Faculty of Natural and Applied Sciences Journal of Scientific Innovations
Print ISSN: 2814-0877 e-ISSN: 2814-0923
www.fnasjournals.com
Volume 6; Issue 4; May 2025; Page No. 11-22.

Impact of Quarrying Activities on Biochemical Properties and Air Pollution Tolerance Index of Edible Tree Species around Quarries in the Federal Capital Territory, Abuja, Nigeria

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Abstract
The research work assessed the impact of quarrying activities on some biochemical properties and their air pollution tolerance index of selected edible tree plants in areas around selected quarries in the Federal Capital Territory, Abuja. It specifically determines the biochemical properties and analysis of leaf extracts of selected edible plants, and also evaluates the Air Pollution Tolerance Index (APTI). Laboratory analysis of leaf extracts was one of the methodologies applied to carry out the research. ANOVA at a 0.05 level of Probability, T-test, were some of the statistical tools employed. Findings reveal that quarrying affects the biochemical properties and the APTI level of the plants. The biochemical properties of the leaf extracts were generally higher at the control site, except for the total chlorophyll content, indicating a relatively stressed plant, especially at a closer range from the quarry. The air pollution tolerance index (APTI) shows that the selected edible plants are generally sensitive. Regular soil and plant tissue tests, and monitoring; dust control policies, and public awareness of the negative effects of quarrying are some of the recommendations to mitigate the effects of quarrying activities.

Keywords: Quarrying Activities, Biochemical Properties, Edible Plants, APTI, FCT

Introduction

Rock quarrying and stone crushing are global phenomena and have been a cause of concern everywhere, including in advanced countries (Okafor, 2006). Quarrying activity is a necessity that provides much of the materials used in traditional hard floorings, such as granite, limestone, marble, sandstone, slate, and even just clay to make ceramic tiles. However, like many other man-made activities, quarrying activities significantly impact the environment (Okafor, 2006). In particular, it is often necessary to blast rocks with explosives to extract material for processing. Still, this extraction method gives rise to noise pollution, air pollution, damage to biodiversity, and habitat destruction (Okafor, 2006). Dust from quarry sites is a major source of air pollution. For example, limestone quarries produce highly alkaline (and reactive) dust, whereas coal mines produce acidic dust (Lameed & Ayodele, 2010). Air pollution is not only a nuisance (in terms of deposition on surfaces, but dust can also have physical effects on the surrounding plants, such as blocking and damaging their internal structures and abrasion of leaves and cuticles, as well as chemical effects which may affect long-term survival (Guach, 2001; Lameed & Ayodele, 2010). Vegetation which refers to the plant cover of the earth, displays patterns that reflect a wide variety of environmental characteristics as well as temporal aspects operating on it (Kumi-Boateng et al., 2012). This is because it supports critical functions in the biosphere by regulating the flow of numerous biogeochemical cycles like that of water, carbon, and nitrogen; it is also of great importance in local and global energy balance (Kumi-Boateng et al., 2012). Removing vegetation cover strongly affects soil characteristics, including soil fertility, chemistry, and texture (David & Mark, 2005). Although vegetation is of high environmental and biological importance, it is often under intense human pressure in mining areas especially where surface mining and illegal small-scale mining activities are prevalent, resulting in changes in land-use/land cover of mine areas (Adewoye, 2005; David & Mark, 2005). Directly or indirectly, mining has been seen to be a major factor responsible for vegetation loss in mining areas the world over (David & Mark, 2005). Directly, it is caused by vegetation clearance for various mining activities and indirectly, by dust pollution as the volume of dust is discharged into the air during the process of quarrying (Adewoye, 2005). This eventually gets deposited on the leaves of plants and flowers as well as the soil supporting the plants (David & Mark, 2005). The overall effect of this is that the photosynthetic and fruiting ability of the plants is impaired (David & Mark, 2005). When calcium, sulfur-dioxide among other chemical constituents enters the plants through the stomata pores it leads to the destruction of chlorophyll and disruption of photosynthesis in plants subsequently leading to stunted growth or death (Ujoh & Alhassan, 2014; Unanaonwi & Amonum, 2017).

Plants, which include edible plants are major components of the ecosystem – a complex interaction between the biotic and abiotic entities of the environment (Osha, 2006). Unfortunately, the quarry industry discharges dust that settles on land, plants, and trees, including economic/edible tree plants, and on surface waters used for drinking and other domestic chores by the community (Osha, 2006). Green plants including economic/edible trees by their photosynthetic activities occupy an important position in the existence of life because of their ability to maintain a balance in the volume of Oxygen and Carbon dioxide which leads to the purification of the environment (Lameed & Ayodele, 2010). They supply man with food, drugs, fibres, fuel, building, and other raw materials and serve as ornamentals. The plants, including edible plants, by their activities, influence and determine to a large extent, the type of fauna to be expected, and any change or tilt in their composition, affects the animal life in terms of food, shelter, security, and comfort (Wang, 2007). Such vegetation changes are the main concern of environmental botanists and ecologists in recent years who have advocated a careful and cautious approach to activities promoting such changes (Wang, 2007). Air pollution generally and especially dust from quarry sites is known to be responsible for vegetation injury and crop yield loss and thus threatens the survival of plants in industrial areas (Iqbal & Shafig, 2001). Such dusts reduce plant cover, height, and number of leaves. Apart from the dust emitted, toxic compounds such as fluoride, Magnesium, Lead, Zinc, Copper, Beryllium, Sulphuric acid, and Hydrochloric acid are injurious to the vegetation (Iqbal & Shafig, 2001).

A major source of air pollution is the suspended particulate matter from quarry sites. The severity of this pollution is guided by factors that include local climate, particle load in the ambient air, and the size and chemistry of the dust particles (Lameed & Ayodele, 2010). Pollution as a result of dust particles from quarrying and other activities has been known to have adverse effects on human health, soil, air quality, and vegetation including economic/edible trees. Plants including edible trees play many roles including serving as a source of medicine and food, and are essential in the natural systems stabilization (Sofowora, 2008). These plants are stationary and are therefore a reliable means of monitoring air pollution from various sources including quarry sites (Ogbonna et al., 2015). Their leaves and other parts also provide a canopy or platform that traps and accumulates particulate matter (Bennet et al., 2010). More stress and damages are suffered by plants with higher lengths such as trees. Alterations in physiological and biochemical characteristics are observed in plants including economic trees in the vicinity of stressed environments. Physiological damage usually supersedes morphological changes. This paper, therefore, aims to investigate the impact of quarrying on some of the biochemical properties of selected edible tree plants in areas around selected quarries, and their air pollution tolerance index.

Materials and Methods

Study Area

The study was carried out in areas around some selected quarry sites within the Federal Capital Territory (FCT), Abuja, Nigeria. The FCT is made up of Six (6) area councils namely AMAC (Abuja Municipal Area Council), Bwari, Kuje, Gwagwalada, Kwali, and Abaji. The territory is located just north of the confluence of the Niger River and Benue River lying between latitudes 8.25 and 9.20 north of the equator and longitude 6.45 and 7.39 east of Greenwich Meridian. Abuja is geographically located in the centre of the country

Study Site/Site Selection

The study was carried out in areas around two selected quarry sites: CCECC quarry located at the Idu industrial area of Abuja Municipal Area Council, and Zeberced quarry located along the Kubwa/Bwari area of the Federal Capital Territory (FCT), Abuja, Nigeria

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Table 1: GPS of sampling points

Sampling locations	Latitude	Longitude
1. CCECC quarry	9º· 0048'	7º .4109'
2. Zeberced quarry	9º· 1631'	7º ·3093'
3. Control site	9º. 0108'	7º. 4134'

The CCECC (China Civil Engineering Construction Corporation) and Zeberced quarries are two major stone functional quarries in the Federal Capital Territory (FCT), Abuja, Nigeria. The location of both quarries has a predominant vegetation which includes economic/edible tree plant species, hence being selected for the study. The distance between both quarries is about twenty (20) to twenty-five (25) kilometres by road, depending on the route taken. These quarries supply granite and other construction materials for the city's infrastructure development, including roads, bridges, and buildings. The climate of the FCT, Abuja, is a tropical savanna, with two distinct seasons: the rainy season (wet) and the dry season. These seasons affect both quarries similarly.

The Rainy Season (April to October): During this period, the region experiences heavy rainfall, which can affect quarry operations due to soil erosion, flooding in lower areas, and reduced visibility. The average annual rainfall is between 1,100 mm and 1,600 mm. Most quarry operations are slowed down due to waterlogging and slippery conditions caused by frequent rainfall.

The Dry Season (November to March): The dry season is characterized by Harmattan winds, which blow dust from the Sahara Desert into the region, resulting in low humidity and hazy conditions. The dry conditions make quarry operations easier, though dust can be an issue. Temperatures during the dry season can range from 28°C to 38°C during the day, while at night, temperatures can drop to 18°C or lower, especially during the Harmattan months of December and January.

The Vegetation of the area surrounding the quarries in Abuja primarily features savanna vegetation with scattered trees and shrubs due to the climatic conditions. The vegetation is predominantly grassland, interspersed with trees like acacia, baobab, and various types of palm trees, mangoes, shea butter, locust bean trees, etc.

The soil composition in and around the CCECC and Zeberced quarries is important for understanding the conditions under which quarry operations occur. The soil in Abuja and the surrounding regions is typically ferruginous tropical soils that are red or reddish-brown due to the high iron content. The soil is generally loamy-sandy, with a good level of permeability, which can be a disadvantage during the rainy season as the water washes away the soil layers, causing erosion.

The topography of the areas where the CCECC and Zeberced quarries are located is defined by a mix of rocky outcrops, undulating plains, and hills. The quarries are situated near granite hills, which are typical of the geology of Abuja. The region is known for its abundance of granite rock formations, which are quarried for construction materials. The surrounding landscape features rolling hills and plateaus that give way to steep drops in some places, particularly around the quarry sites where excavation has significantly altered the natural landscape (Federal_Capital_Territory_Nigeria, 2020).

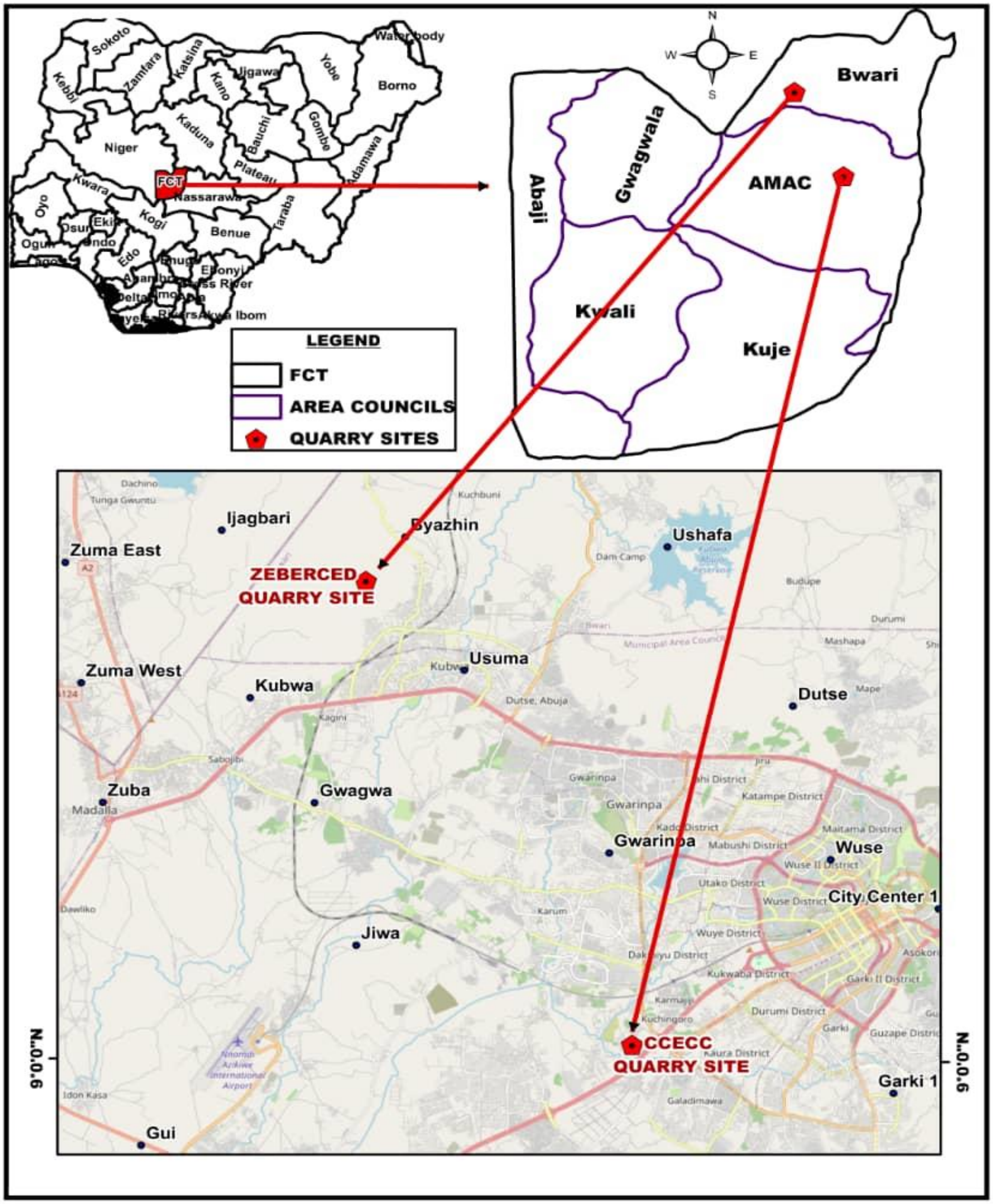

Figure 1. Map of Nigeria showing the location of the Federal Capital Territory (FCT), and the Quarry Areas (**Source**: Nassarawa state Geographical Information System, NAGIS. ArcGIS software, ArcMap online; Coordinate system: WGS84

Plant Selection

Plant Selection

The study plant selection consists of edible tree plants that grow in areas around the quarry sites. Edible tree plants within the quarry sites were identified and enumerated at intervals of a hundred (100) metres away from the quarry plant. Edible plants were also identified and enumerated at the control site. Leaf samples were randomly collected from each of the selected edible plants growing in the different sites (Ogbonna et al., 2015). A collection of the leaf samples of each edible plant were put together for laboratory analysis.

Laboratory/Biochemical Analysis

The Biochemical analysis was conducted and this includes the determination of the Ascorbic acid content, Total chlorophyll content, pH level, and the Relative Water content of the leaf extracts.

Ascorbic acid was determined by the titrimetric method as described by Ogbonna et al. (2015). The ascorbic acid was extracted with 20ml of distilled H2O in 30ml H2SO4 and 0.5mol, oxalic acid. Exactly 2g of the pulverized leaf sample was added to the mixture and stirred thoroughly for 10 minutes. The mixture was filtered and 10ml of the filtrate was titrated against 0.05mol iodine solution, using starch mucilage as an indicator of endpoint. The pH represents the acidity and alkalinity of the aqueous solution. The pH was determined by the Direct Reading Engineering Method using a digital pH meter (Otuu et al., 2015). The leaf extract was prepared by manual squeezing with distilled water and squeezed directly into an already labeled test tube. The pH meter was pre-calibrated before its usage, using a buffer solution of pH 7.4. The electrode was carefully dipped into the extract in a 10ml beaker. The value displayed on the Crystal Liquid Display Panel (CLD) of the pH meter was recorded as the pH value. The relative water content, of fresh leaf samples, was weighed and recorded as Fresh Mass (FM). It was floated in distilled water inside a closed petri-dish, at room temperature for 24hrs. At the end of the incubation period, the leaf sample was wiped dry to obtain the Turgid Mass (TM). It was then placed in a preheated oven at 100°C for 5hrs after which the leaf was weighed to obtain the Dry Mass (DM). The assay was done in triplicates and the average of the readings was used. The relative water content was calculated by substituting the formula:

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

Where:

FW- Fresh weight, DW- Dry weight, and TW- Turgid weight.

Chlorophyll Content was determined by the method as described in Ogbonna et al. (2017). Exactly 3g of the leaf samples were blended and then extracted with 10 ml of 80% acetone, was left for 15 minutes and the liquid portion was decanted and centrifuged at 2,500 rpm for 3 minutes. The supernatant was collected and its absorbance was measured at 663 nm using a spectrophotometer. The Air Pollution Tolerance Index (APTI) was calculated using the following formula (Ogbonna et al., 2017):

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

Where A = Ascorbic acid (mg/g) P = pH of leaf extract T = Total chlorophyll (mg/g) R = Relative water content (%) Gradation of APTI was done by dividing APTI values into four grades such as – Tolerant, Intermediate, Sensitive, and very sensitive: APTI Index range: - < 1 = very sensitive 1 to 16 = Sensitive 17 to 29 = > Intermediate 30 to 100 = > Tolerant 3.8.

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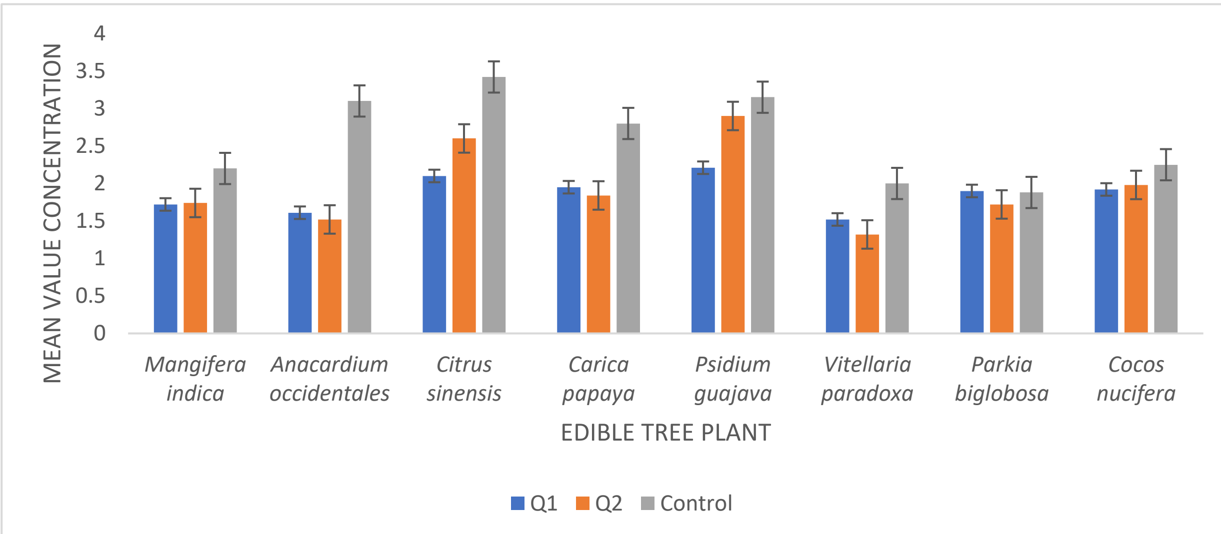
Results

Ascorbic acid Content

Figure 2: Ascorbic acid Contents of Leaf Extracts Selected Edible Trees



The result from Figure 2 shows that the ascorbic acid content ranges from 1.32 mg/g in *Vitellaria paradoxa* to 2.90 mg/g in Psidium guajava, and 1.90 mg/g in *Parkia biglobosa* to 3.42 mg/g in *Citrus sinensis* at the control sites. This study reveals variations in the levels of ascorbic acid in the selected edible tree species of quarry sites.

pH of leaf extract

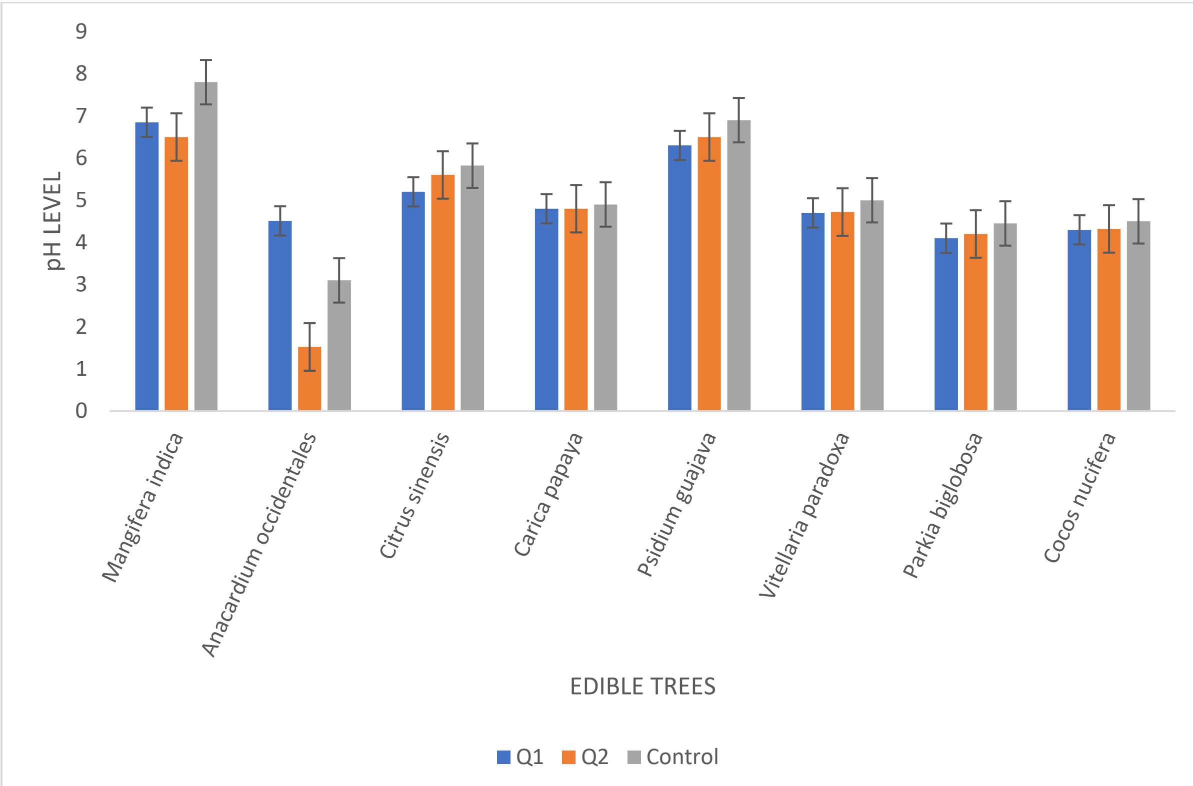


Fig. 3: pH level of Leaf Extracts of Selected Edible Trees

The result from Figure 3 shows that the pH of leaf extracts ranged from 4.10 in *Parkia biglobosa* to 6.85 in *Mangifera indica* at quarry sites whereas it ranged from 4.45 in *Parkia biglobosa* to 7.80 in *Mangifera indica* at the control site. It showed pH is moderately acidic to slightly alkaline range

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Relative water content

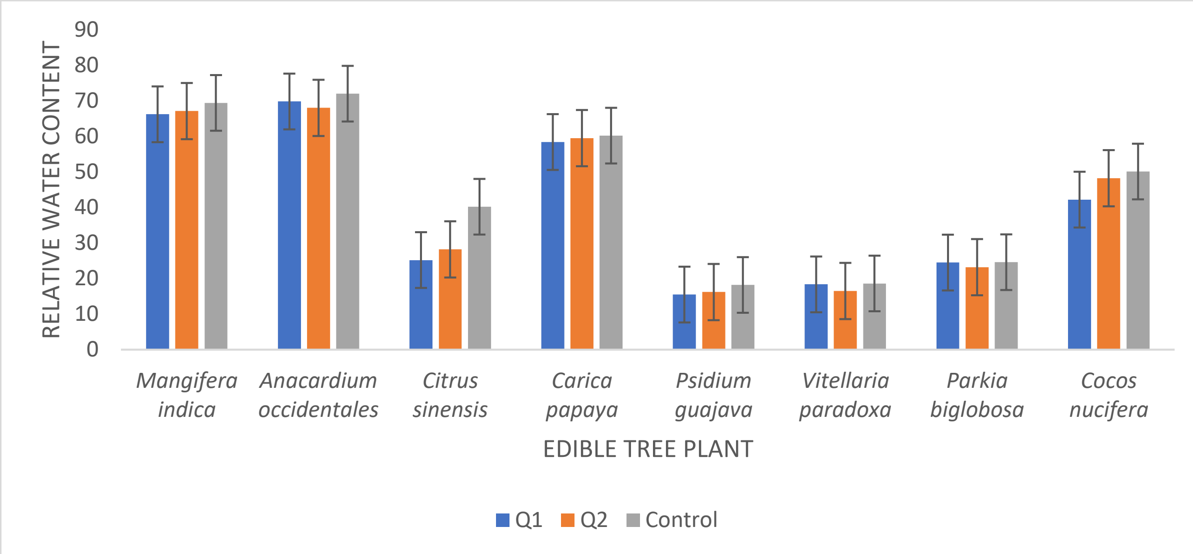

Fig. 4: Relative Water Content of Leaf Extracts of Selected Edible Trees The result from Figure 4 shows that RWC of edible tree species ranges from 15.50 percent in *Psidium guajava* to 69.0 percent in *Anarcadium occidentale* at quarry sites, and 18.20 percent in *Psidium guajava* to 72 percent in *Anarcadium occidentale* at control site

Total Chlorophyll content

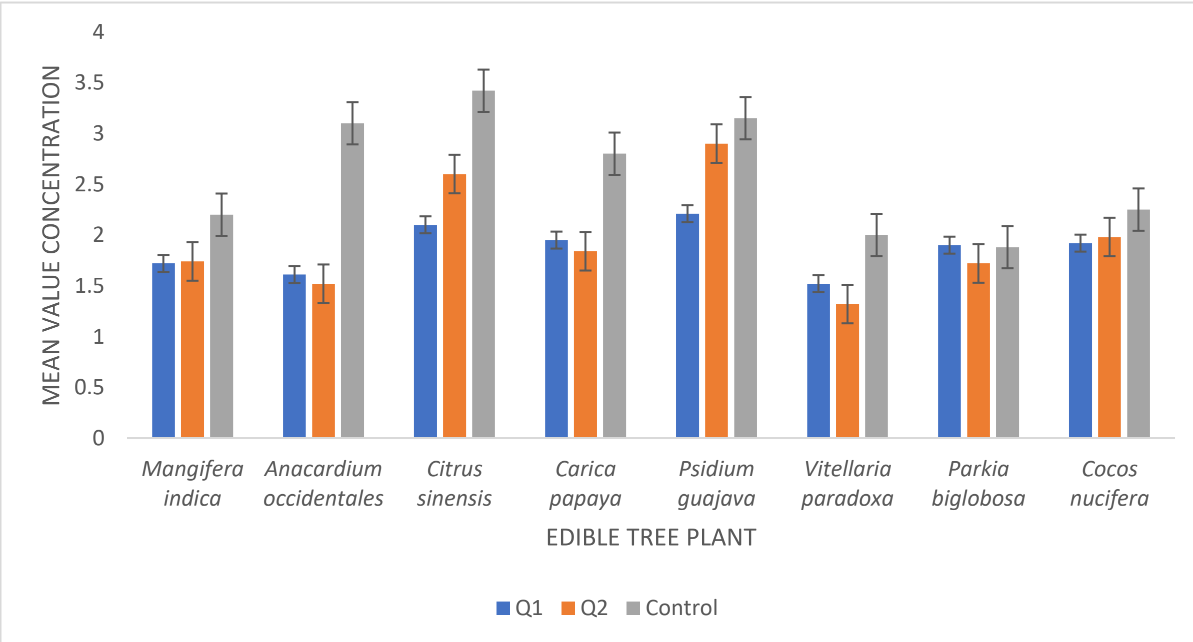

Fig. 5: Total Chlorophyll Content of Selected Edible Trees

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The result from Figure 5 shows that total chlorophyll content ranges from 14.20 mg/g in *Anarcadium occidentales* to 22.52 mg/g in *Parkia biglobosa* at quarry sites, and 12.50 mg/g in Psidium guajava to 22.20 mg/g in *Parkia biglobosa* at control site

Evaluation of Air Pollution Tolerance Index (APTI)

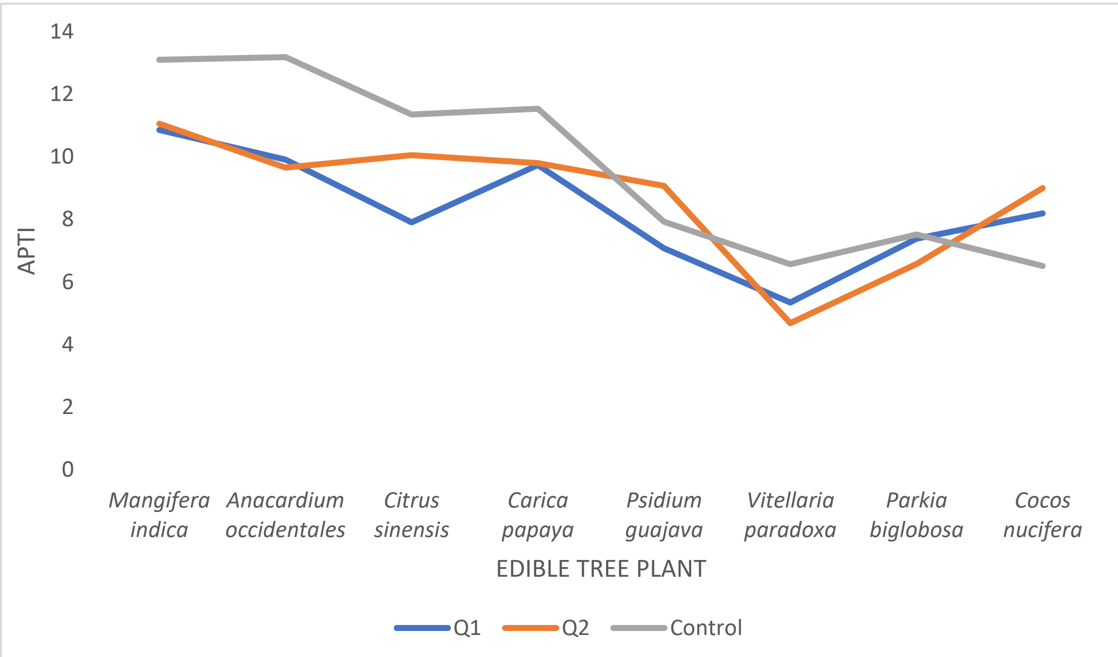

Fig. 6: Air Pollution Tolerance Index (APTI) of Selected Edible Tree Plants.

Discussion

The biochemical analysis involved the determination of the ascorbic acid, chlorophyll, pH and relative water content of leaf extracts (Ogbonna et al., 2017). Ascorbic acid is a natural antioxidant and plays a vital role in pollution tolerance. It activates many physiological and defence mechanisms in plants (Ogbonna et al., 2017). It is concerned with photosynthetic reactions. In this study, the ascorbic acid content ranges from 1.32 mg/g in *Vitellaria paradoxa* to 2.90 mg/g in *Psidium guajava*, and 1.90 mg/g in *Parkia biglobosa* to 3.42 mg/g in *Citrus sinensis* at the control sites. This study reveals variations in the levels of ascorbic acid in the selected edible tree species of quarry sites (Fig. 2). Ogbonna (2017), in his research study, reported that the ascorbic acid content of control or non-quarry sites was higher than those of the quarry sites. This result suggests that the ascorbic acid content has been altered due to the effect of pollution from quarry activities. Ascorbic acid plays an important role in plant physiology due to its possession of antioxidant and cellular reductant properties. It equally plays a vital role in plant growth and development and the regulation of a broad spectrum of plant cellular mechanisms against environmental stress (Enete & Ogbonna, 2012). The ascorbic acid content of the plant is an important indicator of oxidative stress and hence a crucial tolerance factor that activates defence mechanisms (Ogbonna et al., 2015; Arora et al., 2002). The significance of this parameter is evident in this study, as *Citrus sinensis*, *Magnifera indica*, *Psidium quajava*, and *Anacardium occidentales* are among the edible plants with high ascorbic acid content. However, the ANOVA test (with a p-value of 0.045) shows there is statistically a significant difference in ascorbic acid content across the different sites, at 0.05 level of probability. Hence, this indicates that there is a significant relationship between ascorbic acid content and quarrying activities, as posited by Ogbonna (2017).

From the result of the research study, the pH value of the leaf extracts showed variation in the investigation. The pH of the leaf extracts ranged from 4.10 in *Parkia biglobosa* to 6.85 in *Mangifera indica* at quarry sites whereas it ranged from 4.45 in *Parkia biglobosa* to 7.80 in *Mangifera indica* at the control site (Fig. 3). It showed pH is moderately acidic to slightly alkaline. pH at non-quarry sites is relatively higher than at quarry sites. Rai et al. (2013) observed pH values ranging from 5.0 to 7.0 in the industrial site and that of the control site from 6.0 to 9.0 in the non-industrial site. This is closely in agreement with the findings of this research. The relative water content of a leaf is the water present relative to its full turgidity. High water content within the plant body serves as an indicator of drought resistance in plants and helps to maintain its physiological balance under stress conditions such as exposure to air pollution when transpiration rates are usually high (Ogbonna, 2015). The results of this study showed that the RWC of the selected edible tree species ranges from 15.50 percent in *Psidium guajava* to 69.0 percent in *Anarcadium occidentale* at quarry sites, and 18.20 percent in *Psidium guajava* to 72 percent in *Anarcadium occidentale* at control site (Fig. 4). The RWC is relatively high at quarry sites, though higher at the control site. The increased RWC in plants of experimental sites may be due to the maintenance of physiological balance in stress conditions such as exposure to air pollution (Ogbonna, 2017). In this study, the total chlorophyll contents range from 14.20 mg/g in *Anarcadium occidentales* to 22.52 mg/g in *Parkia biglobosa* at quarry sites, and 12.50 mg/g in *Psidium guajava* to 22.20 mg/g in *Parkia biglobosa* at control site (Fig. 5). Though, the study sites recorded a relatively high total chlorophyll content, it is higher at the control site. The chlorophyll content of plants varies from species to species; the age of the leaf and also with the pollution level (Katiyar & Dubey, 2001). Higher levels of total chlorophyll content of plant species may be due to its tolerant nature (Jyoti & Jaya, 2010). Plants maintaining their chlorophyll contents even under polluted environment are said to be tolerant ones (Singh & Verma, 2007). However, plants with relatively low total chlorophyll content may be sensitive plants and, hence could serve as bioindicators. The Air Pollution Tolerance Index (APTI) was calculated for the selected eight edible tree plants at quarry and control sites. APTI values were relatively higher at the control site, there were variations in the values of APTI amongst the edible plants, across the study sites. APTI plays an active role in determining the resistivity and susceptibility of plant species against pollution. Plant which has higher index values are tolerant to air pollution, while plants with low index values show less tolerance and can be used to indicate levels of air pollution, or bioindicators. The result shows that APTI levels were higher in *Mangifera indica, Anarcadium occidentales, and Citrus sinensis.* this implies that these edible plants are more resistance to pollutions at the quarry sites. However, the evaluation of all the edible plants shows that they indicate sensitivity at the study sites.

Conclusion

The research study examined the impact of quarrying activities on economic/edible tree plants, focusing on the assessment of quarrying activities on the biochemical parameters of the plants, including ascorbic acid content, pH level, relative water content (RWC), and the total chlorophyll content, all of which are indicators of plant stress and health, including the evaluation of the air pollution tolerance index (APTI) of the edible tree plants to determine their ability to withstand air pollution and stress associated with quarry activities. The main findings of the research study shows that quarrying activities caused a reduction in the biochemical parameters (ascorbic acid, pH, RWC, and total chlorophyll content) which indicates stress in the edible tree plants. The relatively high total chlorophyll content equally prepares the edible plants to withstand stress. The exposure of these edible tree plants to air pollution, and soil contamination at quarry sites results in reduced biochemical parameters, which are all signs of environmental stress, and this decreases the plant's vitality. The edible tree plants exposed to quarrying activities at the quarry sites had a lower air pollution tolerance index (APTI). The plants were affected by quarrying and hence had lower APTI values due to their reduced ability to withstand air pollution. However, some of the edible plants like *Mangifera indica*, *Anacardium occidentales*, and *Citrus sinensis* shows tendency to withstand stress with their relatively high APTI level.

Recommendations

1. There is a need for the establishment of buffer zones with vegetation barriers between quarry sites and nearby forested (tree plant) areas to minimize the spread of pollutants and to protect the remaining biodiversity, especially the edible and economic tree plants.
2. Rehabilitation programmes should be initiated by quarry operators by planting native tree species and monitoring their growth and health to restore ecological balance and improve biodiversity
3. Government should formulate better dust control policies, and quarry operators should implement these policies and device control measures such as water sprinkling systems or dust covers, to reduce the amount of particulate matter released into the environment.
4. Cultivation of pollution-tolerant species of edible tree plants with very high APTI in areas near quarries should be encouraged and promoted, to ensure the survival of vegetation and reduce air pollution impact.
5. Government agencies, including organized private agencies and organizations should raise awareness about the ecological impact of quarrying, and enforce stricter environmental policies and penalties for non-compliance with environmental protection standards

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