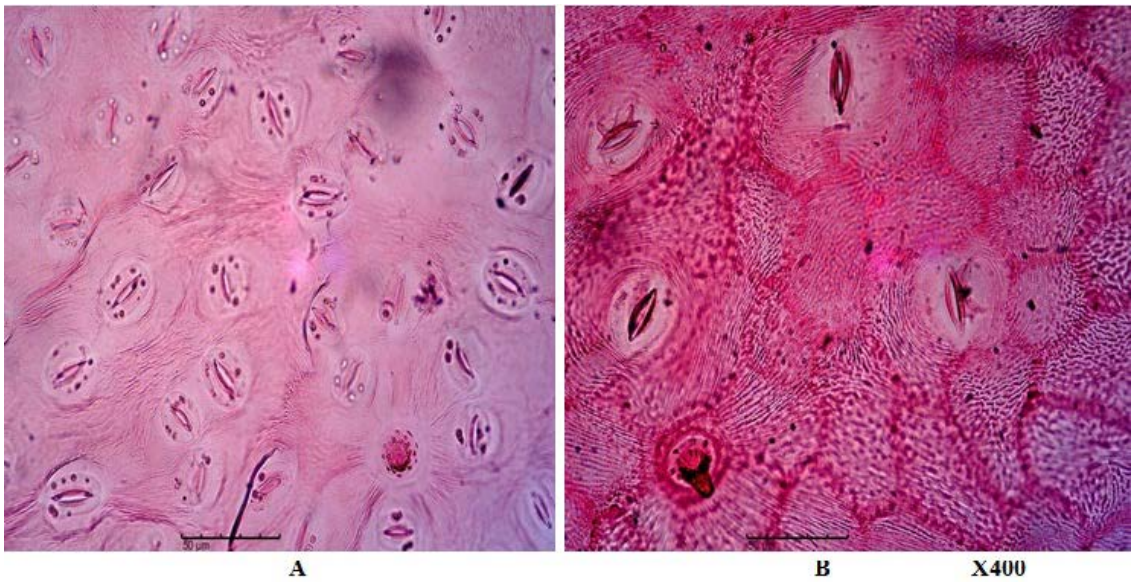

Plate 3. Leaf epidermis of *Nauclea latifolia* for control site: A = abaxial surface; B = adaxial surface

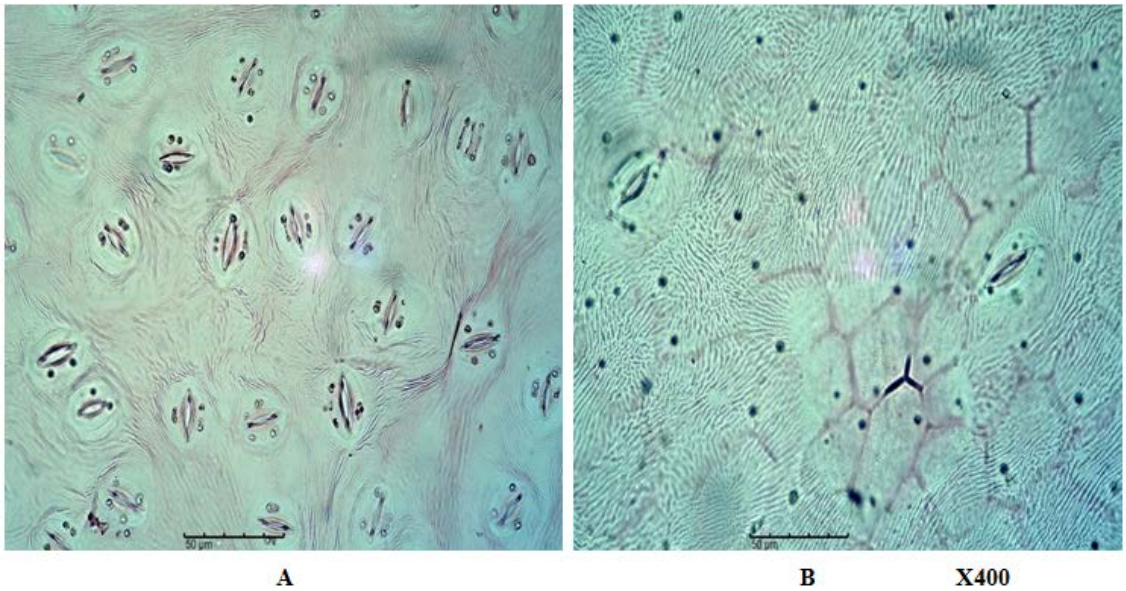

Plate 4. Leaf epidermis of *Nauclea latifolia* for study area: A = abaxial surface; B = adaxial surface

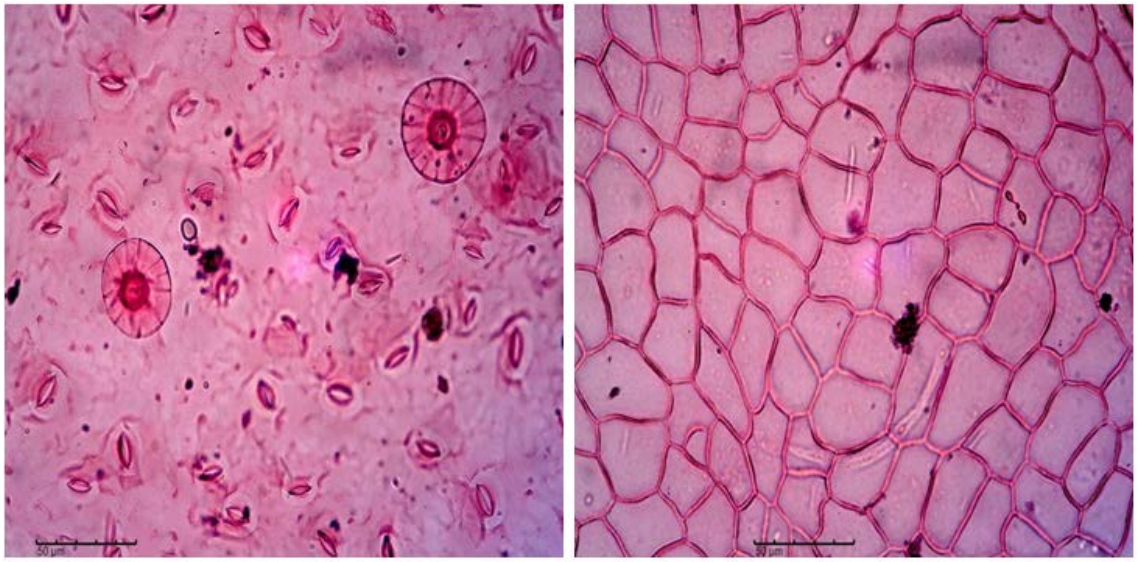

Plate 5. Leaf epidermis of *Newbouldia laevis* for control site: A = abaxial surface; B = adaxial surface

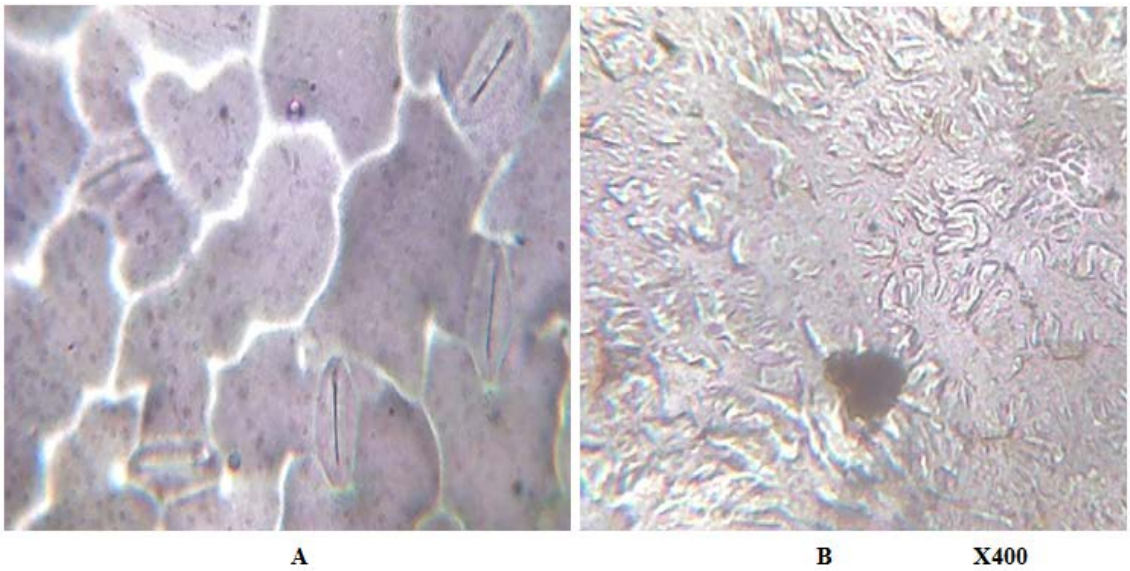

Plate 6. Leaf epidermis of *Newbouldia laevis* for study area : A = abaxial surface; B = adaxial surface

For *A. cordifolia* and *N. laevis,* the samples collected for the study site were affected by quarrying activities. The epidermal cells were completely deformed and the guard cells became plasmolysed (Plate 1, Plate 2, Plate 5 and Plate 6).

3.4. Air Pollution Tolerance of Plants

Results of APTI calculations are presented on Table 7 and Table 8. The results indicate that at the study area, Ph Ranged from 6.63 in *N. latifolia* to 7.53 in *N. laevis,* total chlorophyll ranged from 7.00 in *A. cordifolia* to 17.75 in *N. laevis*.. Ascorbic acid content varied from 1.50 in *A. cordifolia* to 5.00 in *N. laevis,* while relative water content ranged from 84.55% in *N. laevis* to 95.99% in *A. cordifolia*. Among the three plants, values of all parameters analysed were statistically significant (Table 7).

Table 7. Results of biochemical analysis of the plants collected from study site

Study Area	*Newbouldia laevis*	*Nauclea latifolia*	*Alchornea cordifolia*
pH	7.53 ± 0.03^{a}	6.63 ± 0.03^{c}	6.83 ± 0.03^{b}
Total chlorophyll	17.75 ± 0.01^{a}	8.92 ± 0.01^{b}	7.00 ± 0.01^{c}
Ascorbic acid	5.00 ± 0.00^{a}	4.35 ± 0.01^{b}	1.50 ± 0.01^{c}
RWC	84.55 ± 0.01^{c}	88.75 ± 0.01^{b}	95.99 ± 0.01^{a}
APTI	22.34 ± 0.01^{a}	15.63 ± 0.01^{b}	11.67 ± 0.01^{c}

Mean values with different letters as superscript across the row are significantly different at $p \leq 0.05$
Mean values with same letters as superscript along the column are not significantly different at $p \leq 0.05$.

Table 8. Result of biochemical analysis of the plants collected from control site

Test	*Newbouldia laevis*	*Nauclea latifolia*	*Alchornea cordifolia*
pH	6.83 ± 0.03^{a}	6.43 ± 0.03^{c}	6.60 ± 0.00^{b}
Total chlorophyll	22.05 ± 0.01^{a}	9.55 ± 0.01^{b}	7.65 ± 0.01^{c}
Ascorbic acid	6.53 ± 0.01^{a}	4.05 ± 0.01^{b}	1.39 ± 0.01^{c}
RWC	92.25 ± 0.01^{a}	91.94 ± 0.01^{b}	82.83 ± 0.01^{c}
APTI	28.06 ± 0.01^{a}	15.65 ± 0.01^{b}	10.25 ± 0.01^{c}

Mean values with different letters as superscript across the row are significantly different at $p \leq 0.05$
Mean values with same letters as superscript along the column are not significantly different at $p \leq 0.05$.

Table 9. Comparison of biochemical results of the plants from treatment and control sites

	Newbouldia laevis		***Nauclea latifolia***		***Alchornea cordifolia***	
	Study Area	Control site	Study Area	Control site	Study Area	Control site
pH	7.53 ± 0.03*	6.83 ± 0.03	6.63 ± 0.03*	6.43 ± 0.03	6.83 ± 0.03*	6.60 ± 0.00
TC	17.75 ± 0.01	22.05 ± 0.01*	8.92 ± 0.01	9.55 ± 0.01*	7.00 ± 0.01	7.65 ± 0.01*
AA	5.00 ± 0.00	6.53 ± 0.01*	4.35 ± 0.01*	4.05 ± 0.01	1.50 ± 0.01*	1.39 ± 0.01
RWC	84.55 ± 0.01	92.25 ± 0.01*	88.75 ± 0.01	91.94 ± 0.01*	95.99 ± 0.01*	82.83 ± 0.01
APTI	22.34 ± 0.01	28.06 ± 0.01*	15.63 ± 0.01	15.65 ± 0.01^{NS}	11.67 ± 0.01*	10.25 ± 0.01

* = Significantly different at $p \leq 0.05$
^{NS} = Not significantly different at $p \leq 0.05$.

In relation to location (Table 7, Table 8, Table 9), significant difference was found in pH. pH was higher in plants at the study area (Table 8). Total chlorophyll and ascorbic acid values were higher at the control with significant differences in their values. Relative water content was significantly different in all plants at study area and control. The control had higher values with the exception of *A. cordifolia*.

At the study area, APTI ranged from 11.67 for *A. cordifolia* to 22.34 for *N. laevis*. APTI values were significantly different with respect to plant and location.

4. Discussion

Changes in plant anatomy and biochemistry are used as an indicator of air pollution profile since major organs of plants such as leaves are constantly exposed to the atmosphere. The physio-chemical parameters used in the computation of APTI are; ascorbic acid content, total chlorophyll content, pH and relative water content of leaf extracts. [6,23] Results from the foliar epidermal study showed differences in their stomatal variables: *Nauclea latifolia* had the highest values in all the parameters except for pore width while *Alchornea cordifolia* had the lowest in all the stomatal parameters, and while the leaf of *N. laevis* is hypostomatic, amphistomatic leaves were observed in others. These could be best explained with the fact that the three species belong to three different taxonomic families. [24] Irrespective of the plant species however, the epidermal parameters were affected by quarrying activities when compared with the samples collected from the control site. This is characterized by deformed epidermal and guard cells, as well as, changes in the size and density of the stomata as a result of changes in the physiological and metabolic activities of the plants. [25] Quantitative analysis of stomata parameters showed that samples from the study site had higher number of stomata per unit area than those from control site while samples from control site had higher values for stomata size and pore size. Similar results have been reported by previous authors [16,26,27]. Dust particles from quarrying sites tend to clog stomatal openings and thereby decrease the rate of gas exchange. [25]

It was further observed from the foliar anatomical features that *N. laevis* was the most tolerant plant to the quarrying activities. This could be attributed to the fact that the plant possesses compound and hypostomatic leaves according to Ulrichs et al. [28] who stated that particulate matters from quarrying activities mostly affect trees with compound leaves, and that the dust particles settle more on the upper surfaces than on the lower surfaces. Since *N. laevis* only possess stomata on the lower surface there would be reduced effect on its physiological and metabolic activities [28].

Ascorbic acid content is crucial factor in plant tolerance due to its antioxidant properties which enhances plant defense against oxidative stress [6,13]. This was why *N. laevis* which had higher concentrations of ascorbic acid at study area and control also had the highest APTI at both locations. Ascorbic acid levels are usually expected to be higher in plants at stressed environments as was the case of *N. latifolia* and *A. cordifolia*. Relative water content was higher in plants at the control site with the exception of *A. cordifolia*. Water content is crucial for the maintenance of physiological balance in plants being lower in plants exposed to stress. [29] The observed high relative water content in *A. cordifolia* could be as a result of stomata occlusion by dust particles from the quarry site which reduced water loss by the plant through transpiration. Ogbonna et al. [30,31], in a similar study in a lead-zinc mining site reported a lower water content of 61.90% for *A. cordifolia*. The variation in water content of the plant may be attributed to differences in environmental factors, including the nature of mining activities.

Newbouldia leavis had the highest APTI of 22.34 suggesting that the plant had intermediate tolerance for air pollution from the quarry site. *Alchornea cordiolia* and

Nauclea latifolia with APTI of 11.67 and 15.63 respectively are classified as sensitive to air pollution. Plants that are tolerant or have intermediate tolerance to air pollution are used for biomitigation of air pollution and greenbelt development while those that are sensitive can be used only as bioindicators of air pollution. *Newbouldia leavis* is therefore recommended for biomitigation of air pollution from the quarry site while *Alchornea cordiolia* and *Nauclea latifolia* can be used as bioindicators of air pollution.

5. Conclusion

The study analysed the foliar micro structure and biochemical properties of three plants growing in a quarrying environment with a view of assessing their tolerance to air pollution. Foliar analysis indicated that stomata parameters of *Alchornea cordifolia* and *Nauclae latiffolia* were completely altered and destroyed in comparison with control site samples. Differences were also observed in stomata parameters at study site and control site with control samples having higher values. The APTI derived from a synthesis of the biochemical properties indicated that *Newbouldia leavis* was the most tolerant to air pollution from the study site. The APTI of 22.34 suggests that *Newbouldia leavis* has intermediate tolerance to air pollution. In addition the plant showed less foliar alteration and destruction further suggesting a higher capacity to withstand effects of air pollution. The study therefore recommends *Newbouldia leavis* for greenbelt development in the study area and possibly other quarrying sites. Further research to evaluate anticipated performance index of the plants used in this study will help to validate the findings of this study with respect to the suitability of *Newbouldia leavis* in air pollution mitigation.

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