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*Research Article*

# Soil Fertility Indictors in Low-Input Agriculture in Communities of Southeastern Nigeria

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**ABSTRACT**

**The study investigated the fertility of soils under *Caladium, Costus*, *Setaria* and *Imperata* in 10 locations of southeastern Nigeria. Soil samples were collected at random on soils formed over coastal plain sands of southeastern Nigeria. Soil samples were bulked, quartered and air-dried before laboratory analysis. Soil samples were sieved using a 2-mm sieve and analyzed for some soil fertility indices. Variation in soil fertility indices were computed using analysis of variance (ANOVA) while means were separated with least significant difference (LSD) at 5% level of probability. Calcium- magnesium ratios varied significantly (p=0.05) among plant species, and values ranged from 3.6 (*Caladium*). *Setaria* (1.9), *Costus* (1.7) and *Imperata* (0.8). Nitrate-nitrogen differed significantly (p=0.05) among plant species and distributed as follows: 0.13 g/kg (*Caladium*), 0.12g/kg (*Setaria*), 0.11g/kg (*Costus*) and 0.08 g/kg (*Imperata*). Base saturation values decreased in the order of *Caladium* (56%), *Setaria* (49%), *Costus* (41%) and *Imperata* (21%). These soil parameters had significant (P< 0.05) positive relationships with total carbon. It can be concluded that soils under *Caladium* can be used to infer greater soil fertility in farmland.**

## INTRODUCTION

High cost of soil survey coupled with the ignorance of its application in the determination of soil resource suitability is discouraging to resource –poor farmers. Existence of certain plant species in a geo-location has been associated with soil status. Gilbertson *et al.* (1990) reported some relationships between abundance of plant species with environmental conditions, observing that annual meadow grass (*Poa annua*) dominated in trampled and compacted soils. Soils under legumes were richer in soil nitrogen as they sourced nitrogen from the atmosphere (Stanley *et al.*, 2003). Spatial variability in soil properties was higher in forest soils when compared with reports from grassland soils (Jarvinen *et al*, 1993). There was strong relationship between plant and soil contents less than 10cm depth (long *et al*, 1997). Bulk density, total porosity and carbon-nitrogen ratio were related to organic matter in forest soil (Prevost, 2004). Soils under sugar maple had low concentrations of basic cations of calcium, magnesium and potassium (Cote *et al.*, 1995; Horseley *et al.*, 2000).

Southeastern Nigeria has a significant proportion of resource poor farmers especially in the country sides. These farmers hold tenaciously to traditional systems of slash-and- burn land clearing techniques and allow soils to regenerate after a fallow period. But, the fallow length is shortened due to population pressure and conflictive land use. It becomes difficult to readily ascertain soil fertility status using the traditional bush fallow, more so where the region is under high scourge of soil erosion. Yet these soils are not tested for suitability evaluation as most farmers cannot afford the cost of field studies, laboratory analyses and reporting involved in a soil survey process. Thus, this study investigated the nutrients status of soil carrying selected plants: *Caladium, Costus, Setaria* and *Imperata* in southeastern Nigeria.

## MATERIALS AND METHODS

**Study area:** Soil samples were collected from selected locations from Abia and Imo States, southeastern Nigeria (latitudes 4$^o$40$^1$ to 8$^o$15$^1$N, and longitude 6$^o$40$^1$ to 8$^o$15$^1$ E). Abia and Imo State occupy an area of about 13,032 km$^2$. The area belongs to the lowlying part of southeastern Nigeria, and soils are derived from coastal plain sands, shale, false bedded sandstone, alluvial deposits, upper and lower coal measures. Rainforest vegetation is dominant in the area while it has a humid tropical climate. Total mean annual rainfall is between 1800 and 2500 mm, and is bimodal. Mean annual temperature ranges from 26 to 30 $^o$C. Low-input arable farming is the dominant socio economic activity in the area.

**Field Studies**: Soil samples were collected on soils with 0 to 1 % slope. Soil samples were collected with the aid of an auger to a depth of 0-15 cm from soils formed over coastal plain sands (Benin Formation). The locations for samples collection were Alike Obowo, Amuzu Mbaise , Amakama Umuahia, Asaa Ohaji, Egbu Owerri, Umuohie Okpala, Owerrinta, Okwuzi Egbema, Umuguma Owerri and Atta Ikeduru. Five soil samples were collected each in soils dominated by *Caladium, Costus, Setaria* and *Imperata* in each of the locations. These soil samples were later bulked and quartered to produce 10 replicates for each plant species. The soil samples were air-dried and sieved through 2-mm sieve preparatory to laboratory analyses.

**Laboratory Analysis:** Particle size distribution was determined by hydrometer method (Gee and Bauder, 1986). Ammonium-nitrogen ($NH_4^+$ -N) was measured using specific ion electrode method (Mulvaney, 1986). Nittrate-nitrogen ($NO_3^-$ -N) was estimated using Griffin (1995). Total nitrogen was determined using Kjedahl method (Bremner, 1996). Total carbon was estimated according to the procedure of Nelson and Sommers (1982). Available phosphorus was determined by Bray II method (Olsen and Sommers, (1982). Exchangeable basic cations were estimated using Wolf and Beegle (1995). Cation exchange capacity was determined according to the procedure of Rhoades (1982). Soil pH was determined electrometrically in a soil liquid ratio of 1:2.5 using a pH meter. Base saturation was calculated as total exchangeable bases divided by cation exchange capacity multiplied by 100 percent.

**Data Analysis:** Soil data collected were subjected to Analysis of variance (ANOVA) for a completely randomized design (CRD) using plant species as treatments, and quartered bulk samples as replicates as outlined in Murray and Larry (1996). Means were separated using least significant difference at 5% level of probability.

## RESULTS AND DISCUSSION

### Particle size distribution

Sand loam textures were reported in soils of all plant species (Table 1). There were significant(P=0.05)differences in the distribution of clay- and silt sized particle sizes (Table 1). There was no significant difference in the distribution of total sand in soils although numerically, soils under *Imperata* recorded the highest value of sand (880 g/kg) (Table 1) .Significant differences in the distribution of silt and clay could be traced to the protective and canopy effect of plant species. Plant species with broader leaves and greater density may cover soils from direct raindrop effect which shatter soil particles, making lighter silt and clay prone to moving runoff water, hence significant variation recorded.

**Table1: Particles size distribution (g/kg) at 0.15cm depth**

| Plant species | Sand | Silt | Clay | Texture |
|---|---|---|---|---|
| Caladium | 850 | 10 | 110 | Sandy loam |
| Costus | 840 | 50 | 110 | Sandy loam |
| Setaria | 850 | 20 | 130 | Sandy loam |
| Imperata | 880 | 20 | 100 | Sandy loam |
| **LSD $_{0.05}$** | **Ns** | **4.2** | **6.5** | |

## Exchangeable Basic Cations

There were significant (P=0.05) differences in the distribution of exchangeable basic cations of Ca, Mg and K among plant species (Table 2). Values of exchangeable Ca are highest in soils under *Caladium* (2.2 cmol (+)/kg), followed by *Setaria* (1.7 cmol (+)/kg), then *Costus* (1.0 cmol (+)/kg) and least in *Imperata* (0.8 cmol(+)/kg). But, values of exchangeable Mg was in this order: *Setaria* (0.9 cmol(+)/kg) *Imperata* (0.7 cmol (+)/kg) and (0.6 cmol (+/kg) for soils under *Caladium* and *Costus*. Calcium Magnesium ratios were low in *Setaria*, *Costus* and *Imperata* but high in soils under *Caladium* (Ca/Mg=3.6), indicating that soils in the latter are more fertile than the former plant species. Landon (1991) stated that soils with Ca/Mg ratio less than 3.0 are poor in fertility; implying soils under *Caladium* are more suitable for agronomic purposes.

**Table 2: Concentration of basic cations (cmol/kg) at 0-15 depth**

| Plant species | Ca | Mg | K | Ca/mg |
|---|---|---|---|---|
| Caladium | 2.2 | 0.6 | 0.04 | 3.6 |
| Costus | 1.0 | 0.6 | 0.02 | 1.7 |
| Setaria | 1.7 | 0.9 | 0.02 | 1.9 |
| Impearta | 0.8 | 0.7 | 0.01 | 1.1 |
| **LSD $_{0.05}$** | **0.06** | **0.02** | **Ns** | **0.04** |

## Soil Organic Fractions

Table 3 shows the distribution of soil organic fractions among plant species. Total carbon, total nitrogen, nitrate-nitrogen and ammonium-nitrogen showed significant (p=0.05) differences in their distribution in these soils. Changes in these organic fractions may be related to the level of exposure of soils in line with findings of Bird and Torn (2006) on soils under *Ponderosa* pine. There were significant (p=0.05) changes in carbon – nitrogen ratio in soils. Soils under *Caladium* have a more favourable C: N ratio as soils with narrow ratios are relatively rich in nitrogen while those with wider ratios suggest low nitrogen content (Foth, 1984).

Total carbon values were distributed as 14.0 g/kg, 13.0 g/kg, 11.0 g/kg and 8.0 g/kg for soils under *Caladium, Setaria, Costus* and *Imperata*, respectively. The vegetal type and varying rates of plant species litter decomposition possibly affected the distribution of total soil carbon in agreement with earlier studies (Nepstad *et al*, 2008).

Nitrate – nitrogen and $NH_4^+$ -N values followed similar trend as total carbon while total nitrogen decreased from 1.7g/kg (*Caladium*), 0.5 g/kg (*Costus*), 0.49 g/kg (*Setaria*) and 0.25g/kg (*Imperata*) (Table 3).

Base saturation ranged from 56% (*Caladium*), 49% (*Setaria*), 41% (*Costus*) and 21% (*Imperata*) (Table 4). Available soil phosphorus and soil pH followed similar distribution pattern, decreasing in the order of *Caladium, Setaria, Costus* and *Imperata*.

**Table 3: Concentration of organic manure fractions (g/kg) at 0.15in depth**

| Plant species | Total carbon | Total nitrogen | $NO_3^{-1}$-N | $NH_4^+$-N | C/N |
|---|---|---|---|---|---|
| Caladium | 14.0 | 1.7 | 0.13 | 0.220 | 8.2 |
| Costus | 11.0 | 0.56 | 0.11 | 0.180 | 19.6 |
| Setaria | 13.0 | 0.49 | 0.12 | 0.200 | 26.5 |
| Imperata | 8.0 | 10.25 | 0.08 | 0.090 | 32.0 |
| **LSD $_{0.05}$** | **2.9** | **0.50** | **0.011** | **0.009** | **6.3** |

**Table 4: Distribution of base saturation available phosphorus and soil pH at 0-15 cm depth**

| Plant species | Base saturation % | Available phosphorus (mg/kg) | Soil PH water |
|---|---|---|---|
| Caladium | 56 | 12.9 | 6.2 |
| Costus | 41 | 8.7 | 5.6 |
| Setaria | 49 | 9.5 | 5.8 |
| Imperata | 21 | 2.4 | 4.5 |
| **LSD $_{0.05}$** | **8.2** | **2.5** | **2.83** |

In all these plant species, total carbon had varying levels of relationship with exchangeable calcium, available phosphorus, clay, silt, soil pH and total nitrogen (Table 5). Significant relationships were established between total carbon and exchangeable calcium (r =0.81; p=0.01), available phosphorus (r=0.68; P= 0.01), clay (r= 0.78; p=0.02), total nitrogen (r=0.90; p=0.01), silt (r=0.56; P=0.05) and soil pH (r=0.51; p=0.05) (Table 5). High positive relationship between exchangeable calcium and total carbon implies that increase in one leads to the increase of the other factor. Earlier, Baldock and Skjemstad (2000) remarked that calcium stabilizes organic matter and forms calcium humate with humic acid fractions which increases organic matter turnover (Nguyen *et al*., 2004). Increase in clay content resulted in higher total carbon in line with the findings of Foth (1984) who observed that clays absorb organic matter which may slow down the decomposition rate.

**Table 5, correlation between total carbon and some soil properties (N=40)**

| Soil property | Correlation coefficient (r) | Level of significant |
|---|---|---|
| Ca VS Total carbon | 0.81 | ** |
| Avail. P VS Total carbon | 0.68 | ** |
| Clay VS Total carbon | 0.78 | ** |
| Silt VS Total carbon | 0.56 | * |
| Soil PH VS Total carbon | 0.51 | * |
| Total nitrogen VS total carbon | 0.90 | * * |

Ca= calcium, Avail. P = available phosphorus
** = p=0.01, *= p = 0.05

## CONCLUSION

The study revealed that significant (P=0.05) differences exist in studied soils in the concentration of Ca, Mg and Ca/Mg ratios. There were significant (P=0.05) variations in organic fractions in soils under *Caladium, Costa, Setaria* and *Imperata*.

In these soils, total carbon had positive significant (P=0.05) with exchangeable calcium, available phosphorus, clay, silt, pH and total nitrogen. These relationships can be of high predictive relevance in rural agriculture.

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