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PJBS

ISSN 1028-8880

Pakistan Journal of Biological Sciences

ANSInet
Asian Network for Scientific Information
308 Lasani Town, Sargodha Road, Faisalabad - Pakistan

OPEN ACCESS Pakistan Journal of Biological Sciences

ISSN 1028-8880
DOI: 10.3923/pjbs.2020.1044.1054

Research Article
Effect of Quarrying and Stone Crushing Activities on Nutritional Composition, Heavy Metals and Oxidative Stress Indices of *Aspilia africana*

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Abstract

Background and Objective: Physiological and biochemical changes in plants are indicators used for monitoring cellular activity of plant prior and post exposure to harsh environment. This study investigated the impact of quarrying and stone crushing activities on heavy metals, plant nutritional composition, phytochemicals and oxidative stress indices of *Aspilia africana*. **Materials and Methods:** Different parts of *A. africana* were collected from the quarry site and compared to those growing from non-quarry mining environment. **Results:** The result shows that *A. africana* from quarry mining site had significant ($p<0.05$) increase in phenol, tannin, alkaloid, saponin, flavonoid, Mg^{2+}, Na^{+}, Fe^{2+}, Cu^{2+} and Zn^{2+} levels when compared to that of control site. Ascorbic acid, chlorophyll and Air Pollution Tolerance Index (APTI) level significantly ($p<0.05$) decreased in the quarry site. The photomicrograph of the *A. africana* leaves from the quarry site demonstrated a squeezed venial arrangement, necrotized surface, closed stomata and compressed vein. **Conclusion:** The result suggests that quarrying and stone crushing activities may induce oxidative stress on *A. africana*. Based on its APTI rating, *A. african* can be used in the monitoring of air pollution. The results revealed that quarrying and stone crushing activities increased health promoting phytochemicals and some minerals of *A. africana* growing around the quarry environment.

Key words: *Aspilia africana*, quarrying activities, air pollution, oxidative stress, human health

Citation: Ogbonna Chidi Enyinnaya, Ude Victor Chibueze, Ugbogu Ositadinma Chinyere, Emmanuel Okezie, Nnorom Innocent Chidi and Ugbogu Eziuche Amadike, 2020. Effect of quarrying and stone crushing activities on nutritional composition, heavy metals and oxidative stress indices of *Aspilia africana*. Pak. J. Biol. Sci., 23: 1044-1054.

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Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Anthropogenic activities such as; deforestation, quarrying or stone crushing and burning of fossil fuel have the greatest negative influence on plants other than any other components of the environment[1,2]. They change the natural habitat in the vegetation and forest ecosystem[3]. Herbaceous plants change their biomass in response to environmental stress conditions[4]. However, quarrying and stone crushing activities like the other anthropogenic activities are globally considered as economically essential because of the daily uses of the crushed stones in building of houses, construction of roads and bridges. Notwithstanding the overwhelming benefits of quarrying or stone crushing operations, they are destructive activities whose socio-economic benefits may be unable to compensate for the overall detrimental effects on natural ecosystem. For example pollution is highly associated with quarrying or stone crushing activities[5,6], especially in the developing countries such as Nigeria, where regulations guiding mining are not followed strictly. During quarrying process, dusts containing various heavy metals and toxicant are released into the air[7] and in most cases deposited on the surface of the plant leaves. Due to the static nature of plants, they seem essential in monitoring environmental pollution as they do not have the ability to move away from a harsh environment. They can only adapt to the harsh condition which may lead to over production or under secretion of biochemical compounds such as plant antioxidants to ameliorate the adverse effect of the pollution[8]. When the plants are unable to withstand the environmental condition, it may lead to physiological damage which may be shown on the morphology of the plant parts such as leaves, stems, flowers and roots[8]. The morphological changes may occur in form of distorted foliar structure, abrasion of leaves and cuticles, decreased photosynthesis, stomata conductance, oxidative stress, necrosis, reduction in growth rate and death[9-11]. The accumulation of pollutants in the crops (leaves, roots and stem) may lead to low yield, stunted growth or plant death[12]. Plants that are very close to quarry sites tend to accumulate dusts and heavy metals which have been shown to reduce carbohydrate and chlorophyll levels, thus reducing the level of photosynthesis and delay flowering[13]. Maletsika *et al*.[9] reported that decrease in chlorophyll and increase in phenolic content of plant due to oxidative stress leads to metal imbalance. It has been reported that particulate matters coming from the dust have the potential to induce morphological changes on the plant leaves[8]. Dust deposition on plants surfaces can induce ultra structural alterations, increase lipid droplets and cause swelling of cellular components, thylakoid degeneration and plasmolysis thereby inducing aging of the plant cells[14]. Farahat *et al*.[15] demonstrated that quarry dust deposition induced a decrease in growth rate of *Tsuga canadensis* (L.) carriere. Researchers have investigated the impact of quarrying or stone crushing activities on plants. However, no published information has been reported for *A. africana*. *Aspilia africana* is a tropical herbaceous shrub that belongs to the Asteraceae family[16]. It is commonly grazed by cattle, goats, rabbits and sheep as a source of nutrient. It is a medicinal plant that is widely used by humans in the treatment of several ailments such as; rheumatic pains, wounds, hepatitis, inflammations and digestive disorders. Ethnopharmaceutical studies have also shown that it possesses homeostatic, antibacterial[17], antioxidant and growth promoting activities. Abii and Onuoha[18] reported that *A. africana* is a good source of Ca^{2+}, P, K^{+}, Mg^{2+}, Fe^{2+} and Zn^{2+}. Apori[19] reported that *A. africana* is very rich in protein (10.5%), a value greater than the recommended minimum protein concentration (6-7%) for efficient functioning of the rumen microbes and therefore, opined that it can be used to feed ruminant livestock without any further protein supplementation. This study, therefore, evaluates the impact of quarrying and stone crushing activities on heavy metals, plant nutritional composition, phytochemicals and oxidative stress indices of *A. africana*.

MATERIALS AND METHODS

Study area: This study lasted for 4 months (June-September, 2018). *Aspilia africana* was harvested from a quarry mining site located at Ugwuele community in Uturu Isuikwuato Local Government of Abia state. Ugwuele is situated at latitude 50°35' N and 50°55' N and between longitudes 70°22' E and 70°30' E whilst the quarry site is situated at 50°87' 15" N and 70°42' 54"E (Fig. 1). The study area is in the humid tropics and experiences high rainfall (1500 and 2000 mm), temperature (27°C) and humidity (70%) levels. The soil type is ferralitic with tropical rain forest vegetation. The quarry harvested plant was compared to those harvested growing from non-quarry mining environment. The non-quarry environment is Abia State University Uturu, located between latitudes 5°49'3.57" and 5°49' 31.85" to longitudes 7°23' 26.65" and 7°23' 49.5".

Identification, collection and authentication of plants: *Aspilia africana*, a locally used medicinal plant was identified and collected from the study area and from a control area (500 m away from the quarry site). This was done by following interviews held with notable traditional medicine practitioners in the study area who helped to identify the plants. Triplicate

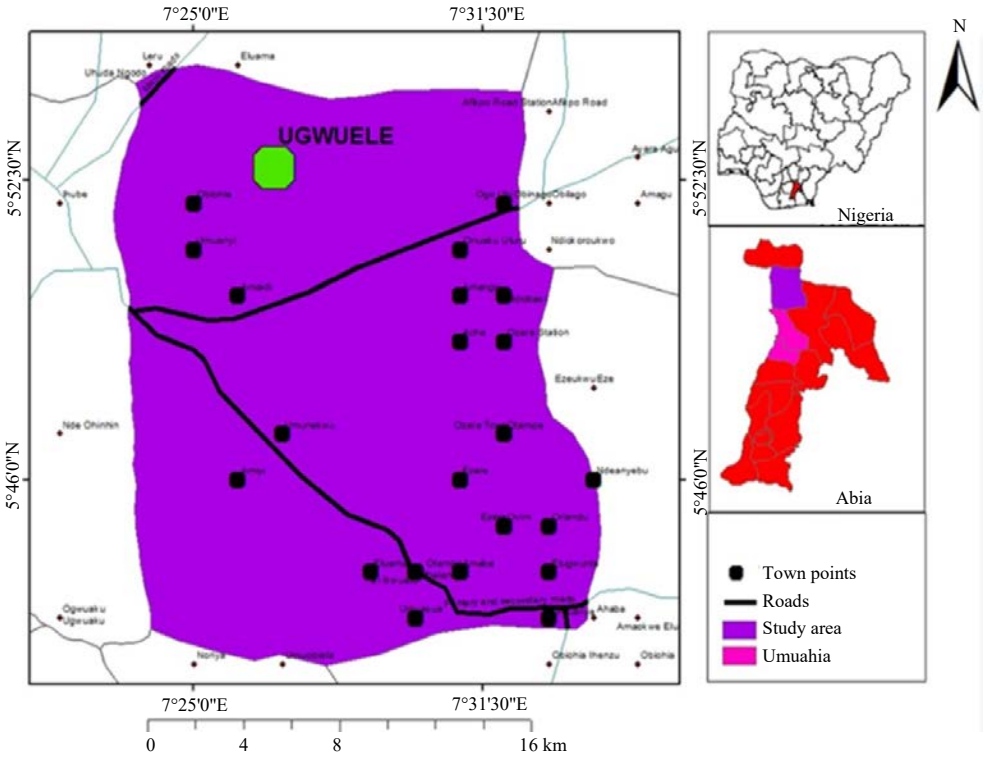

Fig. 1: Map of Ugwuele showing the study area

fresh samples of *A. africana* were randomly collected within the quarry site and from the control site. The *A. africana* was used due to its broad leaf and because their medicinal properties have been widely studied[17]. The plants were re-identified and authenticated by a taxonomist.

Sample preparation: The freshly collected *A. africana* were cleaned and then separated into leaves, stem and roots by cutting and then air-dried separately for 8 days. The dried samples of leaves, stems and roots were ground and placed in a polythene bags, which was labelled and sealed to prevent the plant from further moisture absorption. The plants in polythene bag were then stored in a refrigerator at 4°C and used for analysis when required.

Phytochemical analysis: Alkaloids, phenolics, saponins, hydrogen cyanide (HCN) and flavonoids in the leaves, stem and roots were estimated quantitatively using the methods described by Harborne[20]. Tannin was estimated with Folin-Denis spectrophotometric method as described by Shabbir *et al.*[21].

Proximate analysis: The proximate composition (moisture, ash, crude lipid, crude protein, crude fibre and carbohydrate) of the leaves, stems and roots of *A. africana* were estimated following the methods recommended by Association of Official Analytical Chemists[22].

Assessment of mineral and heavy metal composition of *A. africana*: Mineral composition of the leaves, stems and roots of *A. africana* comprising of potassium (K^+), magnesium (Mg^{2+}), iron (Fe^{2+}), calcium (Ca^{2+}), copper (Cu^{2+}), chromium (Cr^{2+}), lead (Pb^{2+}), nickel (Ni^{2+}), cadmium (Cd^{2+}), cobalt (Co^{2+}), manganese (Mn^{2+}) and zinc (Zn^{2+}) were determined using Atomic Absorption Spectrophotometry (AAS) model 210/211 VGP Buck scientific, whereas sodium (Na^+) was determined using flame photometer model Jenway PFP-7, UK.[22].

Determination of ascorbic acid content: Ascorbic acid content was investigated as described by Bajaj and Kaur[23] using spectrophotometer (SmartSpec™ 3000, Bio-Rad). Exactly 1 g of the leaf sample was treated with 4 mL 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 kept on the bench for 15 min, after which the absorbance was read at 760 nm. The concentration of ascorbic acid was extrapolated from a standard ascorbic acid curve.

Determination of chlorophyll content (TCH): Chlorophyll content was quantified following the method described by Arnon[24]. Exactly 3 g of the leaf sample was added to 10 mL of 80% acetone. The extract was kept for 15 min and the liquid portion decanted and centrifuged at 2,500 rpm for 3 min. The supernatant was collected and its absorbance read with spectrophotometer at 663 nm.

Determination of leaf pH: Leaf pH was determined by "Direct Reading Engineering Method" (DREM) using a digital pH meter as described by Otuu *et al.*[25]. The leaf extract was made by cold maceration of the leaf with deionised water, filtered through Whatman® Grade No. 1 filter paper (Sigma-Aldrich, UK) and the filtrate used for pH determination. The pH meter was calibrated with buffer solution of pH 4 and 9 before usage. The pH electrode was carefully dipped into the filtrate in a 10 mL beaker. The value displayed on the Crystal Liquid Panel (CLP) was taken as the true pH value. The exercise was done in triplicate and the average of the three readings was used.

Determination of Relative Water Content (RWC) (%): The method described by Singh[26] was used to determine relative water content. The weight of freshly collected leaf sample was determined and recorded as Fresh Mass (FM). The leaf samples were then floated in distilled water in a closed Petri dish at room temperature. After 24 h, the leaf sample was wiped dry gently with blotted paper and weighed again to obtain the Turgid Mass (TM). The leaf sample was then placed in a pre-heated oven at 80°C for 48 h and weighed to obtain to the Dry Mass (DM) and then used to calculate the relative water content using Eq. 1:

$$\text{Relative water content (RWC) (\%)} = \frac{\text{FM} - \text{DM}}{\text{TM} - \text{DM}} \times 100 \quad (1)$$

Where:
FM = Fresh mass
DM = Dry mass
TM = Turgid mass

Determination of Air Pollution Tolerance Index (APTI): APTI was derived using Eq. 2[27]:

$$\text{Air pollution tolerance index (APTI)} = \frac{\text{A(T+P)R}}{10} \quad (2)$$

Where:
A = Ascorbic acid content (mg g^{-1})
T = Total chlorophyll content (mg g^{-1})
P = pH of leaf sample
R = Relative water content (%)

Assessment of foliar structure: To assess the foliar structure, the adaxial (upper surface) and abaxial (lower surfaces) epidermis of the leaves for the experiment were prepared following impression method[25]. A camel hair brush was used to apply nail-vanish on 22×22 cm portion of the adaxial and abaxial surfaces followed by drying for 10 min. The samples were further coated with nail polish two times and dried for 10 min each time. This was followed by passage through air current for 1 h for effective drying. Using forceps, the epidermal strips of the leaf samples were gently scrapped and placed on a clean slide, stained with safarin. The samples were washed three times with alcohol, covered with a cover slip and examined using 20iss light microscope at X40 magnifications and photomicrographs taken with MC'35 camera for 53 mm film at X400 magnification.

Statistical analysis: The results obtained from this study were presented as Mean±SD of triplicate determinations. One-way Analysis of Variance (ANOVA) at $p \leq 0.05$ with a Tukey test *post hoc* was used to determine statistical significance between groups.

RESULTS

Mineral and heavy metal composition of *A. africana*: Table 1 shows the mineral compositions of leaf, stem and root extracts of *A. africana* from quarry mining and control sites, respectively. The leaf, stem and root extract from the quarry mining site demonstrated a significant ($p<0.05$) decrease in Ca^{2+} and K^{+} level compared to control. Mg^{2+}, Na^{+}, Cu^{2+}, Fe^{2+} and Zn^{2+} levels of the leaf, stem and root increased significantly ($p<0.05$) in the quarry site compared to that of control site. A very low level of Mn^{2+}, Pb^{2+}, Cr^{2+}, Cd^{2+}, Ni^{2+} and Co^{2+} were observed in the leaf, stem and root extract of *A. africana* at the control and quarry mining site (Table 2).

Table 1: Mineral compositions of *A. africana* from a control and quarry site (mg/100 g) n = 3

	Leaf		Stem		Root	
Parameters	Control site	Quarry site	Control site	Quarry site	Control site	Quarry site
Ca^{2+}	139.97±1.35*	42.27±0.12	155.73±0.31*	23.34±0.07	167.20±0.92*	32.45±0.09
Mg^{2+}	27.34±0.87	146.04±0.07*	13.43±0.40	116.07±0.12*	40.10±0.95	148.04±0.08*
K^{+}	69.71±1.45*	0.17±0.08	51.33±0.06*	0.06±0.02	89.57±1.21*	BDL
Na^{+}	11.91±0.03	21.04±0.06*	6.20±0.02	23.03±0.05*	16.11±0.07	39.04±0.06*
Fe^{2+}	4.12±0.02	14.93±0.05*	1.82±0.06	25.76±1.78*	8.00±0.04	21.86±0.11*
Zn^{2+}	1.02±0.02	2.66±0.11*	0.50±0.02	1.48±0.09*	1.18±0.02	1.68±0.12

Values are Mean±SD for triplicate determination, BDL: Below detection limit, control and quarry site values of mineral content of leaf, stem and root extracts were compared separately, *Significance at p<0.05

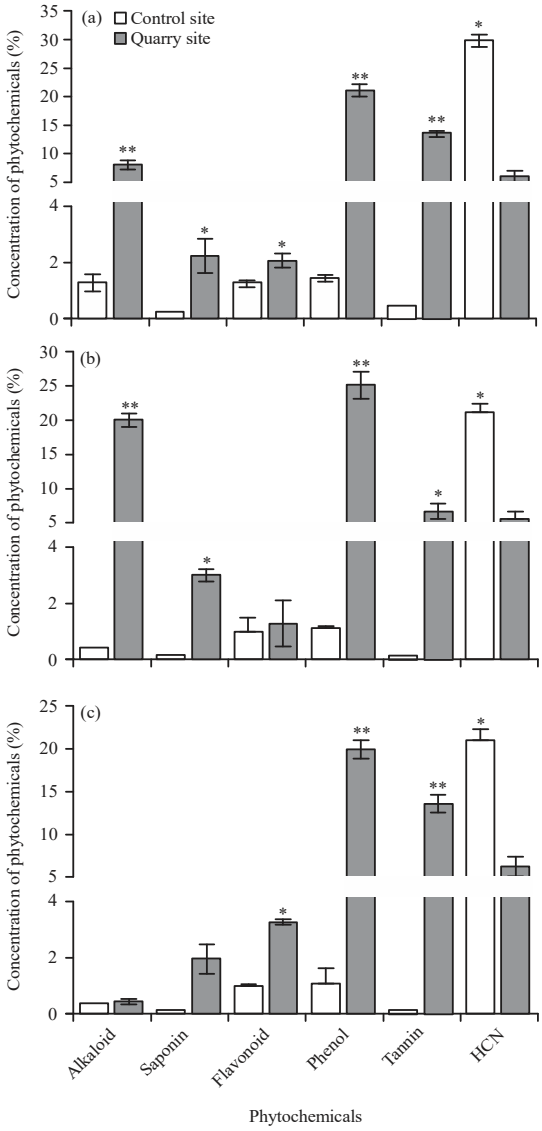

Fig. 2(a-c): Phytochemical compositions of (a) Leaf, (b) Stem and (c) root extract of *A. africana* from a control and quarry mining site expressed in percentage
Values are Mean±SD for triplicate determination, *Statistical significance at p<0.05 and ** p<0.01, HCN: Hydrogen cyanide

However, Pb^{2+}, Cr^{2+}, Cd^{2+} and Ni^{2+} were detected in the leaf extract, Cr^{2+}, Cd^{2+} and Ni^{2+} were not detected in the stem extract, Cr^{2+} and Cd^{2+} were not detected from the root extract of *A. africana* from the quarry site (Table 2).

Phytochemical and proximate compositions of *A. africana*: Phytochemical concentration of *A. africana* was observed in Fig. 2a-c. The *A. africana* leaf, stem and root collected from the quarry site demonstrated a significant (p<0.05) increase in phenol and tannin production compared to control whereas HCN was higher in the control site (Fig. 2). Only the leaf and the stem had a significant increase (p<0.05) in alkaloid and saponin at the quarry site and the flavonoid was produced at a significant concentration in the leaf and root but not in the stem (Fig. 2).

The crude protein and lipid content were not affected in the leaf, stem and root of plant collected from the quarry site compared to the control (Fig. 3). The moisture content of the stem and the root increased significant at the quarry site whereas the leaf was not affected (Fig. 3). The crude fibre of the leaf, stem and root extract significantly (p<0.05) decreased at the quarry compared to the control whist ash level was not affected. The leaf demonstrated a significant increase in total carbohydrate (Fig. 3a) and that of the stem was not affected (Fig. 3b), whereas, the carbohydrate level of the root decreased significantly (p<0.05) (Fig. 3c).

Oxidative stress, air pollution tolerance index and photomicrograph of *A. africana*: Figure 4 shows the ascorbic acid, chlorophyll, percentage relative water content pH and Air Pollution Tolerance Index (APTI) level. A decrease in ascorbic acid and chlorophyll level was observed in the leaf collected from the quarry site compared to control (Fig. 4a, b). The relative water content of the leaf decreased slightly (Fig. 4c) while the pH increased slightly compared to the control (Fig. 4d). The APTI which was calculated from the ascorbic acid level, chlorophyll, pH and relative water retention level decreased compared to the control (Fig. 4e).

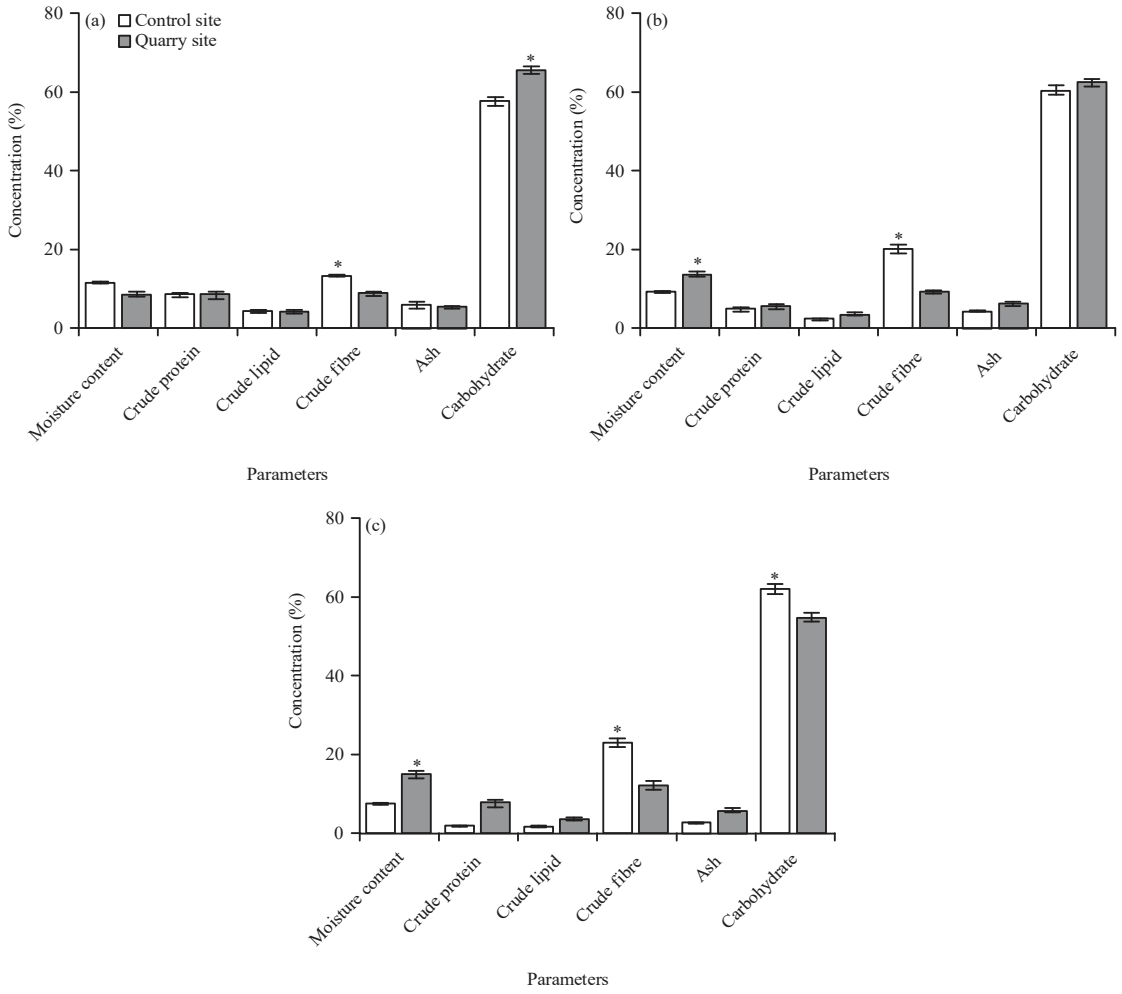

Fig. 3(a-c): Proximate analysis of (a) Leaf, (b) Stem and (c) Root extract of *A. africana* from a control and quarry mining site expressed in percentage

Values are Mean±SD for triplicate determination. Statistical significance is represented with asterisk (*) for $p<0.05$

Table 2: Heavy metal composition of *A. africana* from a control and quarry mining site (mg/100 g)

	Leaf		Stem		Root	
Parameters	Control site	Quarry site	Control site	Quarry site	Control site	Quarry site
Zn^{2+}	1.02±0.02	2.66±0.11*	0.50±0.02	1.48±0.09*	1.18±0.02	1.68±0.12
Mn^{2+}	0.14±0.02	0.24±0.06	0.09±0.01	0.12±0.07	0.23±0.03	0.17±0.08
Pb^{2+}	0.53±0.02	BDL	0.23±0.03	0.08±0.03	0.70±0.02	0.12±0.05
Cr^{2+}	0.04±0.02	BDL	BDL	BDL	0.08±0.01	BDL
Cd^{2+}	0.16±0.02	BDL	0.07±0.01	BDL	0.22±0.01	BDL
Ni^{2+}	0.45±0.01	BDL	0.27±0.01	BDL	0.12±0.03	0.26±0.05
Cu^{2+}	0.17±0.01	0.35±0.09*	0.05±0.01	0.54±0.06*	0.13±0.03	0.56±0.11*
Co^{2+}	0.07±0.01	0.04±0.01	0.03±0.01	0.13±0.07	0.05±0.01	0.04±0.01

Values are Mean±SD for triplicate determination, BDL: Below detection limit, control and quarry site values of mineral content of leaf, stem and root extracts were compared separately, *Significance at $p<0.05$

The photomicrograph of *A. africana* is shown in Fig. 5a-d. The adaxial of the leaf collected from the quarry site demonstrated a squeezed venial arrangement, necrotized surface and closed stroma whereas the leaf from the control site had relaxed veins with prominent mid vein with an open stroma. The abaxial of the leaf collected from the quarry site also showed a compressed vein and closed stroma whereas the abaxial of the leaf from the control showed a relaxed venial arrangement with the stroma open as observed in the adaxial (Fig. 5a-d).

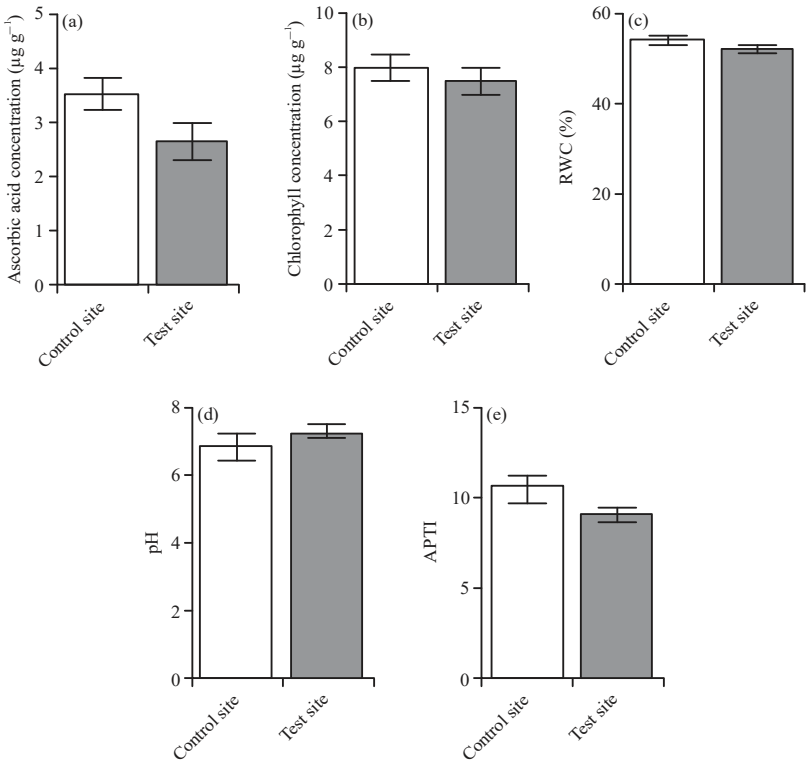

Fig. 4(a-d): Oxidative stress and air pollution tolerance index of *A. africana,* (a) Ascorbic acid concentration, (b) Chlorophyll concentration, (c) Relative water content (%), (d) pH and (e) Air pollution tolerance index (APTI)

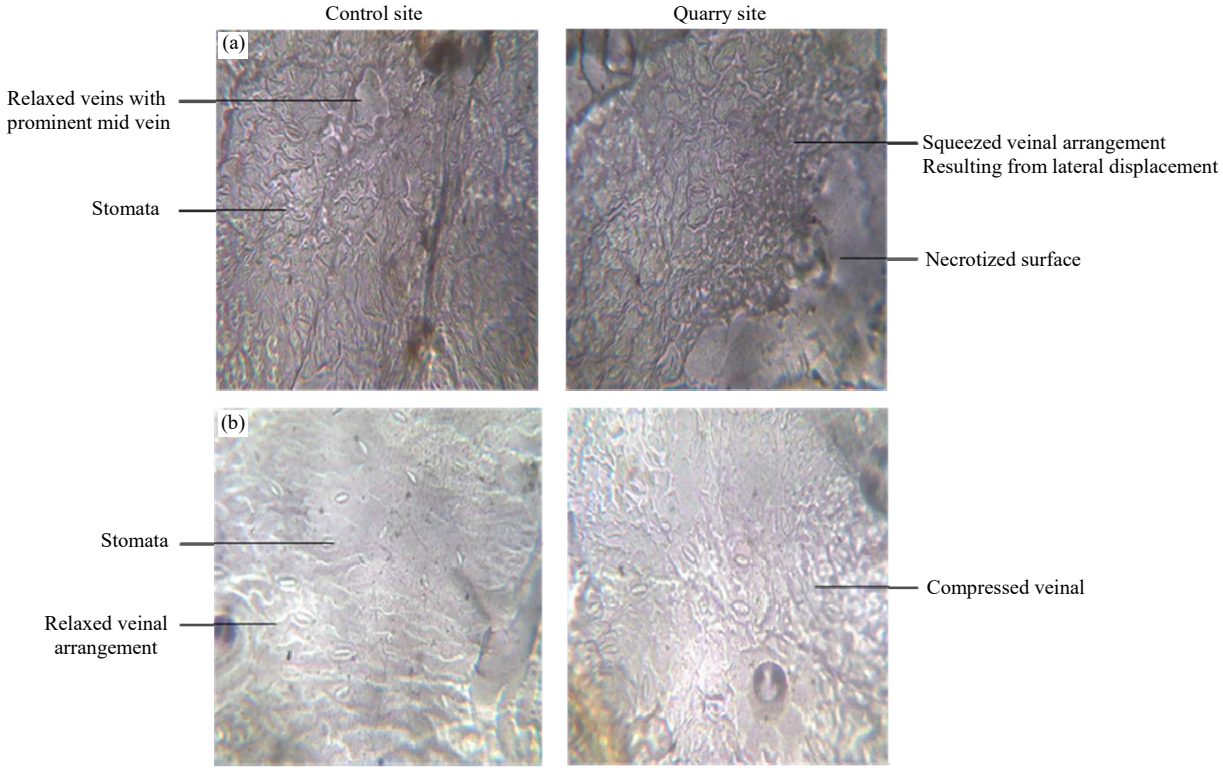

Fig. 5(a-b): Photomicrograph of *A. Africana*, (a) Adaxial and (b) Abaxial

DISCUSSION

Human activities such as quarrying and stone crushing have a huge damage on the plant biodiversity and survival[3]. They also pose danger to the livestock, wildlife and humans. This study investigated the effect of quarrying and stone crushing activities on heavy metals, plant nutritional composition, phytochemicals and oxidative stress indices of *A. africana* in Ugwuele quarrying and stone crushing sites. Minerals of plant origin are essential, because they serve as components of macromolecules, enzymatic reactions cofactors and are also used to maintain osmotic solutes for proper water potential[28]. However, high concentration of minerals including heavy metals may be toxic to plants. In this study, accumulation of heavy metals and minerals such as, Zn^{2+}, Cu^{2+}, Fe^{2+}, Mg^{2+} and Na^{+} were observed to be higher in quarry site when compared to the control site. Although, Zn^{2+}, Cu^{2+}, Mg^{2+} and Fe^{2+} are known as essential plant nutrients involved in enzyme catalytic activities, redox reactions, component of proteins including haem proteins[28], high concentrations have been shown to stimulate oxidative stress via reactive oxygen species (ROS) production, decrease in the level of antioxidant or denaturation of thiol containing proteins[29]. High concentration of heavy metals may also lead to disruption of various biochemical process in plant, which may lead to reduced subcellular structure, chlorophyll content, photosynthesis, lack of flowering, low yield and death[30,31]. High concentration of Na^{+} has been shown to induce reduced growth and plant yield[32]. A significant reduction of Ca^{2+} and K^{+} concentrations in the leaf, stem and root extract of *A. africana* collected from quarry site compared to control were observed. This could be because the observed high concentration of Na^{+} decreased the absorption rate of Ca^{2+} and K^{+} as excess level of Na^{+} have been reported to cause reduced absorption of minerals in plants[28].

A significant ($p<0.05$) increase in phytochemicals (alkaloid, tannin, flavonoid, saponin and phenol) were observed among samples collected from the quarry site. The increased phytochemical secretion may be a means of adaptation to environmental changes. Alkaloids, phenols and flavonoids are antioxidants and oxidative stress may lead to increased production of these antioxidants to enable plants neutralize the impact of free radicals including reactive oxygen species (ROS) and reactive nitrogen species (RNS)[33,34]. Phenols are known as stress metabolites which are synthesized at high concentration as a result of injury or shock[33]. Plant produces hydrogen cyanide as a protective measure against their invaders via the breakdown of cyanogenic compounds[35,36].

In this study, an increase in carbohydrate concentration was observed in leaf extract of quarry plants compared to the control plant. It has been demonstrated that industrial polluted land induced increase in carbohydrate concentration in *Callistemon citrinus*[37]. Changes in protein concentration have been shown to be useful in assessment of environmental pollution[38]. The quarry activities did not produce any significant effect on the ash, protein and lipid levels (Fig. 2). The relative water content of the leaf extract reduced slightly. Since water play an important role in plant survival, a high-water content may favour resistance to adverse environmental condition as water helps to maintain physiological balance[39]. The reduced water content may be as a result of increased leaf cell permeability due to pollution from the quarry dust thereby increasing the rate of water loss from the leaf. The increase water content of the stem and root may have been triggered by reduced water content of the leaf which could induce more water absorption by the root.

Ascorbic acid is an antioxidant existing naturally in plants which are essential for photosynthesis, activation of defense mechanism, light reaction II in the absence of water and can detoxify air pollutants[39,40]. The ROS are the main causes of oxidative stress and ascorbic acid plays essential roles reducing ROS levels[8]. In this study, a observed decreased level of ascorbic acid in plant leaves collected from quarry site compare to control was observed. The level of resistance of plants has been shown previously to directly relate to the level of ascorbic acid in plant[41]. High concentration of ROS as a result of heavy metals from contaminated sites and oxygen radicals have been reported to cause oxidative stress which may lead to biochemical changes such as amino acid, protein, membrane lipids and DNA modification[8,42]. Here, a decreased level of chlorophyll was observed in the leaves of plant collected from quarry site compared to control site indicating that the dust from the quarry site may have initiated this decrease via induction of oxidative stress or through inhibition of the enzymes involved in chlorophyll synthesis[43].

The pH of plant leaves grown in a polluted environment is dependent on the constituent of pollutant and plant biochemical reactions are optimum at a range of pH[8]. Any increase or decrease in pH due to pollutants may lead to adverse effect to the plant, such as; reduced absorption of minerals, denaturation of proteins, decrease chloroplast and hydrolysis of lipid[44]. The observed slight increase in pH in the leaves of plants collected from quarry mining area may be as result of the pollutants from the quarry mining site. This study demonstrated a decreased APTI in the leaves collected form

the quarry compared to that of control. Other researchers have shown that quarry mining can lead to decrease in APTI[45]. The decreased APTI suggested that the quarry mining may have caused changes in biochemical parameters and APTI are used to measure the impact of pollutant on biochemical parameter[8]. It has also been reported that the use of APTI is plant species dependent (tolerant and sensitive)[45], therefore, *A. africana* is a good species for measurement of quarry mining pollution due to its sensitivity to air pollution.

Foliar micrograph of *A. africana* showed a squeezed veinal arrangement, necrotized surface and compressed vein in leaves collected from quarry site, but not in those collected from the control site. Current result agreed with the previous findings in environmentally polluted sites[27]. This study suggested that quarry mining activities can increase phytochemical production and cause oxidative stress on *A. africana*. The results also demonstrated that *A. africana* is sensitive and can be used to assess environmental pollution caused by quarry mining. Therefore, future research should investigate the dose requirements as well as the *in vivo* toxicity effects of *A. africana* found in quarry mining sites.

CONCLUSION

Quarry mining is one of the major causes of environmental pollution in Africa especially in Nigeria. It has negative effect on plants. Plants possess a great potential of being used for monitoring the level of impact they cause to the environment. In this study, it was observed that quarry mining reduced K^+ and Ca^{2+} absorption. Carbohydrate, phytochemicals, ascorbic acid, chlorophyll, veinal arrangement, stomata and APTI of *A. africana* were also affected by the mining activities.

SIGNIFICANCE STATEMENT

The reason for this study was to establish if quarrying activities have negative impact on the herbaceous plant-*A. africana* or if the plant has the capacity to adapt to environmental changes by modifying their structural, morphological and various physiological responses. The present study showed that *A. africana* may not be used for biomitigation because as its low APTI levels upon exposure to harsh environment signifies it is less tolerable to air pollution. Also, the observed impact on phytochemical parameters also shows that quarry mining may increase the medicinal value of *A. africana*.

ACKNOWLEDGMENT

All the authors are happy and give resounding cheers to the research-loving Vice Chancellor of Abia State University, Uturu, Professor E.U. Ikonne and his team-cohorts for offering an enabling environment for this study to be done. This research was funded by Tertiary Education Trust Fund Institutional Base Research Grant (TETFUND/ABSU/RP/20016/020) from Abia State University, Uturu Nigeria.

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