Nigerian Research Journal of Engineering and Environmental Sciences
Journal homepage: www.rjees.com

Original Research Article

Assessment of Macro-Nutrient Content in Plants in Wet and Dry Season at Coal Mining Sites in Enugu State, Nigeria

***[1]Ogbonna, P.C., [1]Nzegbule, E.C. and [2]Okorie, P.E.**
[1]Department of Environmental Management and Toxicology, Michael Okpara University of Agriculture, Umudike, Umuahia, Abia State, Nigeria.
[2]Department of Forestry and Environmental Management, Michael Okpara University of Agriculture, Umudike, Umuahia, Abia State, Nigeria
*ogbonna_princewill@yahoo.com

ARTICLE INFORMATION

Article history:
Received 05 June, 2019
Revised 09 June, 2019
Accepted 10 June, 2019
Available online 30 June, 2019

Keywords:
Macro-nutrient
Plants
Coal mines
Wet and dry season
Enugu State

ABSTRACT

The study was carried out to assess the impact of coal mining on macronutrient (Ca, Mg, K, N, and P) content in plant species at Akwuke and Iva in Enugu State, Nigeria. Leaf samples were collected randomly from different plant species (Andropogon gayanus, Irvingia gabonensis, Dialium guinense, Mangifera indica, Alchornea cordifolia, Icacina trichantha, and Manihot esculenta) and were processed. The plant samples were cleaned sequentially and placed in large clean crucibles where they were oven dried at 60 °C for 72 h. Thereafter, the dried plant samples were milled and analyzed separately. The results indicate that the highest values of macronutrient (Ca=13.36±0.25, Mg=350.10±0.42, K=607.30±3.82, N=2.28±0.20, and P=0.40±0.03 cmol/kg) at the two mining sites were observed in plants sampled from Akwuke mining site during the dry season. Andropogon gayanus assimilated more macronutrient (Mg, N, ang P) than the other plant species, which suggest that A. gayanus could be used for fast reclamation of mine sites. Strong significant positive correlation occurred between Mg and K (r=0.566, p<0.05) as well as N and P (r=0.523, p<0.05) in plant in wet season at Akwuke mining site.

1. INTRODUCTION

Coal mining is the process of extracting coal from under the ground (Ogbonna *et al*., 2012). This anthropogenic activity culminates to removal of the overlying soil layer with existing vegetation that are deposited in another fresh area. The deposition of million tons of overburdens in the forms of rocks, shale, coarse tailing results in barren, biologically inert overburden dumps called mine spoils (Hazarika *et al*., 2006). Deforestation on a large scale which precedes mining of minerals affects the diversity and stability of plant communities in any location. The decline in plant diversity reduces biomass production and release of organic materials by plants and this may affect negatively nutrient recycling and soil stabilization via litter fall (Ogbonna *et al.*, 2018a).

Coal contains a significant amount of pyrites and the exposure of pyrite to atmospheric oxygen through mining activities causes its oxidation to ferrous sulphate and sulphuric acid in the presence of bacteria. The sulphuric acid formed lowers the pH of the soil and water, which affects the populations and activities of organisms inhabiting these environments (Sarma, 2002). The reduction in populations and or activities of organisms such as soil macro fauna (e.g. earthworm) can affect adversely the decomposition of organic material within or around a coal mining site (Ogbonna *et al.*, 2019). This, in turn, may decrease the macronutrient content in soil. Macronutrients are very important in plant growth vis-à-vis productivity and yield. The high level of food insecurity and environmental challenges in south east Nigeria may be attributed to high rate of deforestation, sharp decline in soil nutrient due to low biomass production by plants as well as low rate of litter decomposition by micro and macro organisms in soil.

The mining environment alters the climatic and edaphic complexes of the plant communities leading to a drastic reduction in the plant growth (Down, 1974). Mine spoils constitute very rigid substrata that hardly encourage plant growth and development (Sarma, 2002). Soil particles size (Down, 1974) and compaction (Hall, 1957; Richardson, 1975) influence the colonization of plants on overburdens. Richardson *et al.* (1971) reported that with high clay content, the soils become water logged, whereas with high silt content, the soils become compact forming crust that restrict seedling growth and entry of water and air into the soil system.

Coal processing activities releases heavy metals into the surroundings (Ogbonna *et al.*, 2018a, b). High level of heavy metal accumulation in forest soils affect nutrient recycling in the ecosystem by impeding litter decomposition (Fritze *et al.*, 1989) and release of nutrients by mineralization (Derome and Lindroos, 1998). Heavy metals also produce toxic effects on roots and mycorrhizas (Colpaert and Van Assche, 1992) which reduces nutrient uptake by plants (Derome and Nieminen, 1998). The decline in nutrient uptake culminates in poor growth and loss of vigour by the plants (Lukina *et al.*, 1993; Freedman and Hutchinson, 1980) thus, reducing vegetal regrowth.

Coal mining as a land use has the capacity of changing ecological processes because of the nature of the mineral, method of exploitation and the extensive area involved. A literature search showed that no work has been carried out on macronutrient content in seven plant species growing on or near coal mine sites in Nigeria. The seven species sampled in this study (*Irvingia gabonensis*, *Dialium guinense*, *Mangifera indica*, *Icacina trichantha*, *Alchornea cordifolia*, *Andropogon gayanus*, and *Manihot esculenta*) are very important source of nutritional fruits (*Mangifera indica*, *Irvingia gabonensis*, *Dialium guinense*), medicine (*Icacina trichantha*), condiment (*Irvingia gabonensis*) and staple food (*Manihot esculenta*) for man while *Andropogon gayanus* and *Alchornea cordifolia* are important fodder plants for herbivores in South east Nigeria (Ogbonna *et al.*, 2018c). This study, therefore, is aimed at investigating the values of macronutrient in plants around the coal mine sites. The results of the study will provide the background information on the levels of macronutrient in the plants and contribute to knowledge.

MATERIALS AND METHODS

2.1. The Study Area

The study was carried out at Akwuke and Iva mining sites in Enugu State, south east Nigeria. It has large deposit of sub-bituminous coal and lies within latitude 6^{o} 23' and 6^{o} 26' N and longitude 7^{o} 27' and 7^{o} 30' E (Ogbonna *et al.*, 2018b) and the mean monthly temperature lies between 27 and 29 °C (Ekere and Ukoha, 2013). The area has tropical climate and experiences two seasons both of which are warm. The shales weather rapidly to red clay soil that forms lateritic capping of considerably thickness (Ezeigbo and Ezeanyim, 1993). The three largely conformable geologic formations are Enugu shale (Campanian), the Mamu

Formation (Lower Maastrichtian) and the Ajali sandstone (Upper Maastrichtian) which constitutes the geology of the Enugu coal mine area. The Mamu formation consists of fine to medium grained sandstones, sandy shales, shales and mudstones. The formations are highly fractured and are about 395 km in the area and contain pyrite flakes and show sulphur stains (Ezeigbo and Ezeanyim, 1993). The Ajali Sandstone which overlies the Mamu formation consists of thick friable, poorly sorted highly cross-bedded sandstone that is generally white in colour but sometimes is iron stained, and is about 406m thick in the area that is overlain by lateritic/red earth deposit (Ezeigbo and Ezeanyim, 1993).

2.2. Sample Collection

Prior to the sample collection, a reconnaissance survey was carried out to determine the altitude of the mined sites (251 and 259 m for Akwuke and Iva mines, respectively), and plant species that were common at the 2 mined sites since mining sites are very slow in vegetation regrowth. The control samples were taken from a 5-year upland bush fallow that is 2 km away from the abandoned mines.

2.3. Plant Sampling and Analysis of Macronutrients Content

In this study, plant sampling for determination of macronutrient content in plants was carried out on individual plant species that had up to 3 frequency of occurrence in each of the mined (Akwuke and Iva) and unmined (control) sites. Mature leaves were sampled from different shoots/branches and parts of different woody species 7-9 years of age, except for root crops (cassava) and grass (gamba grass) that is less than 2 years. The leaves of *Andropogon gayanus* (Gamba grass, Family- Poaceae), *Irvingia gabonensis* (Wild.) (bush mango, Family- Irvingiaceae), *Dialium guinense* wild (black velvet, velvet tamarind, Family- Fabaceae), *Mangifera indica* L. (mango, Family- Anacardiaceae), *Alchornea cordifolia* (Schum. & Thonn.) Muell. Arg. (christmas bush, Family- Euphorbiaceae), *Icacina trichantha* Oliv. (pflamzenfen, Family- Icacinaceae), and *Manihot esculenta* (cassava, Family- Euphorbiaceae) were randomly collected in February (dry season) and June (wet season) separately from each individual plant using well-cleaned secateurs at the 2 mined locations and unmined plot (a 5 year upland bush fallow that is 2 km from the mined sites where there was no visible source of contamination). Three replicates of each plant species were collected and mixed separately to obtain a composite sample. The plant samples were cleaned sequentially with a phosphate–free detergent (Extran 2 %), rinsed once with tap water, once with distilled water and finally twice with deioninized water to remove adhering materials such as dust and pollen particles and placed in large clean crucibles where they were oven dried at 60^{o}C for 72 h. Thereafter, the dried plant samples were milled with a Thomas Wiley milling machine (Model ED-5 USA). The procedure according to Awofolu (2005) was used for digestion of plant sample. Each sieved leaf sample (0.5 g) was weighed into a 100 ml beaker. A mixture of 5 ml concentrated trioxonitrate (IV) acid and 2 ml perchloric acid was added and digested at 80 ^{o}C using hot plate until the content was about 2 ml. The digest was allowed to cool, filtered into 50 ml standard flask using 0.45 um Millipore filter kit. The beaker was rinsed with small portions of doubled distilled water and then filtered into the flask.

2.4. Macro-element Content

The macro-elements were determined by milling the leaf samples and digesting according to the wet digestion method of Novozamsky *et al.* (1983) for multi-element plant analysis. Ca and Mg in the digest were determined by EDTA titration method, K was determined by flame photometry, P was determined by the Vanodo-molybdate spectrophotometric method while N was determined by the micro Kjeldahl distillation method (Bremner and Mulvancy, 1982).

2.5. Experimental Design and Data Analysis

A single factor experiment was conducted in a randomized complete block design (RCBD) with 3 replications. Data collected on macronutrient content in plant species were subjected to a 2-way analysis of variance (ANOVA) using Statistical Package for Social Sciences (SPSS) v. 15 and means were separated (Steel and Torrie, 1980) at $P < 0.05$ using Duncan New Multiple Range Test (DNMRT).

3. RESULTS AND DISCUSSION

3.1. Macronutrient Content in Plants in wet and dry Season at Akwuke and Iva Mining Sites

Tables 1 and 2 summarized the content (levels) of macronutrients in plants in wet and dry season at the mining sites (Akwuke and Iva mine) as well as the control site. The results indicate that the highest and the lowest macronutrient in plants were obtained at the control site and the mine sites, respectively. Since soil organic matter (SOM) level at the control site is significantly ($p<0.05$) higher than SOM at the mined sites (Tables 3 and 4), the high macronutrient in plants at the control site is attributed to effective decomposition of organic material by micro and macro organisms, release of macronutrients and subsequent uptake by plants. Organic matter (OM) build up aid in steady supply and absorption of nutrients, and make the soil less susceptible to leaching and erosion (Reijntjes *et al*., 1992; Sekhon and Meelu, 1994). The highest content of Ca (25.71 ± 3.80 cmol/kg) in *Irvingia gabonensis*, Mg (375.80 ± 7.35 cmol/kg) and N (3.76 ± 0.08 cmol/kg) in *Andropogon gayanus*, P (1.21 ± 0.15 cmol/kg) in *Alchornea cordifolia*, and K (639.85 ± 11.53 cmol/kg) in *Dialium guinense* at the control site during dry season is significantly ($p<0.05$) higher than the highest values of 13.36 ± 0.25 (*I. gabonensis*), 350.10 ± 0.42 cmol/kg (*A. gayanus*), 2.28 ± 0.20 cmol/kg (*A. gayanus*), 0.40 ± 0.03 cmol/kg (*A. gayanus*), and 607.30 ± 3.82 cmol/kg (*D. guinense*) as well as 12.61 ± 0.06 cmol/kg (*A. cordifolia*), 197.10 ± 1.27 cmol/kg (*M. esculenta*), 0.37 ± 0.03 cmol/kg (*A. gayanus*), 0.32 ± 0.07 cmol/kg and 279.00 ± 14.71 cmol/kg (*M. esculenta*) obtained for Ca, Mg, N, P and K at the mined sites (Akwuke and Iva mine) in wet and dry season, respectively. The values of Ca (25.71 ± 3.80 cmol/kg), Mg (375.80 ± 7.35 cmol/kg), N (3.76 ± 0.08 cmol/kg), P (1.21 ± 0.15 cmol/kg), and K (639.85 ± 11.53 cmol/kg) at the control site is 1.92, 1.07, 1.65, 3.03 and 1.05 times higher than the values of these macronutrients (Ca, Mg, N, P, and K) at Akwuke mining site as well as 2.04, 1.91, 10.16, 3.78 and 2.15 times higher than the values obtained at Iva mining site, respectively. The values of macronutrients at the control site were observed to have peaked during the dry season. Lower levels of macronutrient in plants during the wet season may be attributed to dilution effect via through-fall by rain especially in the early wet season.

The level of all macronutrients in plants at the study sites were raised to different levels in wet and dry season. Among the macronutrients investigated in plants at the two mine sites, K recorded the highest value in plant species with 607.30 ± 3.82 cmol/kg (*D. guinense*) at Akwuke mine. The value of K (607.30 ± 3.82 cmol/kg) is 45.46, 1.73, 266.36, and 1,518.25 times higher than the highest values recorded for Ca, Mg, N, and P at the mining sites site.

Table 1: Macronutrient content (cmol/kg) in plants in wet and dry seasons at Akwuke mining site

Plants/season	Ca	Mg	K	N	P
Irvingia gabonensis (wet)	$10.11^{efg} \pm 0.14$	$288.10^{e} \pm 12.02$	$548.60^{ef} \pm 1.41$	$0.23^{jk} \pm 0.03$	$0.12^{fg} \pm 0.03$
Irvingia gabonensis (dry)	$13.36^{d} \pm 0.25$	$302.80^{cde} \pm 1.41$	$560.50^{e} \pm 2.26$	$0.31^{jk} \pm 0.03$	$0.08^{g} \pm 0.00$
Irvingia gabonensis control (wet)	$22.08^{b} \pm 2.86$	$315.74^{cd} \pm 8.31$	$574.35^{d} \pm 5.16$	$0.35^{jk} \pm 0.06$	$0.89^{bcd} \pm 0.21$
Irvingia gabonensis control (dry)	$25.71^{a} \pm 3.80$	$322.05^{c} \pm 5.73$	$582.30^{cd} \pm 5.80$	$0.42^{ij} \pm 0.06$	$1.12^{ab} \pm 0.20$
Dialium guinense (wet)	$4.24^{lmn} \pm 0.11$	$108.90^{m} \pm 1.98$	$607.30^{b} \pm 3.82$	$0.14^{jk} \pm 0.01$	$0.20^{efg} \pm 0.03$
Dialium guinense (dry)	$5.18^{kjlm} \pm 0.04$	$150.20^{kl} \pm 0.71$	$591.70^{c} \pm 3.82$	$0.22^{jk} \pm 0.06$	$0.22^{efg} \pm 0.06$
Dialium guinense control (wet)	$8.89^{fgh} \pm 0.40$	$176.00^{ijk} \pm 6.51$	$635.30^{a} \pm 11.60$	$0.26^{jk} \pm 0.03$	$0.87^{bcd} \pm 0.23$
Dialium guinense control (dry)	$10.89^{def} \pm 0.11$	$181.95^{ij} \pm 5.87$	$639.85^{a} \pm 11.53$	$0.34^{jk} \pm 0.07$	$1.08^{ab} \pm 0.30$
Mangifera indica (wet)	$13.30^{d} \pm 0.07$	$93.10^{m} \pm 0.85$	$59.10^{r} \pm 1.84$	$0.28^{jk} \pm 0.03$	$0.10^{fg} \pm 0.04$
Mangifera indica (dry)	$10.01^{efg} \pm 0.06$	$116.40^{m} \pm 0.85$	$63.10^{r} \pm 0.42$	$0.11^{k} \pm 0.04$	$0.08^{g} \pm 0.03$
Mangifera indica control (wet)	$16.21^{c} \pm 0.39$	$169.05^{jk} \pm 4.88$	$209.55^{mn} \pm 3.61$	$0.99^{efg} \pm 0.14$	$0.77^{cd} \pm 0.06$
Mangifera indica control (dry)	$17.88^{c} \pm 1.03$	$172.05^{ijk} \pm 5.73$	$215.30^{m} \pm 5.09$	$1.14^{ef} \pm 0.22$	$0.95^{bcd} \pm 0.04$
Icacina trichantha (wet)	$3.08^{mn} \pm 0.06$	$141.30^{l} \pm 1.13$	$178.20^{p} \pm 3.68$	$0.82^{gh} \pm 0.01$	$0.21^{efg} \pm 0.03$
Icacina trichantha (dry)	$2.47^{mn} \pm 0.16$	$154.30^{kl} \pm 50.49$	$164.20^{q} \pm 0.99$	$0.63^{hi} \pm 0.01$	$0.24^{efg} \pm 0.01$
Icacina trichantha control (wet)	$7.03^{hijk} \pm 0.22$	$168.05^{jk} \pm 8.56$	$191.20^{op} \pm 0.85$	$0.75^{gh} \pm 0.06$	$0.73^{d} \pm 0.08$
Icacina trichantha control (dry)	$7.60^{ghij} \pm 0.76$	$171.55^{ijk} \pm 9.69$	$196.30^{no} \pm 3.25$	$0.90^{fgh} \pm 0.06$	$0.92^{bcd} \pm 0.08$
Alchornea cordifolia (wet)	$8.20^{ghi} \pm 0.57$	$216.00^{g} \pm 1.70$	$326.20^{j} \pm 0.85$	$1.22^{e} \pm 0.17$	$0.30^{efg} \pm 0.04$
Alchornea cordifolia (dry)	$12.06^{de} \pm 0.48$	$218.20^{g} \pm 2.12$	$347.30^{i} \pm 0.85$	$1.18^{ef} \pm 0.08$	$0.36^{ef} \pm 0.06$
Alchornea cordifolia control (wet)	$13.15^{d} \pm 2.62$	$251.30^{f} \pm 12.02$	$372.15^{h} \pm 5.87$	$1.94^{d} \pm 0.05$	$1.03^{abc} \pm 0.01$
Alchornea cordifolia control (dry)	$15.95^{c} \pm 1.51$	$254.55^{f} \pm 10.54$	$375.70^{h} \pm 7.64$	$2.09^{cd} \pm 0.04$	$1.21^{a} \pm 0.15$
Andropogon gayanus (wet)	$3.82^{lmn} \pm 0.08$	$350.10^{b} \pm 0.42$	$542.90^{f} \pm 1.98$	$2.28^{c} \pm 0.20$	$0.26^{efg} \pm 0.03$
Andropogon gayanus (dry)	$4.81^{klmn} \pm 0.07$	$293.40^{de} \pm 1.13$	$501.00^{g} \pm 0.85$	$2.16^{cd} \pm 0.11$	$0.40^{e} \pm 0.03$
Andropogon gayanus control (wet)	$7.86^{ghij} \pm 0.49$	$371.40^{ab} \pm 5.94$	$552.15^{ef} \pm 16.62$	$3.24^{b} \pm 0.32$	$0.75^{d} \pm 0.06$
Andropogon gayanus control (dry)	$9.36^{fgh} \pm 1.76$	$375.80^{a} \pm 7.35$	$555.65^{ef} \pm 17.75$	$3.76^{a} \pm 0.08$	$0.92^{bcd} \pm 0.08$
Manihot esculenta (wet)	$2.42^{n} \pm 0.08$	$186.30^{hij} \pm 0.71$	$292.90^{k} \pm 5.23$	$0.20^{jk} \pm 0.07$	$0.25^{efg} \pm 0.03$
Manihot esculenta (dry)	$3.78^{lmn} \pm 0.13$	$197.10^{ghi} \pm 0.28$	$265.20^{l} \pm 1.84$	$0.20^{jk} \pm 0.03$	$0.32^{ef} \pm 0.04$
Manihot esculenta control (wet)	$6.11^{ijkl} \pm 0.13$	$207.55^{gh} \pm 6.15$	$317.70^{j} \pm 6.65$	$0.77^{gh} \pm 0.30$	$0.91^{bcd} \pm 0.16$
Manihot esculenta control (dry)	$7.63^{ghij} \pm 0.24$	$212.45^{g} \pm 5.44$	$321.30^{j} \pm 3.82$	$1.04^{efg} \pm 0.25$	$1.07^{ab} \pm 0.19$

a, b, c, d, e, f, g, h, i, j, k, l, m, n, o, p, q, r, means in a column with different superscript are significantly different ($P<0.05$), values are mean ± standard deviation of 3 replications

Table 2: Macronutrient content (cmol/kg) in plants in wet and dry seasons at Iva mining site

Plants/season	Ca	Mg	K	N	P
Irvingia gabonensis (wet)	3.08^{j} ± 0.06	40.60^{o} ± 1.56	84.40^{n} ± 0.71	0.16^{fgh} ± 0.03	0.13^{e} ± 0.03
Irvingia gabonensis (dry)	4.02^{ij} ± 0.08	58.40^{n} ± 1.41	72.10^{n} ± 0.85	0.21^{fgh} ± 0.01	0.08^{e} ± 0.06
Irvingia gabonensis control (wet)	22.08^{b} ± 2.86	315.74^{b} ± 8.31	574.35^{b} ± 5.16	0.35^{fgh} ± 0.06	0.89^{bcd} ± 0.21
Irvingia gabonensis control (dry)	25.71^{a} ± 3.80	322.05^{b} ± 5.73	582.30^{b} ± 5.80	0.42^{f} ± 0.06	1.12^{ab} ± 0.20
Dialium guinense (wet)	8.70^{efgh} ± 0.01	81.00^{m} ± 1.98	108.60^{m} ± 1.84	0.08^{h} ± 0.00	0.18^{e} ± 0.04
Dialium guinense (dry)	7.94^{fgh} ± 0.11	68.20^{n} ± 1.27	103.10^{m} ± 1.13	0.18^{fgh} ± 0.03	0.28^{e} ± 0.06
Dialium guinense control (wet)	8.89^{efg} ± 0.40	176.00^{ghi} ± 6.51	635.30^{a} ± 11.60	0.26^{fgh} ± 0.03	0.87^{bcd} ± 0.23
Dialium guinense control (dry)	10.89^{de} ± 0.11	181.95^{gh} ± 5.87	639.85^{a} ± 11.53	0.34^{fgh} ± 0.07	1.08^{ab} ± 0.30
Mangifera indica (wet)	8.40^{efgh} ± 0.71	136.30^{j} ± 2.40	180.10^{jk} ± 0.71	0.11^{gh} ± 0.04	0.11^{e} ± 0.03
Mangifera indica (dry)	11.07^{de} ± 0.04	148.30^{j} ± 0.99	162.00^{l} ± 0.95	0.17^{fgh} ± 0.03	0.16^{e} ± 0.03
Mangifera indica control (wet)	16.21^{c} ± 0.39	169.05^{i} ± 4.88	209.55^{gh} ± 3.61	0.99^{de} ± 0.14	0.77^{cd} ± 0.06
Mangifera indica control (dry)	17.88^{c} ± 1.03	172.05^{hi} ± 5.73	215.30^{g} ± 5.09	1.14^{d} ± 0.22	0.95^{bcd} ± 0.04
Icacina trichantha (wet)	3.51^{ij} ± 0.07	118.20^{k} ± 1.98	170.00^{kl} ± 1.41	0.17^{fgh} ± 0.03	0.16^{e} ± 0.03
Icacina trichantha (dry)	2.30^{j} ± 0.57	143.20^{j} ± 0.57	157.20^{l} ± 0.42	0.19^{fgh} ± 0.04	0.25^{e} ± 0.06
Icacina trichantha control (wet)	7.03^{gh} ± 0.22	168.05^{i} ± 8.56	191.20^{ij} ± 0.85	0.75^{e} ± 0.06	0.73^{d} ± 0.08
Icacina trichantha control (dry)	7.60^{fgh} ± 0.76	171.55^{hi} ± 9.69	196.30^{hi} ± 3.25	0.90^{de} ± 0.06	0.92^{bcd} ± 0.08
Alchornea cordifolia (wet)	10.01^{ef} ± 0.16	122.70^{k} ± 1.56	199.40^{hi} ± 0.99	0.14^{fgh} ± 0.03	0.26^{e} ± 0.06
Alchornea cordifolia (dry)	12.61^{d} ± 0.06	139.60^{j} ± 0.21	186.40^{ij} ± 5.80	0.23^{fgh} ± 0.06	0.11^{e} ± 0.03
Alchornea cordifolia control (wet)	13.15^{d} ± 2.62	251.30^{c} ± 12.02	372.15^{d} ± 5.87	1.94^{c} ± 0.05	1.03^{abc} ± 0.01
Alchornea cordifolia control (dry)	15.95^{c} ± 1.51	254.55^{c} ± 10.54	375.70^{d} ± 7.64	2.09^{c} ± 0.04	1.21^{a} ± 0.15
Andropogon gayanus (wet)	6.00^{hi} ± 0.20	113.40^{k} ± 1.56	114.50^{m} ± 1.84	0.30^{fgh} ± 0.07	0.16^{e} ± 0.01
Andropogon gayanus (dry)	4.11^{ij} ± 0.04	102.00^{l} ± 0.57	108.00^{m} ± 0.57	0.37^{fg} ± 0.03	0.22^{e} ± 0.07
Andropogon gayanus control (wet)	7.86^{fgh} ± 0.49	371.40^{a} ± 5.94	552.15^{c} ± 16.62	3.24^{b} ± 0.32	0.75^{d} ± 0.06
Andropogon gayanus control (dry)	9.36^{efg} ± 1.76	375.80^{a} ± 7.35	555.65^{c} ± 17.75	3.76^{a} ± 0.08	0.92^{bcd} ± 0.08
Manihot esculenta (wet)	2.42^{j} ± 0.14	186.00^{fg} ± 1.98	279.00^{f} ± 14.71	0.20^{fgh} ± 0.01	0.25^{e} ± 0.03
Manihot esculenta (dry)	3.78^{ij} ± 0.25	197.10^{ef} ± 1.27	265.20^{f} ± 0.99	0.20^{fgh} ± 0.07	0.32^{e} ± 0.07
Manihot esculenta control (wet)	6.11^{hi} ± 0.13	207.55^{de} ± 6.15	317.70^{e} ± 6.65	0.77^{e} ± 0.30	0.91^{bcd} ± 0.16
Manihot esculenta control (dry)	7.63^{fgh} ± 0.24	212.45^{d} ± 5.44	321.30^{e} ± 3.82	1.04^{d} ± 0.25	1.07^{ab} ± 0.19

a, b, c, d, e, f, g, h, i, j, k, l, m, n, o means in a column with different superscript are significantly different (P<0.05), values are mean ± standard deviation of 3 replications

Table 3: Macronutrient (cmol/kg), soil pH and organic matter (%) content in soil at Akwuke mining site in wet and dry season (Ogbonna *et al.*, 2018a)

Location	Depth	Season	Ca	Mg	K	N	P	pH (H_2O)	OM (%)
Crest	0-10cm	Wet	4.22^{efg} ± 0.06	147.00^{l} ± 1.41	179.10^{h} ± 0.71	0.10^{e} ± 0.01	0.20^{l} ± 0.03	4.60^{fgh} ± 0.02	0.86^{c} ± 0.05
		Dry	6.02^{cde} ± 0.14	251.90^{e} ± 1.41	119.55^{n} ± 0.64	0.22^{de} ± 0.04	0.34^{ghi} ± 0.13	4.34^{ij} ± 0.04	0.96^{c} ± 0.04
	10-20cm	Wet	4.29^{efg} ± 0.20	137.00^{jk} ± 2.12	183.90^{h} ± 1.56	0.13^{e} ± 0.03	0.34^{ghi} ± 0.03	4.53^{h} ± 0.03	0.20^{b} ± 0.01
		Dry	8.12^{bc} ± 0.14	183.20^{g} ± 0.42	87.10^{o} ± 0.57	0.29^{de} ± 0.06	0.43^{gh} ± 0.06	4.39^{i} ± 0.06	0.22^{e} ± 0.00
	20-30cm	Wet	4.25^{efg} ± 0.13	142.00^{ij} ± 1.41	180.60^{h} ± 1.56	0.16^{e} ± 0.03	0.27^{hi} ± 0.03	4.58^{gh} ± 0.05	0.03^{g} ± 0.01
		Dry	4.11^{efg} ± 0.14	168.00^{h} ± 0.28	158.00^{ij} ± 12.73	0.20^{de} ± 0.03	0.31^{hi} ± 0.04	4.22^{jkl} ± 0.08	0.13^{f} ± 0.04
Middle slope	0-10cm	Wet	2.81^{fgh} ± 0.11	133.70k ± 1.27	182.50^{h} ± 0.85	0.12^{e} ± 0.01	0.35^{ghi} ± 0.03	4.68^{fg} ± 0.02	0.64^{d} ± 0.05
		Dry	4.16^{efg} ± 0.06	169.00^{h} ± 1.13	95.60^{o} ± 0.99	0.28^{de} ± 0.06	0.38^{ghi} ± 0.04	4.31^{ijk} ± 0.08	0.75^{cd} ± 0.01
	10-20cm	Wet	1.65^{gh} ± 0.03	115.10^{m} ± 0.71	156.10^{jk} ± 0.42	0.14^{e} ± 0.03	0.42^{gh} ± 0.01	4.72^{f} ± 0.02	0.11^{f} ± 0.01
		Dry	4.09^{efg} ± 0.04	121.80^{l} ± 1.27	151.80^{jk} ± 0.57	0.36^{de} ± 0.03	0.46^{gh} ± 0.04	4.19^{kl} ± 0.05	0.12^{f} ± 0.00
	20-30cm	Wet	2.20^{gh} ± 0.06	123.00^{l} ± 0.85	168.00^{i} ± 14.14	0.17^{de} ± 0.03	0.39^{ghi} ± 0.04	4.29^{jk} ± 0.03	0.02^{g} ± 0.01
		Dry	2.00^{gh} ± 0.20	108.00^{n} ± 0.85	122.10^{n} ± 0.71	0.24^{de} ± 0.06	0.52^{g} ± 0.06	4.14^{l} ± 0.03	0.06^{g} ± 0.03
Valley	0-10cm	Wet	1.21^{h} ± 0.04	86.25^{o} ± 0.21	145.95^{kl} ± 0.64	0.11^{e} ± 0.01	0.28^{hi} ± 0.06	6.10^{b} ± 0.13	0.15^{f} ± 0.04
		Dry	4.02^{efg} ± 0.13	193.50^{f} ± 0.85	126.80^{mn} ± 1.27	0.19^{de} ± 0.04	0.33^{ghi} ± 0.06	5.39^{e} ± 0.07	0.28^{e} ± 0.02
	10-20cm	Wet	2.05^{gh} ± 0.07	68.30^{q} ± 0.71	124.70^{n} ± 1.70	0.14^{e} ± 0.03	0.36^{ghi} ± 0.03	6.14^{b} ± 0.04	0.05^{g} ± 0.01
		Dry	1.05^{h} ± 0.07	120.20^{lm} ± 0.85	212.00^{f} ± 0.57	0.23^{de} ± 0.14	0.41^{gh} ± 0.04	5.39^{e} ± 0.21	0.03^{g} ± 0.01
	20-30cm	Wet	1.70^{gh} ± 0.08	78.00^{p} ± 0.57	136.40^{lm} ± 0.28	0.13^{e} ± 0.01	0.30^{hi} ± 0.06	5.83^{c} ± 0.05	0.01^{gh} ± 0.00
		Dry	1.16^{h} ± 0.16	89.60^{o} ± 1.41	158.20^{ij} ± 0.57	0.19^{de} ± 0.14	0.42^{gh} ± 0.04	5.58^{d} ± 0.02	0.01^{gh} ± 0.00
Control	0-10cm	Wet	9.60^{b} ± 0.08	301.10^{d} ± 0.85	422.00^{b} ± 0.57	0.81^{c} ± 0.08	2.94^{f} ± 0.11	6.52^{a} ± 0.06	20.66^{a} ± 0.08
		Dry	12.04^{a} ± 0.08	380.00^{a} ± 1.13	471.00^{a} ± 4.24	1.46^{a} ± 0.10	3.21^{e} ± 0.27	6.55^{a} ± 0.14	26.21^{a} ± 0.34
	10-20cm	Wet	7.14^{bcd} ± 0.23	310.00^{c} ± 12.73	280.10^{d} ± 0.85	0.92^{c} ± 0.08	4.01^{d} ± 0.16	6.48^{a} ± 0.08	1.06^{c} ± 0.07
		Dry	9.20^{b} ± 0.07	367.10^{b} ± 4.10	316.00^{c} ± 13.86	1.20^{b} ± 0.16	4.40^{c} ± 0.03	6.19^{b} ± 0.03	1.15^{b} ± 0.09
	20-30cm	Wet	4.03^{efg} ± 0.13	198.10^{f} ± 0.85	200.00^{g} ± 2.83	0.44^{d} ± 0.45	5.82^{b} ± 0.01	6.24^{b} ± 0.04	0.00^{gh} ± 0.00
		Dry	5.16^{def} ± 0.14	248.00^{e} ± 1.56	224.00^{e} ± 1.70	1.01^{bc} ± 0.01	6.28^{a} ± 0.14	5.90^{c} ± 0.10	0.00^{gh} ± 0.00

a, b, c, d, e, f, g, h, i, j, k, l, m, n, o, p, q means in a column with different superscript are significantly different (P<0.05). Values are mean ± standard deviation of 3 replications; OM = organic matter

Table 4: Macronutrient (cmol/kg), soil pH and organic matter (%) content in soil at Iva mining site in wet and dry season (Ogbonna *et al*., 2018b)

Location	Depth	Season	Ca	Mg	K	N	P	pH (H_2O)	OM (%)
Crest	0-10cm	Wet	$6.83^{e} \pm 0.10$	$268.90^{c} \pm 12.87$	$278.70^{d} \pm 13.86$	$0.14^{fgh} \pm 0.03$	$0.40^{lmn} \pm 0.42$	$4.12^{jk} \pm 0.10$	$0.86^{c} \pm 0.05$
		Dry	$1.05^{l} \pm 0.14$	$180.70^{ef} \pm 1.70$	$118.80^{ij} \pm 1.84$	$0.19^{e-h} \pm 0.03$	$0.14^{n} \pm 0.04$	$4.82^{m} \pm 0.08$	$0.96^{c} \pm 0.04$
	10-20cm	Wet	$2.84^{j} \pm 0.14$	$248.90^{cd} \pm 1.84$	$191.50^{fgh} \pm 0.99$	$0.09^{h} \pm 0.01$	$0.50^{k-n} \pm 0.10$	$4.20^{ij} \pm 0.03$	$0.50^{de} \pm 0.13$
		Dry	$1.02^{l} \pm 0.14$	$129.80^{g} \pm 0.28$	$97.50^{jkl} \pm 0.99$	$0.13^{fgh} \pm 0.03$	$0.62^{i-m} \pm 0.06$	$4.07^{kl} \pm 0.06$	$0.57^{de} \pm 0.07$
	20-30cm	Wet	$3.86^{h} \pm 0.06$	$259.00^{cd} \pm 15.56$	$230.10^{ef} \pm 1.56$	$0.07^{h} \pm 0.01$	$0.36^{mn} \pm 0.08$	$4.27^{hi} \pm 0.07$	$0.03^{g} \pm 0.01$
		Dry	$1.80^{k} \pm 0.06$	$130.70^{g} \pm 1.56$	$168.10^{gh} \pm 0.28$	$0.26^{ef} \pm 0.07$	$0.38^{lmn} \pm 0.13$	$3.99^{kl} \pm 0.01$	$0.13^{f} \pm 0.04$
Middle slope	0-10cm	Wet	$0.81^{l} \pm 0.03$	$239.80^{d} \pm 13.86$	$192.60^{fgh} \pm 1.13$	$0.06^{h} \pm 0.03$	$1.20^{fgh} \pm 0.06$	$4.37^{h} \pm 0.08$	$0.06^{g} \pm 0.01$
		Dry	$4.15^{g} \pm 0.07$	$167.40^{f} \pm 0.85$	$112.60^{ijk} \pm 1.56$	$0.09^{b} \pm 0.01$	$1.23^{fg} \pm 0.10$	$4.06^{kl} \pm 0.06$	$0.75^{d} \pm 0.01$
	10-20cm	Wet	$5.18^{f} \pm 0.03$	$319.40^{b} \pm 0.85$	$343.00^{c} \pm 0.28$	$0.12^{fgh} \pm 0.03$	$0.84^{h-k} \pm 0.11$	$4.23^{ij} \pm 0.08$	$0.01^{h} \pm 0.00$
		Dry	$3.36^{i} \pm 0.06$	$102.00^{h} \pm 0.99$	$92.10^{jkl} \pm 0.42$	$0.25^{efg} \pm 0.08$	$0.90^{g-j} \pm 0.08$	$4.05^{kl} \pm 0.05$	$0.12^{f} \pm 0.00$
	20-30cm	Wet	$2.90^{j} \pm 0.21$	$235.80^{d} \pm 47.66$	$258.60^{de} \pm 5.66$	$0.80^{d} \pm 0.06$	$1.42^{f} \pm 0.06$	$3.98^{kl} \pm 0.03$	$0.00^{h} \pm 0.00$
		Dry	$2.81^{j} \pm 0.07$	$116.00^{gh} \pm 1.70$	$88.30^{jkl} \pm 16.12$	$0.12^{fg} \pm 0.01$	$0.64^{i-m} \pm 0.11$	$3.96^{l} \pm 0.14$	$0.00^{h} \pm 0.00$
Valley	0-10cm	Wet	$1.63^{k} \pm 0.10$	$256.80^{cd} \pm 3.11$	$187.20^{fgh} \pm 11.60$	$0.20^{e-h} \pm 0.06$	$0.76^{i-l} \pm 0.13$	$6.00^{c} \pm 0.10$	$1.04^{bc} \pm 0.06$
		Dry	$5.33^{f} \pm 0.10$	$124.40^{gh} \pm 3.68$	$90.60^{jkl} \pm 0.57$	$0.26^{ef} \pm 0.07$	$0.81^{ijk} \pm 0.04$	$5.05^{f} \pm 0.05$	$1.14^{b} \pm 0.02$
	10-20cm	Wet	$1.64^{k} \pm 0.11$	$252.00^{cd} \pm 0.57$	$149.10^{hi} \pm 0.71$	$0.16^{e-h} \pm 0.01$	$0.49^{k-n} \pm 0.16$	$5.70^{d} \pm 0.10$	$0.92^{c} \pm 0.05$
		Dry	$5.12^{f} \pm 0.16$	$120.40^{gh} \pm 0.85$	$57.10^{l} \pm 0.57$	$0.29^{e} \pm 0.03$	$0.53^{j-m} \pm 0.04$	$5.34^{e} \pm 0.10$	$0.89^{c} \pm 0.01$
	20-30cm	Wet	$1.64^{k} \pm 0.03$	$250.40^{cd} \pm 0.85$	$88.35^{jkl} \pm 2.18$	$0.11^{gh} \pm 0.03$	$0.82^{ijk} \pm 0.10$	$5.45^{e} \pm 0.05$	$0.00^{h} \pm 0.00$
		Dry	$3.20^{i} \pm 0.08$	$106.00^{gh} \pm 0.99$	$63.00^{kl} \pm 0.71$	$0.18^{e-h} \pm 0.06$	$0.92^{ghi} \pm 0.08$	$4.68^{g} \pm 0.02$	$0.01^{h} \pm 0.00$
Control	0-10cm	Wet	$9.10^{b} \pm 0.08$	$301.10^{b} \pm 0.85$	$422.00^{b} \pm 0.57$	$0.81^{d} \pm 0.08$	$2.94^{e} \pm 0.11$	$6.52^{a} \pm 0.06$	$20.66^{a} \pm 0.08$
		Dry	$12.04^{a} \pm 0.08$	$380.00^{a} \pm 1.13$	$471.00^{a} \pm 4.24$	$1.46^{b} \pm 0.10$	$3.21^{e} \pm 0.27$	$6.55^{a} \pm 0.14$	$26.21^{a} \pm 0.34$
	10-20cm	Wet	$7.14^{d} \pm 0.23$	$310.00^{b} \pm 12.73$	$280.10^{d} \pm 0.85$	$0.92^{cd} \pm 0.08$	$4.01^{d} \pm 0.16$	$6.48^{a} \pm 0.08$	$1.06^{bc} \pm 0.07$
		Dry	$9.20^{c} \pm 0.07$	$367.10^{b} \pm 4.10$	$316.00^{cd} \pm 13.86$	$1.20^{a} \pm 0.16$	$4.40^{c} \pm 0.03$	$6.19^{b} \pm 0.03$	$1.15^{b} \pm 0.09$
	20-30cm	Wet	$4.03^{gh} \pm 0.13$	$198.10^{e} \pm 0.85$	$200.00^{fg} \pm 2.83$	$0.44^{c} \pm 0.45$	$5.82^{b} \pm 0.01$	$6.24^{b} \pm 0.04$	$0.00^{h} \pm 0.00$
		Dry	$5.16^{f} \pm 0.14$	$248.00^{cd} \pm 1.56$	$224.00^{ef} \pm 1.70$	$1.01^{c} \pm 0.01$	$6.53^{a} \pm 0.14$	$5.90^{c} \pm 0.10$	$0.00^{h} \pm 0.00$

a, b, c, d, e, f, g, h, I, j, k, l, men means in a column with different superscript are significantly different (P<0.05). Values are mean ± standard deviation of 3 replications; OM = organic matter

Between the two mined sites, the contents of Ca, Mg, K, N and P in Akwuke mine are 1.06, 1.78, 6.16, 1.25 and 2.04 times higher than the values of Ca, Mg, K, N, and P in plants at Iva mining site. The highest Ca content in plants was obtained in *I. gabonensis* (13.36 ± 0.25 cmol/kg) at Akwuke mining site in dry season (Table 1) but this value is not different (p>0.05) from the highest value for Ca obtained from *A. cordifolia* (12.61 ± 0.06 cmol/kg) in dry season at Iva mining site (Table 2). Since the highest content of Ca (6.02 cmol/kg) in soil (0-10 cm crest) at Akwuke mining site (Table 3) and Ca (6.83 cmol/kg) in soil (0-10 cm crest) at Iva mining site (Table 4) are statistically the same (p>0.05), the high Ca in plants (*I. gabonensis* and *A. cordifolia*) may be attributed to the inherent ability of these plants to accumulate more Ca than other plant species at the two mined sites. In Akwuke mining site, the highest value of Ca was observed in *I. gabonensis* (13.36 ± 0.25 cmol/kg) during dry season and this value is significantly (P<0.05) higher than values obtained from *D. guinense* (4.24 ± 0.11 and 5.18 ± 0.04 cmol/kg), *I. trichantha* (3.08 ± 0.06 and 2.47 ± 0.16 cmol/kg), *A. gayanus* (3.82 ± 0.08 and 4.81 ± 0.07 cmol/kg), and *M. esculenta* (2.42 ± 0.08 and 3.78 ± 0.13 cmol/kg) but statistically (P>0.05) not different from values obtained in *A. cordifolia* (8.20 ± 0.57 and 12.06 ± 0.48 cmol/kg) and *M. indica* (13.30 ± 0.07 and 10.01 ± 0.06 cmol/kg) in wet and dry season, respectively. In Iva mining site, Ca is significantly (p<0.05) higher in *A. cordifolia* (12.61 ± 0.06 cmol/kg) in dry season. The highest Mg content in plants was obtained in *A. gayanus* (350.10 ± 0.42 cmol/kg) in wet season at Akwuke mine (Table 1) and this value is significantly (p<0.05) higher than the highest value for Mg (197.10 cmol/kg) in *M. esculenta* during dry season at Iva mining site (Table 2). Since the highest content of Mg (319.40 cmol/kg) in soil (10-20 cm) middle slope at Iva mine (Table 4) was significantly (p<0.05) higher than Mg (251.90 cmol/kg) in soil (0-10 cm crest) at Akwuke mine (Table 3), the form of Mg in soil solution (i.e. readily available for uptake) is implicated for the increased uptake of this nutrient in *A gayanus*. The value of Mg (350.10 ± 0.42 cmol/kg) in wet season, N (2.28 ± 0.20 cmol/kg) in wet season, and P (0.40 ± 0.03 cmol/kg) in dry season in *A. gayanus* were significantly (p<0.05) higher than values obtained for Mg, N, and P in *I. gabonensis, D. guinense, M. indica, I. trichantha, A. cordifolia*, and *M. esculenta* in wet and dry season at Akwuke mine (Table 1). Similarly, Mg (197.10 ± 1.27 cmol/kg) in dry season, P (0.32 ± 0.07 cmol/kg) in dry season, and K (279.00 ± 14.71 cmol/kg) in wet season were significantly (p<0.05) higher in

M. esculenta while N was in *A. gayanus* (0.37 ± 0.03 cmol/kg) in dry season. In this study, it was observed that *A. gayanus* and *M. esculenta* showed more preference for N, P, and K than Ca and Mg. Generally, plants require the major macronutrients (N, P, and K) for proper growth and development. Similarly, the highest content of K was obtained in *Dialium guinense* (607.30 ± 3.82 cmol/kg) in wet season at Akwuke mine (Table 1) and this value is significantly ($p<0.05$) higher than the highest value for K in *M. esculenta* (279.00 ± 14.71 cmol/kg) during wet season at Iva mine (Table 2). Since the highest content of K (343.00 cmol/kg) in soil (10-20 cm middle slope) at Iva mine (Table 4) was significantly higher than K (212.00 cmol/kg) in soil (10-20 cm valley) at Akwuke mine (Table 3), the form of K in soil solution (i.e. readily available for uptake) is implicated for the increased uptake of this nutrient in *D. guinense*. However, it was observed that the values of Mg in *Andropogon gayanus* (350.10 ± 0.42 cmol/kg) and K in *Dialium guinense* (607.30 ± 3.82 cmol/kg) were higher than the values of Mg (319.40 cmol/kg) and K (343.00 cmol/kg) in soil. The deep rooting system of *D. guinense* may have enhanced the uptake of K from depths (sub-soils) lower than 20-30 cm while the mass rooting system of *A. gayanus* may have enhanced accumulation of Mg in an important organ such as the leaf. The highest value of N was obtained in *A. gayanus* (2.28 ± 0.20 cmol/kg) in wet season at Akwuke mine (Table 1) and this value is significantly ($p<0.05$) higher than the highest value for N in *A. gayanus* (0.37 ± 0.03 cmol/kg) during dry season at Iva mine (Table 2). The higher value of N in *A. gayanus* sampled from Akwuke mine site may be attributed to its (N) occurrence at 10-20 cm depth in middle slope of Akwuke mine (Table 3) where it was easily assessed by the plant unlike the deeper depth of 20-30 cm middle slope of Iva mine (Table 4). The highest value of P in *A. gayanus* (0.40 ± 0.03 cmol/kg) in dry season at Akwuke mine is statistically ($P>0.05$) not different from the highest value obtained for P in *M. esculenta* (0.32 ± 0.07 cmol/kg) during dry season at Iva mine site. The high value of P (1.42 cmol/kg) in soil at Iva mine (Table 4) did not bring about higher uptake of this nutrient (P) in plants. Thus, intrinsic factors may be responsible for the low uptake of P in plant species.

3.2. Correlation Coefficient between Macronutrient in Soil and Plants in wet and dry Season at Akwuke and Iva Mining Sites

Table 5 summarized the correlation coefficient between macronutrient in soil and plants in wet season at Akwuke mine. Strong significant positive correlation occurred between Ca in soil and plant ($r=0.654$, $p<0.01$) as well as between P in soil and plant ($r=0.754$, $p<0.01$). Also, significant positive correlation occurred between Ca in plant and Mg ($r=0.630$, $p<0.01$) and K ($r=0.540$, $p<0.05$) in soil. Similarly, Mg significantly correlated with K ($r=0.566$, $p<0.05$) and N ($r=0.596$, $p<0.01$) in plant whereas N significantly correlated positive with P ($r=0.523$, $p<0.05$) in plant. Notwithstanding this, significant negative correlation occurred between P and Ca ($r=-0.742$, $P<0.01$) in soil. The significant positive correlation that occurred between Ca in soil and plant as well as P in soil and plant signify that the source of these macro elements (Ca and P) in plant is the soil and, that increase in soil content of Ca and P resulted to increase uptake in plant.

The correlation coefficient between macronutrient in soil and plants in dry season at Akwuke mine is presented in Table 6. Significant positive correlation occurred between P in soil and plant ($r=0.549$, $p<0.05$). Also, significant positive correlation occurred between Mg and N ($r=0.480$, $P<0.05$) in plant; K in plant and Mg ($r=0.520$, $P<0.05$) in soil; N and P ($r=0.574$, $p<0.05$) in soil while significant negative correlation occurred between Ca and P ($r=-0.512$, $P<0.05$) in plant; P and Mg ($r=-0.567$, $p<0.05$) in soil; Ca and K ($r=-0.710$, $p<0.01$). The significant positive correlation that occurred between P in soil and plant is a clear indication that the source of phosphorus in plant is the soil and, that increase in P content in soil resulted to increase uptake in plant.

Pearson correlation coefficient between macronutrient in soil and plants in wet season at Iva mine is summarized in Table 7. Significant positive correlation occurred between K and N ($r=0.700$, $p<0.01$) in plant; Ca and Mg ($r=0.517$, $p<0.05$) in soil; Mg and K ($r=0.538$, $p<0.05$) in soil; and N and P ($r=0.607$, $p<0.01$) in soil. Notwithstanding this, significant negative correlations occurred between Ca and K ($r=-0.620$,

$p<0.01$) in soil; Mg and P ($r=-0.483$, $p<0.05$) in soil; and K and P ($r=-0.517$, $p<0.05$) in soil. The significant positive correlations between one macro element and another macro element (e.g., K and N; Ca and Mg) indicate that increase in K resulted to increase in N content and, that the macro elements are from the source (soil).

The correlation coefficient between macronutrients in soil and plants in dry season at Iva mine is presented in Table 8. Significant positive correlation occurred between Ca and Mg ($r=0.879$, $p<0.01$) in soil; Ca and K ($r=0.548$, $p<0.05$) in soil; N and P ($r=0.495$, $p<0.05$) in soil; and Ca and P ($r=0.544$, $p<0.05$) in soil, and Mg and K ($r=0.760$, $p<0.01$) in plant. However, significant negative correlation occurred between Mg and K ($r=-0.624$, $p<0.01$) in soil, and Ca and K ($r=-0.513$, $p<0.05$) in soil. The significant positive correlations between one macro element and another macro element (e.g., K and N; Ca and Mg) indicate that increase in K resulted to increase in N content and, that the macro elements are from the source (soil).

Table 5: Pearson correlation coefficient showing relationship between macronutrient content in soil and plants in wet season at Akwuke mining site

	Ca (plant)	Mg (plant)	K (plant)	N (plant)	P (plant)	Ca (soil)	Mg (soil)	K (soil)	N (soil)	P (soil)
Ca (plant)	1									
Mg (plant)	-.027	1								
K (plant)	-.144	.566*	1							
N (plant)	-.286	.596**	.115	1						
P (plant)	-	.110	-.113	.523*	1					
Ca (soil)	.654**	-.373	.135	-	-.742**	1				
Mg (soil)	.630**	-.232	-.039	-.426	-.414	.794**	1			
K (soil)	.540*	-.232	.009	-.359	-.379	.763**	.963**	1		
N (soil)	.250	-.430	-.442	-.037	.203	-.026	.019	.038	1	
P (soil)	-.465	-.400	-.345	.261	.754**	-.421	-.204	-.159	.381	1

*** Correlation is significant at 1% ($p<0.01$); * Correlation is significant at 5% ($p<0.05$)*

Table 6: Pearson correlation coefficient showing relationship between macronutrient content in soil and plants in dry season at Akwuke mining site

	Ca (plant)	Mg (plant)	K (plant)	N (plant)	P (plant)	Ca (soil)	Mg (soil)	K (soil)	N (soil)	P (soil)
Ca	1									
Mg	.401	1								
K (plant)	.284	.620**	1							
N (plant)	-.173	.480*	.187	1						
P (plant)	-.512*	.145	-.045	.703**	1					
Ca (soil)	.175	.083	.463	-.224	-.384	1				
Mg (soil)	.418	.466	.520*	-.030	-.567*	.748**	1			
K (soil)	-.192	-.233	-.381	.019	.078	-	-.486*	1		
N (soil)	-.277	-.207	-.131	-.001	.324	.247	-.076	-.153	1	
P (soil)	-.092	-.105	-.012	.091	.549*	-.221	-.542*	-.003	.574*	1

*** Correlation is significant at 1% ($p<0.01$); * Correlation is significant at 5% ($p<0.05$)*

Table 7: Pearson correlation coefficient showing relationship between macronutrient content in soil and plants in wet season at Iva mining site

	Ca (plant)	Mg (plant)	K (plant)	N (plant)	P (plant)	Ca (soil)	Mg (soil)	K (soil)	N (soil)	P (soil)
Ca (plant)	1									
Mg (plant)	-.356	1								
K (plant)	.261	.059	1							
N (plant)	.418	-.160	.700**	1						
P (plant)	.032	.437	.144	.262	1					
Ca (soil)	.040	.058	.425	.446	.173	1				
Mg (soil)	-.266	-.035	-.098	-.080	.016	.517*	1			
K (soil)	-	.253	.039	-.105	.282	.343	.538*	1		
N (soil)	-.145	-.426	-.022	-.100	-.054	-.102	-.292	.217	1	
P (soil)	-.193	-.483*	-.517*	-.145	-.099	-.422	-.243	.039	.607**	1

*** Correlation is significant at 1% ($p<0.01$); * Correlation is significant at 5% ($p<0.05$)*

Table 8: Pearson correlation coefficient showing relationship between macronutrient content in soil and plants in dry season at Iva mining site

	Ca (plant)	Mg (plant)	K (plant)	N (plant)	P (plant)	Ca (soil)	Mg (soil)	K (soil)	N (soil)	P (soil)
Ca (plant)	1									
Mg (plant)	.007	1								
K (plant)	.066	.760**	1							
N (plant)	-.188	-.172	.108	1						
P (plant)	-.281	.383	.102	-.193	1					
Ca (soil)	-.163	.365	.112	.387	.263	1				
Mg (soil)	.879**	-.063	-.155	-.284	-.304	-.300	1			
K (soil)	.548*	-	-.308	-.075	-.141	-.513*	.460	1		
N (soil)	-.186	-.040	-.182	.204	.439	.312	-.307	-.014	1	
P (soil)	-.031	.212	.455	.495*	-.137	.544*	-.247	-.313	-.264	1

*** Correlation is significant at 1% ($p<0.01$); * Correlation is significant at 5% ($p<0.05$)*

4. CONCLUSION

The study show that mining activities have impact on (i.e. reduces) the macronutrient content in plants at the two mining sites when compared to the control site. The result also indicates that the values of macronutrient (Ca, Mg, K, N, and P) in plants at Akwuke mining site are higher than their corresponding values in plant species at Iva mining site. The highest values of macronutrient in plants were obtained during the dry season. Among the different plant species tested in the study, *Andropogon gayanus* assimilated more values of macronutrient (Mg, N, and P) than other plants. There was strong positive correlation between some of the macronutrient.

5. CONFLICT OF INTEREST

There is no conflict of interest associated with this work.

REFERENCES

Awofolu, O.R. (2005). A survey of trace metals in vegetation, soil and lower animals along some selected major and minor roads in metropolitan city of Lagos. *Environmental Monitoring and Assessment*, 105, pp. 431-447.

Bremner, J.M. and Mulvancy, C.S. (1982). *Total nitrogen determination.* In: Page AL, Miller RH, Keeny DR (Eds) Methods of Soil Analysis. American Society of Agronomy, p. 595.

Colpaert, J.V. and Van Assche, J.A. (1992). Zinc toxicity in ectomycorrhizal *Pinus sylvestris*. *Plant Soil.* 143, pp. 201-211.

Derome, J. and Lindroos, A.J. (1998). Effects of heavy metal contamination on macronutrient availability and acidification parameters in forest soil in the vicinity of the Hariavatta Cu-Ni Smelter SW Finland. *Environmental Pollution*, 99, pp. 141-148.

Derome, J. and Nieminen, T. (1998). Metal and macronutrient fluxes in heavy-metal polluted scots pine ecosystems in SW Finland. *Environmental Pollution*, 103(2-3), pp. 219-228.

Down, C.G. (1974). The relationship between colliery waste particle sizes and plant growth. *Environmental Conservation*, 1, pp. 29-40.

Ekere, N.R. and Ukoha, O.P. (2013). Heavy metals in street soil dusts of industrial market in Enugu, south east, Nigeria. *International Journal of Physical Sciences*, 8(4), pp. 175-178.

Ezeigbo, H.I. and Ezeanyim, B.N. (1993). Environmental pollution from coal mining activities in the Enugu area, Anambra State, Nigeria. *Mine Water and the Environment*, 12(1), pp. 53-62.

Freedman, B. and Hutchinson, T.C. (1980). Effects of smelter pollutants on forest leaf litter decomposition near a nickel-copper smelter at Sudbury, Ontario, Canada. *Journal of Botany*, 58, pp. 1722-1736.

Fritze, H., Niini, S., Mikkola, K. and Makinen, A. (1989). Soil microbial effects of a Cu-Ni smelter in Southwestern Finland. *Biology and Fertility of Soils*. 8, pp. 87-94.

Hall, I.G. (1957). The ecology of disused pit heaps in England. *Journal of Ecology*, 45, pp. 689-720.

Hazarika, P., Talukdar, N.C. and Singh, Y.P. (2006). Natural colonization of plant species on coal mine spoils at Tikak Colliery, Assam. *Journal of Tropical Ecology*, 47, pp. 37-46.

Lukina, N.V., Lissenko, L.A. and Belova, E.A. (1993). Pollution-induced changes in the vegetation cover of spruce and pine ecosystems in the Kola North region. In: Kozlov, M.V., Haukioja, E., Yarmishko, V.T. (Eds), Aerial Pollution in Kola Peninsula. Proceedings of the International Workshop, 14-16 April, 1992, St. Petersburg, Kola Science Centre, Apatity, Russia. pp. 312-321.

Novozamsky, I., Houba, V.J., Van Eck, G.R. and Van Verk, W. (1983) A novel digestion technique for multi-element plant analysis. *Communication in Soil Science and Plant Analysis,* 14, pp. 239-248.

Ogbonna, P.C., Anigor, T.O. and Teixeira da Silva, J.A. (2012). Heavy metal concentration in soil and plants at a coal mine. *Terrestrial and Aquatic Environmental Toxicology,* 6(2), pp. 127-131.

Ogbonna, P.C., Nzegbule, E.C. and Okorie, P.E. (2018a). Seasonal variation of soil chemical characteristics at Akwuke long wall underground mined Site, Nigeria. *Journal of Applied Sciences and Environmental Management,* 22(9), pp. 1449-1456.

Ogbonna, P.C., Nzegbule, E.C. and Okorie, P.E. (2018b). Soil chemical characteristics in wet and dry season at Iva long wall underground mined site, Nigeria. *Nigerian Journal of Environmental Science and Technology,* 2(1), pp. 96-107.

Ogbonna, P.C., Nzegbule, E.C. and Okorie, P.E. (2018c). Seasonal variation in heavy metal accumulation in plants at coal mine sites and possible health risk. *Nigerian Journal of Environmental Sciences and Technology*, 2(2), pp 196 – 207.

Ogbonna, P.C., Nzegbule, E.C. and Okorie, P.E. (2019). Determination of heavy metal and macronutrients in *Hyperiodrilus africanus* (Earthworm) and *Scolopendra cingulate* (Centipede) at coal mining sites in Enugu State, Nigeria. *Nigerian Research Journal of Engineering and Environmental Sciences*, (In Press).

Reijntjes, C., Haverkort, B. and Waters-Bayer, A. (1992). *Farming for the future: an introduction to low-external-input and sustainable agriculture.* Macmillian Press Ltd, London, pp. 1-272.

Richardson, J.A., Shelton, B.K. and Dicker, R.J. (1971). Botanical studies of natural and planted vegetation on colliery spoil heaps landscape reclamation. IPC Press, Guildford, 1, pp. 84-99.

Richardson, J.A. (1975). *Physical problems of growing plants on colliery wastes*. In: Chadwick, M.J. and Goodman, G.T. (eds.), Ecology of resource degradation and renewal. Blackwell Scientific Publication, Oxford, England. pp. 275-285.

Sarma, K. (2002). Impact of coal mining on vegetation: a case study in Jaintia Hill district of Meghalaya, India. M.Sc. Thesis, submitted to the International Institute for Geo-information Science and Earth Observation, Enschede, The Netherlands, p. 85.

Sekhon, G.S. and Meelu, O.P. (1994). Organic matter management in relation to crop production in stressed rainfed systems. In: stressed ecosystems and sustainable agriculture. In: Virmani S.M., Katyal J.C., Eswaran H., Abrol, I.P. (eds.) Stressed ecosystems and sustainable agriculture, Oxford University Press and IBH Publishing, New Delhi.

Steel, R.G.D. and Torrie, J.H. (1980). *Principles and procedures of statistics: A biometric approach*, McGraw-Hill, New York, p. 633.