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# ASSESSMENT OF PHYSICO-CHEMICAL PROPERTIES OF FERRUGINOUS ULTISOL IN BENIN CITY, EDO STATE – POSSIBLE IMPACT ON PLANT DISTRIBUTION

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**Abstract:** The current study investigate the physico-chemical properties as well as nutrient content of ferruginous soils (FS) in Benin and its possible impact on plant distribution. Six FS and a control were sampled from different regions within Benin metropolis and were analyzed for physico-chemical properties following standard procedures. The FS were observed to be acidic as compared to the control which is slightly acidic. Soil organic matter, available phosphorus, cation exchange capacity, water holding capacity and total nitrogen were significantly low ($p<0.05$) in the FS comparative to the control soil. Iron levels were higher in the FS than the control soil. Significant differences were observed in species frequency between the ferruginous regions. *Eleusine indica* was observed as the most abundant in all the sampled regions. The FS obtained from Ekenwa road, Benin-City (F1) showed poorest fertility properties and low species abundance as well as high iron levels compared to other ferruginous regions. The study recommends sustainable improvement of ferruginous soils in Benin-City for improved agricultural yield.

**Keywords:** ferruginous ultisol, plant distribution, physico-chemical properties, phosphorus, *Eleusine indica*.

## INTRODUCTION

Soil is a critical part of successful agriculture and it's the main source of the nutrients that we use in grow crops (Valera, 1977). It comprises of minerals, organic matter, microbes, water and air (Nnadi *et al.*, 2019). These components of soils greatly influence the fertility, structure, and porosity of different soils and as well, affect the distribution of plants (Ikhajiagbe *et al.*, 2019). Therefore, soil physicochemical properties as well as soil nutrients have great influence on soil quality and ability to grow crops. Soil physicochemical properties such as the pH (Sumner, 1997), nutrient depletion and loss of soil organic matter (Nye and Greenland, 1961), low soil nitrogen, phosphorus deficiency and iron toxicity are considered major hindrances for the growth of myriad agricultural products (Adnan *et al.*, 2018; Joshis *et al.*, 2007). Similar soil properties have been linked with red soils of the humid tropics and have always served as indicators of the intensity of weathering, considering the source of the parental materials as Fe-rich mafic rocks. These soils are otherwise known as ferruginous ultisols (Cho and Ponnamperuma, 1971).

Ferruginous ultisol are acidic red soils that are always found in warm, temperate, humid climates and in regions covered with deciduous or mixed forests (Yu *et al.,* 2016). These special soil landscapes are primarily distributed throughout the tropical and subtropical areas, particularly in Southeast Asia, Oceania, South America, southern North America and Africa. (Zhao, 2014). The total area of red soils is approximately 64 million km$^2$, accounted for 45.2% of the Earth's surface area (Anumalla *et al.*, 2019) and resided by 2.5 billion people, nearly half of the global population (Zhao, 2014). In Nigeria, it is predominant in some southern states such as Edo state, occupying about seven zones, including extreme north and central Benin (Doyou *et al.*, 2017). Climates that are humid tend to have higher instances of red soil rich iron. Red soils are naturally poor in physical conditions and are also characterized by low pH, cation exchange capacity (CEC), and fertility (Zhao, 2014). However, certain species of weeds can be found flourishing in the regions (Anoliefo *et al.*, 2006). Red soil also have low concentrations of P in soil solution and results in frequent P deficiency of plants (Wang *et al.*, 2014). According to Yu *et al.* (2016), red soils are generally derived from crystalline rock. They are usually poor growing soils with low water holding capacity. It can lead to anti-plant growth properties such as stunted growth and low plant yield which affects productivity and food security (Moss, 1957). It can also encourage growth of some weeds making them invasive in areas meant to grow crops. Globally, there is about 40% decrease in agricultural yield associated with iron toxicity in different agro-ecological areas (Anumalla *et al.*, 2019). The chemical composition of red soil include non-soluble material 90.47%, iron 3.61%, aluminum 2.92%, organic matter 1.01%, magnesium 0.70%, lime 0.56%, carbon dioxide 0.30%, soda 0.12%, phosphorus 0.09% and nitrogen 0.08% (Wang *et al.,* 2014). However significant regional differences are observed in the physical, chemical as well as plant distribution. Hence, this research aims at investigating the physico-chemical properties as well as nutrient composition of the ferruginous ultisol in Benin for possible impact on plant distribution and to improvement soil properties. Considering the ever increasing population in Nigeria, there is need to improve soil properties of all arable lands to meet up the food supply.

## MATERIALS AND METHODS

### Soil sample collection

Between September and November 2019, ferruginous ultiosl samples were collected from six

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locations (F1 to F6) and a control soil (Ctr) around Benin City, Edo State of Nigeria (Figure 1). The soil samples were obtained at 5 to 10cm in depth. The samples were collected at 20km apart. About 20 kg each of these soils were collected and sundried in screen house. The soils were further distributed into plastic bag, of which 10g were transferred into a sample bottle and stored immediately in a portable cooler at 4°C. The samples were brought to the laboratory for physical, chemical and soil nutrient analysis. The description of the soil samples used were:

1. F1= Ferruginous ultisol obtained from Ekenwan road, Benin City.
2. F2= Ferruginous ultisol obtained from Botanical garden of the Department of Plant Biology and Biotechnology, University of Benin.
3. F3= Ferruginous ultisol obtained from Capitol road, Benin City.
4. F4= Ferruginous ultisol obtained from Okad road, Benin City.
5. F5= Ferruginous ultisol obtained from Department of Agricultural Sciences, University of Benin.
6. F6= Ferruginous ultisol obtained from Dentistry department, University of Benin and
7. Ctr= Control soil was obtained from an area with high humus soil at the deep underground rhizosphere of a banana tree at the Botanical garden, University of Benin.

**Fig. 1.** Location of soil sample used for this study.

## Soil physico-chemical analysis

The ferruginous soil samples and the control soils were analyzed for physico-chemical parameters such as soil organic matter (SOM), soil available P, cation exchange capacity (CEC), soil pH, total nitrogen, organic carbon (OC), exchangeable acidity (EA), available potassium, available micronutrients, electrical conductivity, soil texture class and maximum water holding capacity. Soil samples were air-dried, and pulverized into fractions of < 2mm and then sent laboratory for physical and chemical analysis. Soil pH and electrical conductivity (EC) were determined by adding 20 ml of distilled water into the soil samples and mixed with a glass rod. Soil pH was measured by utilizing a pH meter (Model PHS-3C), and the soil conductivity read through a handheld conductivity meter (HI 70039P, Hanna Instruments).

SOM was determined following the method a method proposed by Walkley and Black (1934). The soil available phosphorus was measured using calorimetric method following Murphy and Riley (1962) after the available soil P from the soil has been chemically extracted by Olsen method (Olsen *et al.*, 1954) because of the pH rang (4.4 -6.8). CEC of the soils was determined by equilibrating the soil with neutral normal sodium acetate solution following (Anon, 1987). OC content of the soil sample was determined by wet digestion procedure proposed by Walkly and Black (1934). EA of the soil samples were determined following Bertsch and Bloom (1996) by summation as follows:

Exchangeable acidity (cmol/kg) = ($Na0H_{dif}1W$) X (0.1 mmol H + /mL NaOH) X (0.1 cmol $H^+$ /mmol $H^+$) X ($10^3$ g soil/kg soil).

Where:

Exchangeable $H^+$ = Exchangeable acidity — Exchangeable Al

Potassium in soil was investigated by Ammonium acetate method of Hanway and Heidel (1952). Micronutrients such as iron (Fe), Aluminum (Al), Magnesium (Mg), Sodium (Na) and Calcium (Ca) were extracted from the test soils by DTPA method following Lindsay and Norvell (1978) using Atomic Absorption Spectrophotometer (AAS). The maximum water holding capacity was determined following Gleitz *et al.* (1996) using funnel, Whitman paper and 250 mL conical flask, while the soil physical texture was determined by a quantitative method using Hydrometer method (Bouyoucos, 1962).

*Calculation:*

Correction factor (CF) = (Room temp in 0F – 68) x 0.2

$$\text{Percent Silt + Clay} = \frac{(S_1 - B_1) + CF}{\text{wt. of sample (g)}} \times 100$$

Where, $S_1$ and $B_1$ stand for hydrometer readings of sample and blank, taken at 40 seconds.

$$\text{Percent Clay} = \frac{(S_1 - B_1) + CF}{\text{wt. of sample (g)}} \times 100$$

Where, $S_2$ and $B_2$ stand for hydrometer readings of sample and blank, taken after 2 hrs.

Percent Sand = 100 – (Silt + Clay).

### Determination of weed abundance

Before soils were collected from the designated sites, care was taken to observe the weed distribution within and around the various locations, especially those weeds that were in close proximity to the sample site. For the purpose of species distribution studies, an area measured 5m x 5m, which also included the ferruginous area of interest, was separated out for plant observation. Plants were physically counted within designated 25 $m^2$ quadrants and were sent to the Department of Plant Biology and Biotechnology (Herbarium), University of Benin, Benin City for identification following the manual (Akobundu and Agyakwa, 1998). Since the control soil was obtained from deep underground rhizosphere of a banana tree in the botanical garden of the Department of Plant Biology and Biotechnology, University of Benin, weeds were not sampled in the control soil considering the monoculture nature of the garden. However, few species of *Ageratum conyzoides, Alternanthera sessilis, Asystasia gangetica, Axonopus compressus, Desmodium ramossisimum, Eleusine indica* and *Gomphrena celosioides* were observed in the control region.

### Statistical analysis

Data obtained were presented in means and standard errors of three replicates. Data were analyzed following two-way analysis of variance using GENSTAT (8th edition). Where significant p-values were obtained, differences between means were separated using Student Newman Keuls test following (Alika, 2006).

## RESULTS AND DISCUSSION

### Soil organic matter and organic carbon

Soil organic matter (SOM) serves as reservoir of nutrients and water in the soil. In the current study, it was discovered that the control soil had the highest (17.08 %) SOM, while the F1 soil had the lowest (1.50 %) SOM. There was significant difference between the SOM obtained from the different ferruginous soil locations and the control soil, excluding the F1 and F6 soils which shows no significant difference ($p > 0.05$) (Table 1). The low SOM in the F1 and F6 signifies the inability of the soils to hold nutrients. According to Ku-Smita and Sangita (2015), soils that are poor in organic matter enhances the process of soil erosion and reduces soil important properties such as nutrient cycling and supply. On the other hand, soil organic carbon which is a measurable component of SOM followed similar trend in the present study. Organic carbon was observed to be highest (0.72%) in the control soil and least (0.17%) in the F1 soils. This also described the low fertility of the F1 soil (Viscarra *et al.*, 2014). These may be responsible for the low plant species abundance in the F1 soils (Table 2). According to De-Deyn *et al.* (2004), plant community development and distribution is affected by soil organic matter, nutrients and soil biota.

### Soil available phosphorus

A significant difference ($p<0.05$) was observed in soil available phosphorus among all the assayed soil samples. The control soil was observed to have the highest (20.21 mg/kg) bioavailable phosphorus, while the ferruginous soil from (F1) location was observed to have the least available phosphorus (3.20 mg/kg) followed by the F6 soil (3.90 mg/kg). This may be as a results of low SOM observed in the ferruginous soils of F1 and F6 location compared to the control soil. This is consistent with the work of Wang *et al.* (2014) who observed that ferruginous soils usually have low concentrations of phosphorus in soil solution and results in frequent phosphorus deficiency in plants. Ferruginous soils are most times high in insoluble phosphate but deficient in bioavailable phosphate. Approximately 95–99% of soil phosphorous is present in the form of insoluble phosphates and hence cannot be utilized by the plants (Alok *et al.*, 2013).

**Table 1**

**Physico-chemical properties of ferruginous and control soil used for the experiment**

| | **Location** | | | | | | |
|---|---|---|---|---|---|---|---|
| | **F1** | **F2** | **F3** | **F4** | **F5** | **F6** | **Ctr** |
| **SOM (%)** | 1.50 ± 0.01$^a$ | 13.0 ± 0.05$^b$ | 10.1 ± 0.64$^c$ | 7.31 ± 0.09$^d$ | 5.99 ± 0.33$^e$ | 2.30 ± 0.01$^a$ | 17.08 ±0.09$^f$ |
| **Avl. P (mg/kg)** | 3.20 ± 0.01$^a$ | 22.85 ±0.20$^b$ | 11.43 ± 0.02$^c$ | 13.21 ±0.05$^d$ | 9.32 ± 0.02$^e$ | 3.90 ± 0.03$^f$ | 20.21 ± 0.05$^g$ |
| **CEC (cmol/kg)** | 1.42 ± 0.01$^a$ | 2.21 ± 0.01$^b$ | 1.73 ± 0.02$^c$ | 1.92 ± 0.05$^d$ | 0.91 ± 0.05$^e$ | 0.50 ± 0.05$^f$ | 2.22 ± 0.01$^b$ |
| **pH** | 4.47 ± 0.50$^a$ | 6.81 ± 0.09$^b$ | 5.62 ± 0.02$^c$ | 5.82 ± 0.03$^d$ | 5.22 ± 0.02$^e$ | 4.81 ± 0.01$^f$ | 5.92 ± 0.98$^g$ |
| **Total N (%)** | 0.004 ±0.50$^a$ | 0.055±0.01$^b$ | 0.011 ± 0.10$^c$ | 0.037 ±0.82$^d$ | 0.008 ± 0.05$^c$ | 0.002 ± 0.05$^a$ | 0.062 ±0.01$^e$ |
| **Org. C (%)** | 0.17 ± 0.01$^a$ | 0.82 ± 0.14$^b$ | 0.61 ± 0.80$^c$ | 0.71 ± 0.01$^d$ | 0.42 ± 0.01$^e$ | 0.23 ± 0.10$^f$ | 0.72 ± 0.10$^d$ |
| **EA (meq/100g)** | 0.20 ± 0.04$^a$ | 0.20 ± 0.01$^a$ | 0.41 ± 0.01$^b$ | 0.80 ± 0.01$^c$ | 0.50 ± 0.50$^d$ | 0.11 ± 0.15$^e$ | 0.21 ± 0.20$^a$ |
| **EC (µS/cm)** | 290.7 | 110.6 | 89.0 ±0.46$^c$ | 115.8 | 210.0 ± | 309.9 ± | 111.0 ± |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | ±0.04$^{a}$ | ±0.15$^{b}$ | | ±0.81$^{d}$ | 1.39$^{e}$ | 1.14$^{f}$ | 1.55$^{b}$ |
| **TC** | Clay-Sandy | Loamy sand | Loamy sand | Loamy sand | Loamy sand | Sandy | Loam-Silty |
| **Clay (%)** | 38.80 ±0.50$^{a}$ | 09.00 ±0.09$^{b}$ | 09.00 ±0.09$^{b}$ | 09.07 ±0.09$^{b}$ | 09.04 ±0.05$^{b}$ | 03.10 ±0.08$^{c}$ | 25.24 ±0.01$^{d}$ |
| **Silt (%)** | 8.72 ± 0.04$^{a}$ | 3.21 ± 0.02$^{b}$ | 2.10 ± 0.20$^{c}$ | 3.21 ± 0.01$^{b}$ | 2.79 ± 0.47$^{bc}$ | 2.02 ± 0.05$^{c}$ | 40.10 ± 0.09$^{d}$ |
| **Sand (%)** | 52.43 ±0.02$^{a}$ | 87.80 ±0.09$^{b}$ | 88.31 ±0.18$^{c}$ | 87.7 ±0.10$^{b}$ | 88.0 ±0.11$^{b}$ | 94.9 ±0.01$^{d}$ | 34.65 ±0.03$^{e}$ |
| **WHC (%)** | 26.93 ±0.02$^{a}$ | 48.44 ±0.01$^{b}$ | 48.43 ±0.01$^{b}$ | 48.44 ±0.05$^{b}$ | 47.96 ±0.98$^{b}$ | 20.03 ± 0.01$^{f}$ | 85.11 ± 0.02$^{g}$ |

SOM = soil organic matter, Avl. P = available phosphorus, CEC = cation exchange capacity, N = nitrogen, Org. C = organic carbon, EA = exchangeable acidity, EC= electrical conductivity, Fe = iron, TC= textural class, WHC=water holding capacity, F = ferruginous soil. Alphabet (a, b c) denotes significant difference when parameters for both soil samples are compared.

**Cation exchange capacity (CEC)**

This is the total capacity of a soil to hold exchangeable cations. Table 1 showed that the CEC of the analyzed ferruginous soils and the control soil ranged between (0.50-2.22 cmol/kg). The control soil was observed to have the highest CEC, while the least CEC was observed in the F6 soil. There was significant difference ($p<0.05$) in the CEC of all the analyzed soil samples. However, there was no significant difference in CEC between the control soil and F2 soil. Since CEC influence soil's ability to hold onto essential nutrients, soils with higher CEC are expected to have higher nutrients and less acidic (Hazleton and Murphy, 2007). Also, soils with higher organic matter tend to have higher CEC (Ikhajiagbe *et al.*, 2019). This may be the reason why the control soil showed highest SOM and as well showed highest CEC.

**Soil pH**

Table 1 shows significant difference in the pH levels of all the soil samples analyzed. All soils happened to be acidic, ranging between (4.47-6.81). The F1 soil is observed to have the least pH showing higher acidity, while the F2 soil showed highest pH. The plant abundance in all ferruginous soils may influence the pH levels of soils. Also, ferruginous soils are usually acidic and rich in iron with little or no bioavailable phosphate (Yu *et al.*, 2016). The pH of the control soil was (5.92) which is within the ideal pH for higher soil nutrients and perfect plant growth (Ikhajiagbe *et al.*, 2019). This may be the reason why available phosphorus and nitrogen were higher in the control soil than the ferruginous soils.

**Total nitrogen**

Analysis of the total nitrogen in the soil samples showed that there was significant difference ($P<0.05$) in nitrogen levels of the soil from the six ferruginous soil regions and the control soil. The F6 and F1 soils showed no significant difference and were observed to have the least percentage nitrogen (0.002 and 0.004 %). The highest nitrogen was observed in the control soil (0.062 %). This may be as a result of higher SOM and moderate pH which encourage soil nutrient supply and recycling (Hazleton and Murphy, 2007).

**Exchangeable acidity and electrical conductivity**

The result from (Table 1) showed the exchangeable acidity (EA) in the ferruginous soil and the control soil was ranging between (0.11-0.80 meq/100g). The highest EA was observed in the F4 soil while the lowest was observed in the F6 soil. The EA in F1, F2 and the control soils showed no significant difference ($p<0.05$). The EA in the F1 and F6 soils were slightly low (0.20 and 0.11 meq/100g) which may be attributed to the low SOM. Soils with high EA are linked to have high SOM and vice-versa Mbagwu (1992). Asadu and Akamigbo (1990) showed that SOM could contribute an average of 70% of EA of ultisols and oxisols in the tropics. The electrical conductivity (EC) in the analyzed soils also showed no significant difference. The EC was observed to be highest (290.7 µS/cm) in F1 soil and least (89.0 µS/cm) in F3 soil. This may be the reason why ferruginous soils easily conduct phosphate by lowering the pH and changing the soil biogeochemistry (Borch *et al.,* 2010). The control soil is having a slightly low (111.0 µS/cm) EC which may be as a results of low EA in the soil.

**Available soil nutrients**

Available nutrients such as magnesium (Mg), sodium (Na) and aluminum (Al) were presented in Figure 2. The result showed a significant difference in the Mg content of all the sample soils except for the F3 and F4 soils. The highest Mg (9.02 meq/100g) was observed in the F1 soil, while the lowest (1.63 meq/100g) was observed in the control soil. Na level was observed to be higher in the F1 soil and least in the control soil. There was a high significant difference between all the ferruginous soils comparative to the control soil. Al was also significantly high in the F1 soil (15.02 meq/100g) compared to the control soil (0.74 meq/100g). Knowingfully that Mg is a secondary macronutrient while Na and Al are micronutrients for plants, their low levels in the control soil may signify soil-banana rhizosphere interactions. (Atiku and Noma, 2011) who documented the ability of banana tree to influence soil nutrient biogeochemistry. However, results for these three nutrients did not agree with the work of Ikhajiagbe *et al*. (2019) who suggested that soils with higher pH and EC tend to have more nutrients compared to the soil with lower pH.

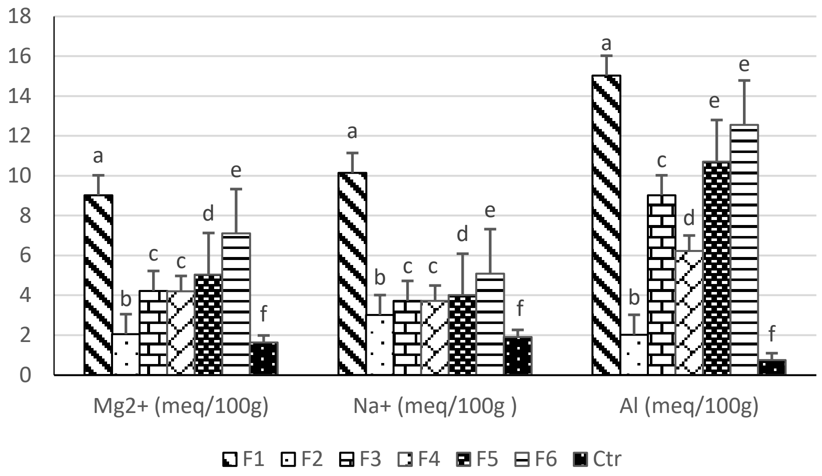

**Fig. 2.** Available soil nutrient.

### Available Potassium

Potassium (K) is an essential nutrient for plant growth (Solanki and Chavda, 2012). Figure 3 showed that the total K in the ferruginous and the control soil ranged between (0.018-0.090 mg/kg). There was no significant difference among all the ferruginous soils. However, a significant difference was observed between the ferruginous soils and the control soil. The highest K was observed in the control soil (0.090 mg/kg), while the lowest (0.018 mg/kg) was observed in the F1 soil. Since K is a primary macronutrient needed by plants in high concentration, the high level of SOM, CEC and pH (Table 1) that was observed in the control soil may be responsible for the high K in the control soil (Ikhajiagbe *et al.*, 2019). This is against the results obtained for the ferruginous soils.

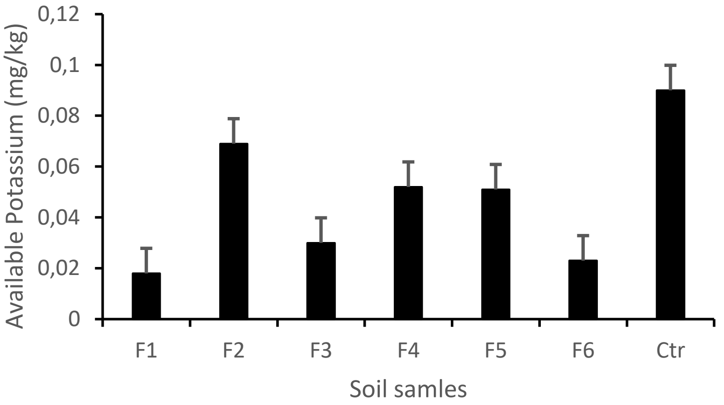

**Fig. 3.** Soil available potassium.

### Soil iron

Ferruginous soils are usually rich in iron, considering the source of the parental materials as Fe-rich mafic rocks (Cho and Ponnamperuma, 1971). According to Wang *et al.* (2014), regional differences may be observed in iron contents of different ferruginous soils. Figure 4 presents the iron levels of different ferruginous sites in Benin-city comparative to the control. The Fe level was observed to range between (200.12-51.22 mg/kg) in all the assayed soils. There were significant differences ($p< 0.05$) between all the sample soils. All the ferruginous soils (F1-F6) showed higher Fe levels compared to the control soil. The array was F1>F6>F5>F3>F4>F2>Ctr. This explains the poor soil parameters such as SOM, CEC, pH, available P, soil Nitrogen that was observed in ferruginous soils compared to the control (Table 1). Ferruginous soils are naturally poor in physical conditions and are also characterized by low pH, CEC, concentration of P and fertility (Zhao, 2014; Wang *et al.*, 2014). The shortage in bioavailable P in iron toxic soils has been linked to the ability of $Fe^{3+}$ to react easily with inorganic $[PO_4]^{3-}$, therefore limiting P-availability. Growing crops that are susceptible to iron toxicity and phosphorus deficiency such as rice may not be yielding in iron rich soils (Cho and Ponnamperuma, 1971). This may be the reason why Edo state is having low rice productivity compared to other states such as Kano (Obayelu, 2015). However, plants such as *E. indica* (Table 2) which was observed flourishing in the ferruginous soils may indicate their resistance to iron toxicity.

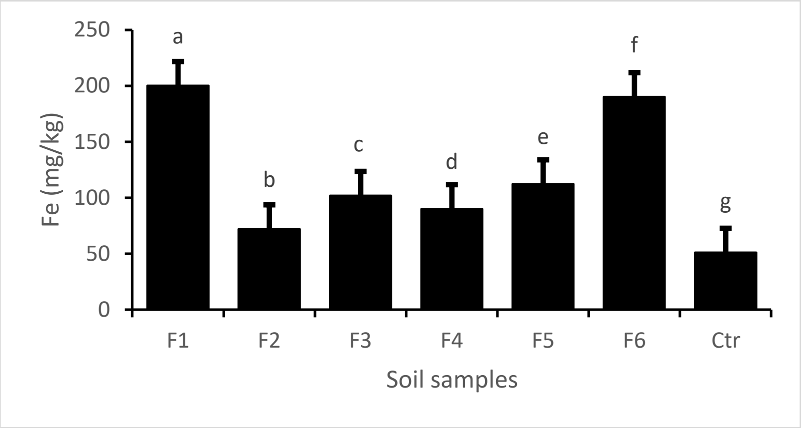

**Fig. 4.** Iron levels in ferruginous soils and control soil.

### Soil physical properties

Table 1 showed the physical properties of all the sample soils. The ferruginous soils and the control soil varied in textural class (TC). The F1 soil showed clay-sandy, F2-F5 soil proved to be loamy sand, F6 showed sandy soil while the control soil was loamy-silty soil. The F1 soil was observed to have the highest (38.80 %) percentage clay, while the F6 had the least (0.3.10 %). This may be as a result of the sandy TC observed in the F6 soil. Percentage silt was highest (40.10 %) in the control soil as compared to the least (2.02 %) percentage silt in the F6 soil. However, the F6 was observed to have the highest percentage sand (94.9 %), while the control soil had the least (34.65 %) sand. This may be as a result of the textural nature of the soil. Water holding capacity (WHC) was observed to be significantly high (85.11 %) in the control soil, while the least WHC was observed in the F6 and F1 soils (20.03 and 26.93 %) respectively. This may be because of the TC of the control soil. (Rosier, 2017) reported that soils with loamy-silty TC are considered ideal for agricultural uses because it retains nutrients as well as high WHC. There was no significant difference in the WHC observed in F2-F5 soils. The low WHC in the F1 soil may be linked to the poor properties of the F1 soil.

### Determination of weed abundance

Twenty three (23) distinct plant species were discovered at the ferruginous regions (Table 2). The F4 soil was observed to have the highest (287) frequency of plant species, while the F2 soil was observed to occupy least (191) species frequency. There was significant difference between the species frequency in all the ferruginous regions which is consistent with the differences in physico-chemical properties of the soils. *Eleusine indica* was observed to be the most dominant species in all the test regions. This plant has been previously identified as a potential plant for bioremediation of heavy metals (Chukwuma, 1995; Anoliefo *et al.*, 2006; Ikhajiagbe *et al.*, 2019).

**Table 2**

**Distribution of plant species within the vicinity of ferruginous and control soils**

| Plant Species | Species population | | | | | | Total |
|---|---|---|---|---|---|---|---|
| | F1 | F2 | F3 | F4 | F5 | F6 | |
| ***Achyranthes aspera*** | 17 | 06 | 06 | 09 | 00 | 09 | 47 |
| ***Ageratum conyzoides*** | 03 | 06 | 05 | 09 | 12 | 09 | 44 |
| ***Alternanthera repens*** | 17 | 14 | 26 | 21 | 12 | 09 | 99 |
| ***Amaranthus spinosus*** | 12 | 34 | 13 | 23 | 21 | 14 | 117 |
| ***Andropogon tectorum*** | 02 | 00 | 03 | 00 | 09 | 00 | 14 |
| ***Axonopus compressus*** | 08 | 03 | 12 | 05 | 14 | 05 | 47 |
| ***Cassia hirsuta*** | 00 | 00 | 00 | 02 | 05 | 10 | 27 |
| ***Eleusine indica*** | 25 | 27 | 23 | 30 | 22 | 21 | 145 |
| ***Euphorbia hirta*** | 01 | 00 | 03 | 11 | 03 | 14 | 32 |
| ***Euphorbia hyssopifolia*** | 06 | 00 | 09 | 00 | 00 | 14 | 29 |
| ***Kyllinga erecta*** | 17 | 03 | 26 | 05 | 09 | 17 | 77 |
| ***Leptochloac aerulescens*** | 08 | 11 | 12 | 17 | 05 | 05 | 58 |
| ***Mallotus oppositifolius*** | 10 | 03 | 04 | 12 | 12 | 09 | 50 |
| ***Malvastrum coromandelianum*** | 08 | 03 | 12 | 23 | 26 | 09 | 81 |
| ***Mariscus alternifolios*** | 11 | 11 | 17 | 17 | 17 | 17 | 90 |
| ***Oldenlandia herbacea*** | 08 | 11 | 12 | 17 | 17 | 17 | 82 |
| ***Panicum maximum*** | 10 | 04 | 08 | 02 | 06 | 02 | 32 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| ***Panicum maximum*** | 08 | 11 | 12 | 17 | 17 | 17 | 82 |
| ***Paspalumscrobiculatum*** | 10 | 14 | 30 | 21 | 09 | 20 | 104 |
| ***Peperomia pellucida*** | 08 | 03 | 12 | 05 | 09 | 09 | 46 |
| ***Phyllantus amarus*** | 04 | 11 | 12 | 17 | 17 | 17 | 78 |
| ***Sida acuta*** | 11 | 08 | 17 | 12 | 17 | 12 | 77 |
| ***Tridax procumbens*** | 06 | 08 | 09 | 12 | 05 | 09 | 49 |
| Total | 210 | 191 | 282 | 287 | 264 | 265 | 1,515 |

## CONCLUSION

The findings of this study showed that ferruginous soils in Benin-City have high iron content and low phosphorus and nitrogen compared to the control soil. Low soil fertility-promoting properties such water holding capacity, soil pH and soil organic matter were also observed in the ferruginous soils. However, significant differences were observed in the physicochemical as well as nutrient levels in different ferruginous regions within Benin metropolis. Differences in plant species frequency around each ferruginous region were also observed. *E. indica* proved to be invasive in all the ferruginous regions. Generally, poor properties of the ferruginous soils in Benin City may be responsible for the low crop yields and invasive weed growth which is likely to affect food security in the region. Studies should be encouraged on sustainable strategies to improve ferruginous soil properties and remediate the iron toxicity in these regions.

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## AUTHORS CONTRIBUTIONS

MSI and BI designed the study, MSI carried out the research under the supervision of BI. MSI carried out the statistical analysis and interpretation of data. MSI wrote the first draft. BI edited the final draft of the manuscripts. The authors read and approved the final manuscript.

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## CONFLICT OF INTERESTS

The authors declare no conflicts of interests.

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