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# The Efficiency of Mehlich-3 Extractant in Extracting Exchangeable Bases on Ferralitic Soils of Delta State, Nigeria

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**Abstract**

A study was carried out in ferralitic soils, Delta State, Nigeria. The aim was to assess the efficiency of Mehlich-3 extractant in extracting exchangeable soil nutrient cations of $Ca^{++}$, $Mg^{++}$, $K^{+}$ and Na+. Four locations namely; Ibusa, Ubulu-uku, Obior and Ossissa were sampled for analysis of locations initial physico-chemical properties and extraction of exchangeable bases using Mehlich-3 extractant. The results of the study indicated that the soils were highly acidic and deficient in major nutrients. Extraction of basic cations by Mehlich-3 extractant showed strong affinity in the extraction of calcium (Ca) with mean extracting value of 4.29 $mgkg^{-1}$, Magnesium (Mg) 1.32 $mgkg^{-1}$, Potassium (K) 0.14 $mgkg^{-1}$ and low affinity for Sodium ($Na^{+}$) 0.11 $mgkg^{-1}$. Correlation coefficient (r-value) showed highly significant linear relation between Mehlich-3 and $Ca^{++}$ ($r = 0.942^{**}$), $Mg^{++}$ ($r = 0.845^{**}$) and $K^{+}$ ($r = 0.798^{**}$). Non-significant relationship was found between extractant and $Na^{+}$ ($r = 0.242$). the general results indicated that Mehlich-3 has strong extracting power in the extraction of calcium ($Ca^{++}$), Magnesium ($Mg^{++}$), Potassium ($K^{+}$) and Sodium ($Na^{+}$) in ferralitic soils;

**Keywords:** Efficiency, Mehlich-3, Exchangeable bases, Ferralitic soils, Delta State.

## Introduction

Ferralitic soils usually referred to as "Crystalline acid soils" are the dominant soil type in the humid region of Delta State. Characteristically, the soils are deep, porous, and low in cation exchange capacity, low in base saturation, and suffer from multiple nutrient deficiencies. The textures range pronouncely from sandy loam to loam and sandy clay loam with clay contents increasing gradually with depth, in exposed profiles (Egbuchua, 2018). The prominent clay type is Kaolinite. Moreover, the soils are excessively leached due to the erratic rainfall nature of the environment, thus, they are strongly acidic with a pH values of 5.0.- 5.5, poor structural stability, low water holding capacity and high susceptibility to water erosion are among the characteristics of ferralitic soils (Agboola *et al.*, 1997).

In contemporary agricultural crop production purposes, the need for soil testing for reliable and guided liming and fertilizers application cannot be under-estimated. In every soil test programmes efforts are usually made to correlate soil test results with plant growth. This has led to the concept of soil extractants. According to Tisdale and Nelson (1996), a soil extractant is a solution base or acid which can remove from the soil an element or elements in plant available or total form. The choice of any extractant depends on the ability of the extractant to remove the quantities of ions or elements that can correlate with crop responses in the field (Adeoye, 1986). Modern methods in soil analysis for soil fertility evaluation have brought about the development of universal or multinutrient soil extractants. According to Jones (1990), these extractants are reagents that can extract more than one nutrient elements or ions from a soil media. Multinutrient extractants are fast gaining universal acceptability in most soil testing and analytical laboratories because of the distinct time in extraction, reproducibility and cost saving advantages (Ibia and Ekpoudia, 2001). Among some of these extractants include, Morgan-Wolf, Mehlich-1 and 1 M $NH_4HCO_3$-DTPA.

Before the development of multinutrient extractants, different extracting solutions were used separately for various nutrient extractions. For instance, Bray No.1 extractant was used purposely for the extraction of phosphorus only. However, the evolution of multinutrient extractants only combine the properties of the single nutrient extractants to assess the different nutrient elements in the soil. Because of the importance of exchangeable bases (Ca, Mg, K and Na) in soil nutrient interaction, soil fertility nutrition studies and soil geneis, it becomes imperative that they are studied in relation to their response in extraction.

In ferralitic soils, the basic cations are considerably low due to low activity clay. However, they are recognised as nutrient elements that are essential for crop growth and soil fertility. Against this background, the objective of this study is to assess the efficiency or extracting ability of Mehlich-3 extractant in removing plant available forms of Ca, Mg, K and Na in ferralitic soil in Delta State.

## Materials and Methods

### *Description of the study areas*

The study was carried out in four locations of Delta State, Nigeria. These locations were Ibusa, Ubulu-uku, Obior, and Ossissa. The locations falls within the coordinates Latitude 5.5000$^{O}$ N and Longitude 6.0000$^{0}$ E of the equator. The areas are characterized by intense annual rainfall of 1.850 – 2, 580 mm per annum, a mean temperature of 28 – 30$^{0}$C, and a mean relative humidity 80 – 85% (NIMET, 2018). The vegetation is typical of rainforest zone characterized by woody trees, shrubs and grasses of different species. The areas are gently undulating and the soil was classified as sandy loam, kaolinitic Haplustalf (Egbuchua, 2012). Land use in the environment is based on rain-fed agriculture and typical crops cultivated include yam, cassava, sweet potatoes, vegetables and gains/cereals.

### *Field study*

A total of sixteen (16) soil samples four each from each location were collected randomly at a depth of 0 – 30 cm in relation to their topographic position and landform. The co-ordinates and altitudes of the locations were obtained using German etrex (2000) GPS meter. Soil sampling was virtually done using nested sampling technique (Wahua, 1999).

### *Sample preparation*

The soil samples collected were air-dried at room temperature of 25 – 27$^{0}$C for three days then crushed using agape-mortar, and sieved to pass through a 2 mm sieve mesh and properly labelled and packaged for laboratory analysis

### *Laboratory studies*

### *Initial physico-chemical properties*

The samples were analysed for the soils initial physico-chemical properties such as: particle size distribution using the methods of Bouyoucous hydrometer method as outlined by Gee and Bauder (1986). The soils pH were estimated using glass electrode digital pH meter in a 1:2.5 soil/water suspension. The soil organic carbon content was measured by the wet-oxidation Dichromate analytical procedure as outlined by Nelson and Sommers (1982). Total nitrogen was measured in a Micro-kjeeldahl digestion and distillation apparatus as described by Bremner and Mulvancy (1982). Available phosphorus was measured using the Bray 1 extracting solution (Bray and Kurtz, 1945). The initial exchangeable cations of the samples were extracted with 1.0 M ammonium acetate at pH 7. The Na and K in the solution measured by Flame photometer, Mg and Ca were determined by EDTA titration. The cation exchange capacity was measured using a neutral solution of ammonium acetate leached at pH 7 as described by Rhoades (1982).

### *Mehlich-3 extractant*

This is a weak acid extractant used for plant nutrient extraction in acid mineral soils. It can be largely used in the extraction of Ca, Mg, K, Na, P and S. it is composed of 0.2 M $CH_3$ COOH, 0.15 M $NH_4F$, 0.13 m $HNO_3$, 0.001 M EDTA. (Ethylene diamine tetra acetic acid)

### *Extraction procedure*

The analysis was carried out in the Faculty of Agriculture Research Laboratory, Delta State University, Asaba Campus. All the soil samples were initially leached with deionzed water in order to remove soluble salts that were likely to be present in the samples. 10 grams of each of the location samples were measured into a dispenser replicated two time. In each of them, 20 ml of Mehlich-3 extracting solution was added and vigorously shaken for 5-minutes using digital shaker at (200 rpm). Thereafter, the filtrate was transferred into a filtrate cup within 5 minutes after shaking and finally transferred into disposable polypropylene test tubes for the analysis of the samples. Potassium (K) and Sodium (Na) were estimated using Flame Atomic Emission Spectroscopy (FAES) while Calcium ($Ca^{++}$) and Magnesium ($Mg^{++}$) concentration were determined by Flame Atomic Absorption

Spectroscopy (FAAS). Correlation studies on the efficacy of the extracting reagent and the exchangeable bases were carried out.

## Results

### *Initial physico-chemical properties*

The Particle size distribution of the soils across the four locations studied showed relatively higher proportion of sand over the other soil separates (Table 1). The texture ranged from sandy loam, to loam. The dominant sand fraction could be attributed to the parent material which is coastal plain sands of sandstone origin (Brady and Weil, 2013). The pH ranged from 4.5 – 5.8, indicating the strong acidic nature of the soils (Udo, 1987). This could be attributed to the acidic sand parent material, high rainfall characteristics which in most cases exceed 1,550 mm/annum. The mean organic matter contents ranged from 3.19 – 4.97 $gkg^{-1}$ which were considerably low. This could be attributed to rainfall nature of the area, bush burning which depletes organic matter accumulation and continuous cultivation (Opara-Nnadi, 1990). Total nitrogen which has direct relationship with soil organic matter was low. The mean location values ranged from 6.35 – 7.26 $mgkg^{-1}$. This could also be attributed to low organic matter status of the soil and continuous cultivation. Phosphorus level was generally low and below 8 $mgkg_{-}^{1}$ established for the ecological zone (FMANR, 1999). Soil organic carbon has been reported to be sink and pool of phosphorus in tropical soils, therefore, low organic matter is synonymous with low phosphorus (Agboola and Unamma, 1991). It could also be attributed to high acidity which decreases P-availability in the soil. The exchangeable bases and cation exchange capacity were all low reflecting the intensely weathered status of the parent rocks and low activity clay of the study areas which are dominantly of the 1:1 clay minerals (Egbuchua, 2018).

### *Extraction efficiency*

The results of extraction with Mehlich-3 (Table 2) showed that in all locations estimated, the Mehlich-3 reagent effectively extracted exchangeable bases maximally from the low status of the soils (Table 4). The efficacy of the extractants was demonstrated in the extraction of calcium ($Ca^{++}$) where less than 5.0 $mgkg^{-1}$ was rated low but the extractant extracted 4.32, 4.30, 4.27 and 4.25 $mgkg^{-1}$ respectively from the four locations studied. This represents over 90% of the extraction potential of the extractant. The same trend was observed in the extraction of Magnesium ($Mg^{++}$), Potassium ($K^{+}$) and Sodium ($Na^{+}$) that existed in an infinistimal levels in the soil.

### *Correlation coefficient (r-value)*

Correlation coefficient (r-value) was meant to show how best an extracting method predicts plant uptake of nutrients. In the study, there was a very significant correlation between Mehlich-3 and $Ca^{++}$ ($r = 0.942^{**}$), $Mg^{++}$ ($r = 0.845^{**}$) and Potassium ($r = 0.798^{**}$). Sodium ($Na^{+}$) concentration which is quite limiting in most upland soils of ferralitic origin had non-significant correlation with Mehlich-3 extractant ($r = 0.242^{ns}$). It was hardly dictated using Mehlich-3 extractnat (Table 3). The step-wise scaling of Mehlich-3 for extracting exchangeable bases in comparison with established rating for the ecological zone showed that the extractant has very high efficiency in extraction and a broad range of applicability over a range of acid soils.

**Table 1:** Initial Physico-chemical properties of ferralitic soils of Delta State, Nigeria

| Location | | Particle size distribution (%) | | | | pH | O.C | Total N | Avail P | Exchangeable cations (cmolkg$^{-1}$) | | | | CEC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | **Sand** | **Silt** | **Clay** | **Texture** | **$H_2O$** | **(gkg$^{-1}$)** | **(gkg$^{-1}$)** | **(mgkg$^{-1}$)** | **$Ca^{++}$** | **$Mg^{+}$** | **$K^{+}$** | **$Na^{+}$** | **cmolkg$^{-1}$** |
| Ibusa | 1 | 82 | 4 | 14 | SL | 5.6 | 3.15 | 1.20 | 6.30 | 2.34 | 0.86 | 0.16 | 0.20 | 8.45 |
| | 2 | 82 | 4 | 14 | SL | 5.6 | 3.20 | 1.18 | 7.20 | 2.40 | 0.85 | 0.18 | 0.20 | 8.62 |
| | 3 | 88 | 4 | 8 | SL | 4.8 | 3.45 | 1.15 | 6.34 | 2.10 | 0.78 | 0.15 | 0.20 | 7.84 |
| | 4 | 84 | 6 | 10 | SL | 4.5 | 2.67 | 1.10 | 5.40 | 1.85 | 0.58 | 0.14 | 0.18 | 6.34 |
| | $\bar{x}$ | 84.0 | 3.50 | 8.50 | | 5.13 | 3.19 | 1.14 | 6.61 | 2.28 | 0.83 | 0.16 | | 8.30 |
| Ubulu- uku | 1 | 84 | 6 | 10 | SL | 4.6 | 3.65 | 1.25 | 5.45 | 1.78 | 0.55 | 0.12 | 0.16 | 6.25 |
| | 2 | 82 | 4 | 14 | SL | 5.4 | 4.55 | 1.20 | 6.38 | 2.14 | 0.76 | 0.17 | 0.25 | 8.38 |
| | 3 | 86 | 4 | 10 | SL | 5.6 | 3.52 | 1.30 | 7.24 | 2.18 | 0.82 | 0.16 | 0.25 | 8.35 |
| | 4 | 88 | 4 | 8 | SL | 4.8 | 3.10 | 1.10 | 6.35 | 2.12 | 0.75 | 0.13 | 0.20 | 7.80 |
| | $\bar{x}$ | 87.0 | 3.5 | 9.5 | | 5.1 | 3.71 | 2.59 | 6.36 | 2.06 | 0.72 | 0.15 | | 7.70 |
| Obior | 1 | 86 | 4 | 10 | SL | 5.6 | 3.44 | 0.95 | 6.34 | 3.14 | 0.83 | 0.40 | 0.18 | 8.38 |
| | 2 | 84 | 6 | 10 | SL | 5.8 | 3.52 | 0.98 | 5.88 | 3.20 | 0.82 | 0.16 | 0.24 | 8.40 |
| | 3 | 86 | 4 | 10 | SL | 4.7 | 3.12 | 1.15 | 6.20 | 2.30 | 0.80 | 0.18 | 0.20 | 7.88 |
| | 4 | 78 | 14 | 8 | SL | 5.5 | 4.15 | 1.10 | 6.38 | 3.42 | 0.85 | 0.17 | 0.23 | 8.50 |
| | $\bar{x}$ | 84.5 | 7.0 | 8.5 | | 5.4 | 3.56 | 1.05 | 6.20 | 3.02 | 0.83 | 0.17 | 0.21 | 8.29 |
| Ossissa | 1 | 82 | 6 | 12 | L | 5.2 | 4.25 | 1.54 | 7.25 | 4.14 | 0.95 | 0.18 | 0.20 | 9.46 |
| | 2 | 78 | 12 | 10 | L | 5.4 | 5.15 | 1.62 | 7.35 | 4.20 | 1.00 | 0.16 | 0.20 | 9.82 |
| | 3 | 76 | 8 | 16 | L | 5.7 | 5.20 | 1.65 | 7.24 | 3.95 | 1.20 | 0.18 | 0.20 | 9.38 |
| | 4 | 82 | 4 | 14 | SL | 5.8 | 5.32 | 1.70 | 7.14 | 4.22 | 1.08 | 0.15 | 0.20 | 9.45 |
| | $\bar{x}$ | 79.5 | 7.5 | 13.0 | | 5.53 | 4.98 | 1.63 | 7.25 | 4.13 | 1.06 | 0.17 | 0.20 | 9.53 |

Abbreviation: Texture: SL = Sandy loam; L = Loam; OC = Organic Carbon; Total N = total nitrogen; Avail P = available phosphorus; CEC = cation exchange capacity

**Table 2:** Results of Mehlich-3 (mgkg$^{-1}$) for exchangeable bases in ferralitic soils, Delta State

| **Parameter** | **Location (mean values)** | **Obtained values (mgkg$^{-1}$)** |
|---|---|---|
| $Ca^{++}$ | 1 | 4.32 |
| | 2 | 4.30 |
| | 3 | 4.27 |
| | 4 | 4.25 |
| | $\bar{X}$ | 4.29 |
| $Mg^{++}$ | 1 | 1.36 |
| | 2 | 1.32 |
| | 3 | 1.29 |
| | 4 | 1.31 |
| | $\bar{X}$ | 1.32 |
| $K^{+}$ | 1 | 0.18 |
| | 2 | 0.16 |
| | 3 | 0.17 |
| | 4 | 0.16 |
| | $\bar{X}$ | 0.16 |
| $Na^{++}$ | 1 | 0.10 |
| | 2 | 0.12 |
| | 3 | 0.10 |
| | 4 | 0.10 |
| | $\bar{X}$ | 0.11 |

**Legend: for sample locations:** 1 – Ibusa**;** 2 – Ubulu-uku**;** 3 – Obior**;** 4 – Ossissa

**Table 3:** Correlation coefficient (r-value) between Mehlich-3 extractant and exchangeable bases

| Exchangeable bases | r-values |
|---|---|
| $Ca^{++}$ | 0.942** |
| $Mg^{++}$ | 0.845** |
| $K^{+}$ | 0.798** |
| $Na^{+}$ | 0.242$^{NS}$ |

** = Significant at P ≤ 0.01; NS = Not significant at P ≤ 0.01

**Table 4:** Step-wise scaling of exchangeable bases for comparison of Mehlichh-3 extraction results

| Elementary concentration(mgkg$^{-1}$) | Ratings | | |
|---|---|---|---|
| | Low | Medium | High |
| $Ca^{++}$ | <50 | 5 – 10 | >10 |
| $Mg^{++}$ | <1.5 | 1.5 – 3.0 | >3.0 |
| $K^{+}$ | <0.20 | 0.20 – 0.40 | >0.40 |
| $Na^{+}$ | <0.3 | 0.3 – 0.7 | >0.7 |

**Source:** FFD (2012).

## Discussion

The ferralitic soils of Delta State are among the most extensively cultivated soils for root and tuber crop production. They are highly weathered and deficient in multiple nutrients (Brady and Weil, 2013). The need to evaluate the efficiency of Mehlich-3 extractant in the soils exchangeable base status became imperative because of the importance of these basic cations in plant nutrition. Mehlich-3 extractant has shown very promising response in soil nutrient extraction in acid mineral soils. In a study carried out in some sedimentary soils of South-west Nigeria. Tunde *et al.* (2014) reported high significant correlation of Mehlich-3 extractant in the extraction of Ca, Mg, K and Na. similarly Ibia and Ekpoudia (2001) expressed the superiority of Mehlich-3 extractants over Mehlich-1 and $NH_4HCO_3$-DTPA extractants in soil exchangeable bases extraction of some wetland soils. In a related study, Hamlon and Johnson (1981) reported high significant relation between Mehlich-3 and exchangeable bases in some acid soils of Okhahoma. In another study, Wang *et al*., (2006) reported good extraction result of Mehlich-3 for P, K, Ca, Mg, Na, Zn, Cu, Mn and Fe when compared with Morgan-Wolf and Mehlich-1 extractions.

In another study conducted to evaluate the efficacy of Mehlich-1 and Mehlich-3 extraction procedures, Mehlich (1984), reported that Mehlich-3 has the advantage of potentially being used for extracting other macro and micronutrients and as a better soil extractant for Ca, Mg, K and Na in acid mineral soils. Mylavarapu *et al*.,(2007) also reported the efficiency of Mehlich-3 in some acidic soils and their significant correlation with exchangeable bases. These associated/related research findings or reports collaborated with the present findings, of this work all pointing to the efficacy of Mehlich-3 in extracting exchangeable bases in acid mineral soils typical of ferralitic origin.

## Conclusion

In view of the nutritional importance of exchangeable bases in plant nutrient interaction, and the place of ferralitic soils of Delta State in root/tuber crop production, It is therefore recommended that any soil test for exchangeable base status, should be done using Mehlich-3 extractant. It has a broad range of applicability and reproductibility, and can be validated through inter-laboratory studies.

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