

ELEMENTAL RATIOS AND THEIR IMPLICATIONS IN FERTILITY STATUS OF SOILS OF OWERRI AGRICULTURAL ZONE

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ABSTRACT

The elemental ratio is an important soil quality parameter used in determining soil fertility status. The implications of soil nutrient elemental ratios were studied in five different locations representing Owerri agricultural zone namely Ohaji, Ezinihite, Umulolo, Nmahu and Nwangele. Complete Randomized Design (CRD) was used for the study and 5 soil samples (replicates) per site were collected for analysis. Soil samples were analysed in the laboratory for soil properties and generated data subjected to Analysis of variance (ANOVA). The results showed that the sites have a sandy texture with mean sand, silt and clay contents ranging from 717-845 g kg⁻¹, 32.2-171 and 55.3-246.7 g kg⁻¹ respectively. The mean calcium and magnesium contents ranged from 0.06 -3.83 cmol+kg⁻¹ and 0.09 -1.94 cmol+kg⁻¹ respectively. The average carbon-nitrogen ratio of the soils ranged from 10:1 at Nmahu to 33:1 in Umulolo. However, with exception of Umulolo and Nwangele soils, the C:N ratios of other locations were favourable. Calcium-magnesium (Ca:Mg), potassium-magnesium (K:Mg) ratios were low in all the sites indicating the low fertility status of the sites. The SAR (0.02-1.42) and sodium (0.02-0.34) content of the soils indicated that the soils have stable aggregates and are neither alkaline nor sodic. Generally, the results of the nutrient elemental ratios showed poor soil fertility status.

Keywords: Calcium, Magnesium, Elemental ratio, Sodium, Potassium, Soil fertility

INTRODUCTION

Soil is the major part of the terrestrial ecology and the understanding of the soil system is the key to a successful land use planning. The knowledge of the influence of soil elemental ratio on soil

fertility status is indispensable in soil fertility evaluation. Soil fertility is affected by various processes such as nutrient leaching, soil erosion, nutrient imbalance and cation antagonism. Cation antagonism is a vital factor in soil nutrient studies since

different nutrient have different harmful and protective effect level. The replacement of a nutrient element by another, results to some soil fertility problems such as adverse soil reaction, nutrient adsorption and other soil fertility related problems. For instance, the replacement of calcium by hydrogen ions results in soil acidification. All soils have most different nutrient contents and ratios, therefore soil treatment without consideration of this fact may trigger nutrient imbalance and/or cation antagonism. The role of soil elemental ratios in nutrient assimilation process has been reported by Loide, (2004) and Loide (2001). Loide, (2004) used calcium-magnesium, potassium-magnesium ratios in eliminating harmful acidity of the soils of Estonia. In south-eastern Nigeria, adequate studies have not been done on the implications of these elemental ratios on soil fertility assessment. In light of this, this work was carried out to determine the implications of the elemental ratios on soil fertility status.

MATERIALS AND METHODS

Study area

The study was carried out in five different locations representing Owerri Agricultural zone of South-eastern Nigeria namely Nwangele (latitude $5^{\circ} 41^1\text{N}$ and longitude $7^{\circ} 50^1\text{E}$), Ezinihite (latitude $5^{\circ} 28^1\text{N}$ and longitude $7^{\circ} 48^1\text{E}$), Nmahu (latitude $5^{\circ} 58^1\text{N}$ and longitude $6^{\circ} 59^1\text{E}$), Umulolo (latitude $5^{\circ} 52^1\text{N}$ and longitude 7°

17^1E) and Ohaji (latitude $5^{\circ} 19^1\text{N}$ and longitude $6^{\circ} 58^1\text{E}$). Soils of the study areas are derived from the Coastal plain sand and Alluvium; and are characterized by low cation exchange capacity (CEC), low organic matter with high leaching of nutrient elements (Onweremaduet *al.*, 2011). Owerri agricultural zone is located within the humid tropical climate with annual rainfall ranges from 2000 - 2500 mm, daily temperature ranges from 21 to 31°C and relative humidity of about 80% during the wet season of the year (NIMET, 2016).

Field Studies and Laboratory analyses

Five agricultural areas were randomly selected for the study. They include Ezinihite in Mbaise, Nmahu in Egbema, Nwangele in Nwangele LGA, Umulolo in Okigwe and Ohaji in Egbema. From each area, five (5) representative soil samples were collected for laboratory analyses. A total of 25 samples were collected for the study. Soil samples were air-dried, sieved and used for varying laboratory analyses. Sand, silt and clay fractions were determined by the hydrometer method (Gee and Or 2002). Soil bulk density was determined by Grossman and Reinch (2002) method. Soil pH was determined using 1:2.5 soil: liquid (water) ratio (Thomas, 1996). Available P was extracted using Bray-P 2 solution (Olsen

and Sommer, 1982). Exchangeable bases were determined by the neutral ammonium acetate (NH₄OAc of pH 7) procedure (Thomas, 1996). Wet digestion method of Nelson and Sommers, (1996) was used for organic carbon determination while total nitrogen was determined by Kjeldahl digestion method (Bremner and Mulvaney, 1982). Ca:Mg ratio and K:Mg ratio were calculated from the exchangeable basic cations, C:N ratio from organic carbon and total nitrogen while SCR was calculated from Silt and clay fractions of the soil. SAR (Sodium Adsorption Ratio) was calculated: $Na^+ / [(Ca^{+2} + Mg^{+2})/2]^{0.5}$

Statistical Analysis

The experiment was a complete randomized design (CRD) using locations as treatments, and five replicated soil samples as replicates. Analysis of variance (ANOVA) was used to test differences in soil properties and Duncan Multiple Range Test (DMRT) was employed to separate means at 5% probability level.

RESULTS AND DISCUSSION

The physical and Chemical Properties of Soils

The mean sand content of the soils ranged from 717 g kg⁻¹ at Nwangele to 845.2 g kg⁻¹ at Ezinihite. Silt and clay content ranged from 32.2 – 171.00 g kg⁻¹ and 55.3-160.90 g kg⁻¹ respectively. Generally,

soils of the studied areas contained a higher proportion of sand than silt and clay. This generally low silt content is in line with the assertion of Akamigbo and Asadu (1983) that soils of South-eastern Nigeria are low in silt as a result of the high degree and extent of weathering and leaching they have undergone. The average bulk density values ranged from 1.12 -1.44 g cm⁻³. These values were below the critical limit of 1.75 – 1.80 mg m⁻³ reported by Soil Survey Staff (2003). At the range of 1.75 -1.80 mg m⁻³, root restriction, poor infiltration, poor root development and reduced soil organic matter may occur. Attah, (2001) reported that low bulk density is beneficial to root activity, water infiltration into the soil, and overall growth of plants.

The chemical properties of soils are shown in Table 1. The mean pH ranged from 4.23 (very strongly acidic) in Ohaji to 6.31 (slightly acidic) at Nwangele. Such reaction is characteristic of soils in South-eastern Nigeria which could be due to the acidic nature of the parent rocks, coupled with the influence of the leaching of base cation under high annual rainfall condition. The average soil organic carbon ranged from 1.54 g kg⁻¹ at Ohaji to 6.64 g kg⁻¹ at Nmahu. Total Nitrogen ranged from 0.13 – 0.69 g kg⁻¹ across the sites. The soil available phosphorus was rated low to moderate (0.4 – 14.91 mg kg⁻¹) across the

sites. The moderate to low available phosphorus concentration is, however, a widespread phenomenon in the humid tropical soils and can be attributed to the high phosphate fixation capacity of these soils resulting majorly from cation antagonism.

Exchangeable calcium varied from 0.06 at Ohaji to 3.83 cmol+kg^{-1} at Nmahu. Similarly, exchangeable magnesium was also low at Ohaji (0.09 cmol+kg^{-1}) and high at Nmahu (2.90 cmol+kg^{-1}). However, at Nmahu, the proportions of exchangeable Ca^{+2} (3.83 cmol+kg^{-1}) and Mg^{+2} (2.90 cmol+kg^{-1}) were generally higher than the critical levels of 2.00 and 1.2 cmol+kg^{-1} reported by Adeoye and Agboola, (1984). Similarly, with exception of soils of Ohaji, the concentration of exchangeable Mg^{+2} was generally higher (sufficient) than the critical level of 0.5 cmol+kg^{-1} soil as suggested by Landon (1991); a concentration less than this value would require an application of magnesium fertilizer. However, at Ohaji, calcium and magnesium deficiencies may occur since exchangeable calcium and magnesium in soil test results are less than 0.5 and 0.2 cmol+kg^{-1} . Calcium and

magnesium levels these low are usually associated with sandy textured soils that are low in pH and organic carbon. According to NSW Agriculture (2002), calcium and magnesium deficiencies may occur where the soil test reports exchangeable calcium between 0.5 to 0.7 meq/100g and magnesium less than 0.2 meq/100g .

Potassium concentration ranged from 0.02 at Umulolo to 2.39 cmol+kg^{-1} at Nwangele. Generally, exchangeable K was categorized as very low (< 0.2) at Nmahu, Umulolo, Ohaji, and Ezinihite, and high (1.51-2.3 cmol+kg^{-1}) at Nwangele respectively. Low potassium concentration in the soils of Umulolo, Ohaji, Ezinihite and Nmahu may be due to the fact that there is generally a low potassium reserve in acid sands of Owerri. This could be attributed to the highly mobile nature of exchangeable potassium relative to calcium and magnesium and its consequent massive loss through leaching. Sodium concentration was generally low ($< 1.0 \text{ cmol+kg}^{-1}$). As such, none of the soils can be classified as sodic or alkaline. Soil sodicity and alkalinity impose many agronomic and environmental problems.

Table 1: Physical and chemical properties of soil

Location	Sand g kg ⁻¹	Silt g kg ⁻¹	Clay g kg ⁻¹	BD gcm ⁻³	pH	OC g kg ⁻¹	TN gkg ⁻¹	AVP mgkg ⁻¹	Ca ————→ 1	Mgcmol+kg ⁻¹	K ←————	Na
Nwangele	717.00b	37.00d	247.00a	1.34a	6.34a	3.61c	0.20b	9.24b	2.23b	1.94b	2.39a	0.05b
Ezinihite	845.20a	32.20d	122.6b	1.44a	5.70b	5.67b	0.50b	12.74a	0.86b	1.23c	0.18b	0.02b
Nmahu	736.26b	102.80c	160.93b	1.31a	5.64b	6.64b	0.69b	6.91b	3.83a	2.90a	0.16b	0.03b
Ohaji	774.00b	171.00a	55.3c	1.27ab	4.23c	1.54d	1.13a	0.40c	0.06c	0.09d	0.04c	0.39a
Umulolo	781.80a	148.00b	70.20c	1.12b	4.62c	12.03a	0.36b	14.91a	2.90b	1.78b	0.02c	0.04b

Note: different letters within the columns indicate significant different (p =0.5). BD = Bulk density, OC = Organic carbon, TN = Total nitrogen, AVP = Available phosphorus, Ca = Calcium, Mg = Magnesium, K = Potassium, Na = Sodium

Elemental ratio

The mean calcium magnesium (Ca:Mg) ratios of the soils ranged from 0.67 to 1.63 (Fig.2). Generally, the Ca:Mg ratio obtained in this study was very low when compared with 3-5:1 (normal range) reported by Landon (1991). According to the report of (NSW) Agriculture, (2002), some agronomist used 4 to 6 as a benchmark for the ratio of the exchangeable Ca to Mg. They claim that this benchmark must be achieved to ensure healthy soil and therefore optimum agricultural production. Landon (1991) further stated that soils with Ca:Mg ratio less than 3.0 are poor in fertility; implying soils of the five locations had poor fertility status and may not be

suitable for agronomic purposes without proper soil fertility management. According to Loide (2004), the Ca:Mg ratio of sandy soils is always too narrow as far as plant nutrition is concerned. He further pointed out that on the average, loamy and clay soils contained more Ca:Mg ratio than sandy soils. Scott and Conyers (1995), reported that the concept of Ca:Mg ratio is a dominant force in shaping lime and fertilizer recombination. From the result, higher Ca:Mg ratios recorded in soils of Umulolo and Nmahu compare to other locations may be attributed to the calcium contents of these soils. The result further showed that soils with high calcium content had a high Ca:Mg ratio.

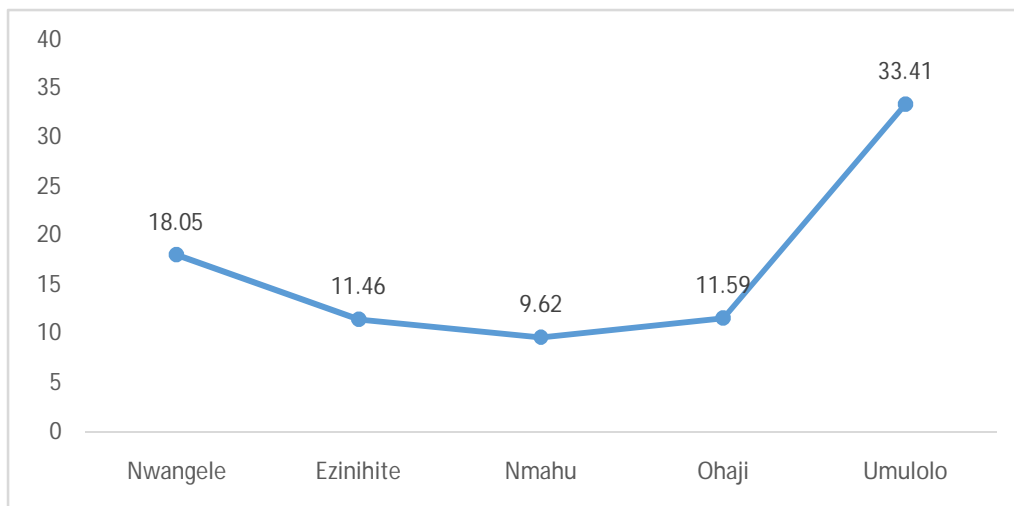


Fig. 1: Carbon-nitrogen ratio of soil

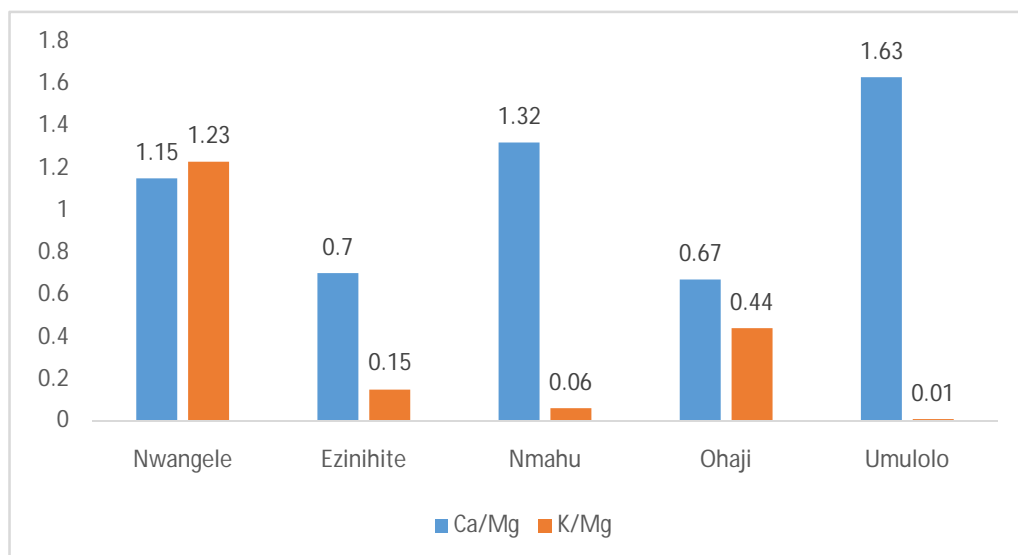


Fig. 2: Ca/Mg, K/Mg ratios of the soils

Potassium-magnesium ratio ranged from 0.01 at Umuloloto 1.23 at Nwangele (Fig. 2). Except for the soils of Nwangele, other soils have K:Mg ratio lower than 0.7 thresholds suggested by Loide (2001), indicating that magnesium dominates in relation to potassium. However, Loide (2004), Landon (1991) reported 1.2:1 for sandy soil, 1:1 for sandy loam and loam and 0.7:1 for clay soil. Similarly, Hannan (2011) suggested a K:Mg concentration between 0.40 and 0.50, regardless of soil texture, to avoid Mg-induced K deficiency.

The average carbon-nitrogen ratio of the soils ranged from 10:1 at Nmahu to 33:1 in Umulolo (Fig.1). However, with exception of Umulolo and Nwangele soils, the C:N ratios of other locations were favourable and could be as a result of the N content of the soils, as soils with narrow ratios are relatively rich in nitrogen while those with wider ratios suggest low nitrogen

content (Foth, 1984). High C/N ratio obtained in Umulolo could be a reflection of the low pH value (4.62) of the area. Ahukaemere(2015) stated that soil with high C/N ratio requires nitrogen fertilizer application. The decomposability of soil organic matter is determined by soil carbon-nitrogen ratio, a sequel to this, soil carbon-nitrogen ratio has an important impact on soil fertility and plant nutrient availability. Apart from the nitrogen content of the soil, the carbon-nitrogen ratio of soil is affected by the climatic condition of an area. The influence of rainfall and temperature on soil carbon-nitrogen ratio has been reported (Johannes and David, 2000; Aitkenhead and McDowell, 2000).

Sodium adsorption ratios (SAR) of the soils were very low ranging from 0.02 in soils of Ezinihite to 1.42 in Ohaji soils (Fig.3). From the result, none of the sites could be regarded as a sodic soil.

Statistically, the SAR of the soils of the varying locations did not differ significantly. In a soil fertility study, SAR plays a very vital role. It is a soil quality parameter used in the management of sodium affected soils (Reeve, 1954). The SAR of soil is a good indicator of the stability of soil structure and particle dispersion. However, SAR of the sites

studied showed that the soils may not be susceptible to spontaneous dispersion in water. Soils that have SAR values of 13 or more may be characterized by an increased dispersion of organic matter and clay particles, reduced saturated hydraulic conductivity (Ksat) and aeration, and general degradation of soil structure (Soil Survey Staff, 2017).

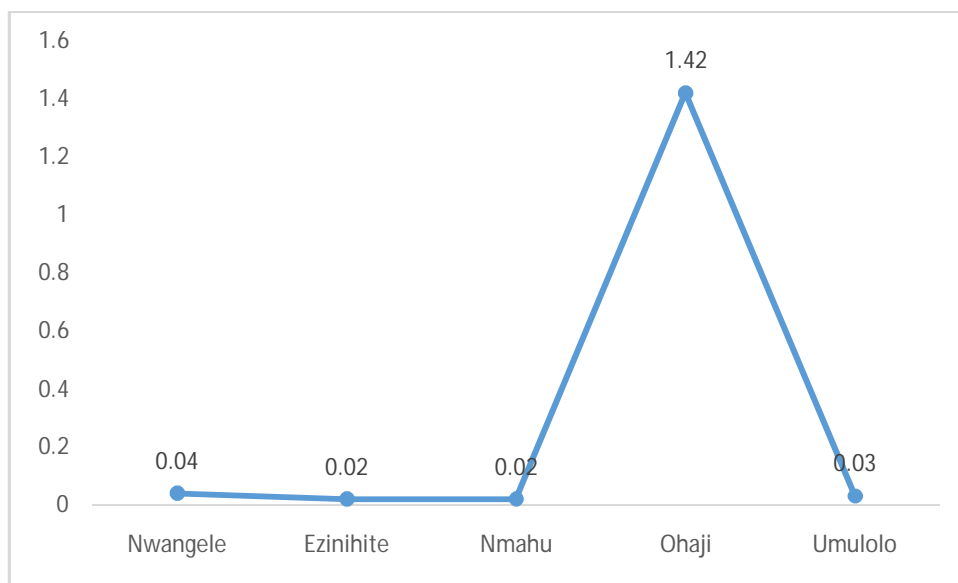


Fig. 3. Sodium Adsorption Ratio (SAR) of soils

CONCLUSIONS

From the results, a too narrow calcium-magnesium and potassium-magnesium ratios obtained in this study reviewed the poor fertility status of the soils. This was further proven by the low organic carbon, available phosphorus and low to moderate total nitrogen recorded in the soil. In view of this, the incorporation of calcium, magnesium and potassium in the soil in sufficient balance quantity is

recommended. None the less, further studies on the implications of these elements and their ratios on fertility are suggested.

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