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Chemical Properties of Soil under Different Redox Potentials

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Abstract

Aim: The experiment was setup in an attempt to determine the effect of redox potentials on soil chemical properties Mat and met: A 3 x 2 x 2 factorial experiment was conducted. The experiment was laid out in Randomized Complete Block Design (RCBD) and consisted of three factors namely: Poultry manure at three levels (0 tha-^{1}, 6 tha-^{1} and 8 tha-^{1}), NPK 15-15-15 at two levels (0 kgha-^{1} and 200 kgha-^{1}) and watering regimes at two levels (waterlogged and field capacity). These factors were used to induce the various redox status of the soil. The combination of these variables resulted in twelve (12) treatments which were replicated three times and repeated. The soils were incubated for about three months after which data were collected on soil chemical properties. Data collected included total N, available P, exchangeable cations and organic matter content. Data collected were subjected to analysis of variance (ANOVA) using SPSS version 17 and means compared using Tukey Honesty Significant Difference (HSD) test to verify significant differences among treatments at 5% probability level. Graphs were generated using Microsoft excel 2010 edition. Result: The results of this research showed that redox potential causes changes in the chemical properties of the soils. There was significant difference ($p < 0.05$) in the nitrogen content among the treatments and the highest was moderately reduced soils being 62.5% greater than the oxidized soil that recorded the lowest. There was also significant difference ($p < 0.05$) in the available P which was highest under oxidized soils, being 76.4% greater than the highly reduced soil that recorded the lowest. Organic matter content was highest under highly reduced soil being 42.9% greater than the oxidized soil that recorded the lowest. There were also significant differences ($p<0.05$) among the treatments in terms of exchangeable cations. Exchangeable cations were lowest in soil under highly reduced conditions. Conclusion: It was concluded that the redox status of a soil is a fundamental property that has the tendency of affecting other soil chemical properties.

Keywords: *oxidized, reduced, cation, nitrogen, phosphorus.*

INTRODUCTION

Redox reaction involves the transfer of electrons from one compound to another. Oxidation is the loss of electrons by a compound while reduction is the gain of electrons by a compound and this loss or gain of electrons play a major role in regulating many reactions in biological systems (Sjulstok *et al.*, 2015). Redox potential (pE or Eh) is the measure of electron availability within systems (Kjaergaard, 2006) and it is measured in volt (V) or millivolt (mV) (Sondergaard, 2009). Oxidation and Reduction reactions regulate many of the biogeochemical reactions in surface environment (Falkowski *et al.*, 2008) and as such are relevant to the various chemical processes going on in the soil.Redox reactions arecommon in areas with prevalence of waterlogging or submerged soils. In such soil systems, rapid changes in moisture content strongly affect soil aeration status (Sajedi *et al.*, 2012) as air will be substituted with water in the pore spaces. In addition to these, there are areas or zones in the soil where movement of oxygen is restricted, such as small pores filled with water or compacted interior of aggregates where oxygen consumption is more rapid than oxygen diffusion (Jose *et al.*, 2015). The chemical changes in these type of soils can affect the character of sediment or soil that forms,the suitability of wet soils for crops, the distribution of plant species around lakes and streams and in estuaries' deltasand marine flood plains, the quality and quantity of aquatic life and the capacity of lakes and seas to serve as sinks for terrestrial wastes (Ponnamperuma, 1972).

Also nutrient absorption in soils involves series of biochemical process controlled by many factors, of them soil redox potential (Eh) and soil pH are considered critical controls. Reactivity, mobility, toxicity, and bioavailability of nutrient elements frequently depend on their redox state (Sigg, 2000). In most cases, the absence of oxygen leads to a greater mobility of redox sensitive elements and cations leading to accumulation of Mn_2, Fe_2, or sulfides up to phytotoxic levels (Pezeshki *et al.*, 1988, Dayo-Olagbende *et al.*, 2021).

The chemistry of acid sulphate soils high in soluble acid and ferric sulphate (FeS) changes drastically resulting from change in soil redox potential due to drainage. Redox potential has been used in many disciplines that deal with living organisms, such as microbial ecology (Alexander, 1964), limnology (Reddy and DeLaune, 2008), bioenergetics (Guérin, 2004; Mathis, 1995), soil science (Chadwick and Chorover, 2001) and physiology and ecophysiology (De Gara et al., 2010; Dessaux *et al.*, 2009; Dietz, 2003; Foyer and Noctor, 2005; Lambers *et al.*, 2008). The activities of soil microbes are also dependent on the soil reaction and oxidation-reduction potential (Falkowski *et al.*, 2008, Dayo-Olagbende *et al.*, 2020). However, very little information is available in literature about soil redox potential, and how it affects the chemical components of the soil. Hence, this research sets out to evaluate the effect of redox potential on soil chemical properties.

MATERIALS AND METHODS

The Study Area

The experiment were conducted concurrently using two farmers farm at "Apatapiti" area, close to FUTA in Akure Southwest Local Government Area, Ondo State Nigeria. The two sites were located at an altitude of 332 m above sea level in the rainforest region of Nigeria. FUTA is located in Akure, capital city of Ondo State, South western Nigeria. Akure has a tropical humid climate with two distinct seasons, a relatively dry season from November to March and a wet or rainy season from April to October. Average annual rainfall ranges between 1405 and 2400 mm of which the rainy season accounts for 90% while the month of April marks the beginning of rainfall (Akinbile, 2006). Temperature ranges from 22^0C to 33^0C while annual relative humidity is 80% and annual total sunshine hour is about 2000 hours (Ajibefun, 2008). The soils of both sites are Alfisols according to USDA classification but both fall under different textural classes according to the textural triangle. Site 1 is a sandy clay loam and Site 2 is a clayey loam.

Establishment

Soil Preparation and Experimental Design

The establishment of the first trial was done in the second week of April, 2018 while that of the second trial was done in the second week of September. Five kilogrammes of soil was placed in each bucket, three buckets represented an experimental unit.

The experiment was a 3 x 2 x 2 factorial experiment laid out in a randomized complete block design (RCBD) and replicated three times. Each replicate has a total of twelve treatments, each represented by three buckets filled with 5 kg of homogenized soil. Three levels of poultry manure (0 tha-1, 6 tha^{-1} and 8 tha^{-1}) were applied. Two levels of N : P : K 15-15-15 (0 kgha^{-1}, and 200 kgha^{-1}) was also applied. Two water regimes [Field capacity (Fc) and waterlogging (Wt) were also used. This gave rise to 12 treatments combinations and four redox potential status.

Treatment Combinations

1= 0 t ha^{-1} PM+ 0 kg ha^{-1} NPK+ Fc
2= 0 t ha^{-1} PM+ 0 kg ha^{-1} NPK+ Wt
3= 0 t ha^{-1} PM+ 200 kg ha^{-1} NPK+ Fc
4= 0 t ha^{-1} PM+200 kg ha^{-1} NPK+ Wt
5= 6 t ha^{-1} PM+ 0 kg ha^{-1} NPK+ Fc
6= 6 t ha^{-1} PM+ 0 kg ha^{-1} NPK+ Wt
7= 6 t ha^{-1} PM+ 200 kg ha^{-1} NPK+ Fc
8= 6 t ha^{-1} PM+ 200 kg ha^{-1} NPK+ Wt
9= 8 t ha^{-1} PM+ 0 kg ha^{-1} NPK+ Fc
10= 8 t ha^{-1} PM+ 0 kg ha^{-1} NPK+ Wt
11= 8 t ha^{-1} PM+ 200 kg ha^{-1} NPK+ Fc
12= 8 t ha^{-1} PM+ 200 kg ha^{-1} NPK+ Wt

Where PM is Poultry manure, Fc is Field capacity and Wt is Waterlogging.

Soil Sampling and Analysis

Pre experimental soil samples were collected from the two sites, top soil from each sites was collected and bulked from which a composite sample was collected and analyzed for soil properties.

The collected soils were air-dried for about 24 hours, ground and sieved through a 2 mm mesh sieve. Chemical analysis was done to determine the redox potential, percentage total Nitrogen, available P, exchangeable K, exchangeable cations (Ca, Mg, Na), pH, organic matter content.

Redox potential was measured using the same method to that described by Rabenhorst *et al.* (2009), 20 g of the soil samples were collected, soaked in water from bottom to top so as to prevent entrapment of air during saturation and allowed to mix for 30 minutes after which 50 ml of the solution was collected and taken to the laboratory for reading. In the laboratory, redox potential (Eh) was measured using a pH/Redox combined meter. Voltage was measured every 10 seconds for 60 seconds and the mean values of the collected measurements were calculated.

$$\mathbf{VT} = \frac{\boldsymbol{V1 + V2 + V3 + V4 + V5 + V6}}{\mathbf{6}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots .\mathbf{equ\ 1}$$

Where :
VT= Mean Voltage
V1= First Voltage reading
V2= Second Voltage reading
V3= Third Voltage reading
V4= Fourth Voltage reading
V5= Fifth Voltage reading
V6= Sixth Voltage reading

Determination of Chemical properties

Twenty grammes of soil was mixed with 50ml of distilled water and stirred at interval for 30 minutes. The pH of the suspension was measured with a pH meter.Percentage total nitrogen was determined by the kjeldahl digestion method. One gramme of the soil sample was digested in conc. H_2SO_4 using selenium tablet as catalyst. The compound formed was then titrated with 0.02 NHCL. Available phosphorus was determined using the Bray and Kurtz (1945) method. Exchangeable cations (K, Ca, Mg and Na) were extracted using 1.0 N ammonium acetate (NH_4OAc) solution at pH 7. About 5 g of soil samples were transferred into a leaching tube and leached with 100 ml of buffered 1.0 *N* ammonium acetate (NH_4OAc) solution.Potassium and sodium content in the soil was determined using the flame photometry method. A standard series of potassium and sodium were prepared by diluting both 1000 mgl^{-1} potassium and sodium solution to 100 mgl^{-1}. This was done by taking a 25 ml portion of each into one 250 ml volumetric flask and made to volume with water. Portions of 0, 5, 10, 15, 20 ml of the 100 mgl^{-1}, standard solution were put into 200 ml volumetric flask respectively. About 100 ml of 1.0 *N* NH_4OAc solution was added to each flask and made to volume with distill water. The standard series obtained was 0, 2.5, 5, 7.5, 10 mgL^{-1} for potassium and sodium. Potassium and sodium were then measured directly by flame photometry at wavelengths of 7665.5 and 589.0 nm respectively. To determine calcium plus magnesium, 25 ml of the extract was transferred into an Erlenmeyer flask. A 1.0 ml portion of hydroxylamine hydrochloride, 1.0 ml of 2.0 percent potassium cyanide buffer (from the burette), 1.0 ml of 2.0 percent potassium ferrocyanide, 10.0 ml ethanolamine buffer and 0.2 ml Eriochrome Black T solution were added. The solution was titrated with 0.01 N EDTA (ethylene diamine tetraacetic acid) to a pure turquoise blue color and the titre values were recorded. The values for calcium were subtracted from this value to get the titre value for magnesium.

Calculation:

$$\mathbf{Ca\ (cmol/kg)} = \frac{\mathbf{V1 - V2\ X\ V4\ X\ N\ X\ 100\ X\ mcfV3\ X\ W}}{\mathbf{V3\ X\ W}} \ldots\ldots\ldots\ldots\ldots\ldots.\mathbf{equ\ 2}$$

Where:

V1 = volume of EDTA required for aliquot sample titration, ml
V2 = volume of EDTA required for blank titration, ml
V3 = volume of aliquot taken, ml
V4 = total volume of original NH_4OAC extract, ml
N = Normality
W = Weight of sample taken in g
Mcf = moisture correlation factor
1 mL 0.01N EDTA = 0.2004 mg Ca^{2+} = 0.1216 Mg^{2+}

Soil organic matter content was determined using the walkley-Black oxidation method which measures the active or decomposable organic matter in the soil. The soil sample was ground into fine powder from which 1 g soil sample was taken and placed in a 250 ml conical flask and 10 ml of 0.167 M K_2Cr_2O7 was added. About 20 ml of conc. H_2SO4 was rapidly added to the mixture and then swirled gently until the soil and the reagents mixed properly. The mixture is the allowed to cool for about 30 minutes. Three drops of ferroin indicator was added and titrated against 0.5 M Iron (II) ammonium sulphate. The end product is a brownish red or maroon color solution. Also a blank titration was done without soil.

Calculations

% Organic Carbon= (B-T) x M x 0.003 x 1.33 x 100/wt

Where:

B= Blank titre value
T= Sample titre Value
M= Molarity of $Fe(SO_4)_2$
Wt= Weight ofdriedsample

Percentage Organic Matter is then further calculated as %OM= % Organic Carbon x 1.724

Statistical Analysis

Data collected were subjected to analysis of variance (ANOVA) using SPSS version 17 and means were compared with Tukey HSD test to verify significant differences among treatments at 5% probability level. Graphs were generated using Microsoft excel 2010 edition.

RESULTS

Pre-experimental Soil Properties

Table 1 presents the pre-experimental properties of the two soils used for the experiment. Site 1 has a sand percentage of 54.8, silt content of 20.5 and clay content 24.7, according to textural triangle it falls into the class of Sandy clay loam. It has an Eh of 260 mv, which makes it an oxidized soil and a pH of 6.26 falling in the slightly acidic range. It has a moderate Organic matter content (1.60) but the total N (0.19) was moderate. Available P (15.2) was moderate while exchangeable cations K, Ca, Mg were low. Site 2 has a sand percentage of 48.0, silt content of 21.4 and clay content 30.6, according to textural triangle it falls into the textural class of clay loam. It has an Eh of 282 mv, which makes it an oxidized soil and a pH of 8.25 falling in the slightly alkaline range. It has moderate Organic matter content (2.36) and the total N (0.17) was moderate. Available P (24.8) was high while exchangeable cations K, Ca, Mg were also low.

Table 1: Pre-experimental Soil Analysis

Properties	Site 1	Site 2
Redox Potential (mv)	260	282
pH (water)	6.26	8.25
Sand %	54.8	48.0
Silt %	20.5	21.4
Clay %	24.7	30.6
Textural Class	Sandy Clay Loam	Clay Loam
Organic Matter %	1.60	2.36
N %	0.19	0.17
P (ppm)	15.2	24.8
K (cmolkg^{-1})	0.16	0.18
Ca (cmolkg^{-1})	3.25	3. 43
Mg (cmolkg^{-1})	1. 53	1.72
Na (cmolkg^{-1})	0.20	0.28

Effect of Treatments on Soil Chemical properties

Tables 2 and 3 present the effect of redox potential on soil chemical properties of the two soils at the end of each trial periods of the experiment. Table 1 represents the first trial while table 2 represents the second trial. For soil 1, 8 t ha^{-1} PM+ 0 kg ha^{-1} NPK+ Wt recorded the highest value for pH while 0 t ha^{-1} PM+ 200 kg ha^{-1} NPK+ Fc gave the lowest. Organic matter content and total nitrogen were highest in treatments with 8 t ha^{-1} PM+ 200 kg ha^{-1} NPK+ Wt and lowest in 0 t ha^{-1} PM+ 0 kg ha^{-1} NPK+ Fc, while 8 t ha^{-1} PM+ 200 kg ha^{-1} NPK+ Fc recorded the highest Available P and 0 t ha^{-1} PM+200 kg ha^{-1} NPK+ Wt had the lowest. Exchangeable calcium was highest at 8 t ha^{-1} PM+ 200 kg ha^{-1} NPK+ Wt and lowest at 0 t ha^{-1} PM+200 kg ha^{-1} NPK+ Wt, while the highest and lowest values for magnesium and sodium contents were recorded in soils with 8 t ha^{-1} PM+ 200 kg ha^{-1} NPK+ Fc and 0 t ha^{-1} PM+200 kg ha^{-1} NPK+ Wt respectively. For soil 2, 0 t ha^{-1} PM+ 0 kg ha^{-1} NPK+ Fc recorded the highest pH value while 6 t ha^{-1} PM+ 200 kg ha^{-1} NPK+ Wt, 8 t ha^{-1} PM+ 0 kg ha^{-1} NPK+ Wt and 8 t ha^{-1} PM+ 200 kg ha^{-1} NPK+ Wt recorded the lowest. Organic matter content was highest at 8 t ha^{-1} PM+ 200 kg ha^{-1} NPK+ Wt and lowest at 0 t ha^{-1} PM+ 200 kg ha^{-1} NPK+ Fc while total percentage nitrogen was highest at 8 t ha^{-1} PM+ 200 kg ha^{-1} NPK+ Fc and lowest at 0 t ha^{-1} PM+ 0 kg ha^{-1} NPK+ Wt. Available P was highest at 8 t ha^{-1} PM+ 200 kg ha^{-1} NPK+ Wt and least at 0 t ha^{-1} PM+ 0 kg ha^{-1} NPK+ Wt, Ca content of 8 t ha^{-1} PM+ 200 kg ha^{-1} NPK+ Fc gave the highest value while 6 t ha^{-1} PM+ 0 kg ha^{-1} NPK+ Wtgave the least. Soils with 8 t ha^{-1} PM+ 0 kg ha^{-1} NPK+ Fc gave the highest value for magnesium while 0 t ha^{-1} PM+200 kg ha^{-1} NPK+ Wt gave the least, Na contents in soils with 6 t ha^{-1} PM+ 0 kg ha^{-1} NPK+ Fc, 6 t ha^{-1} PM+ 0 kg ha^{-1} NPK+ . Figure 1 and 2 presents the rate of organic matter decomposition over 12 weeks for both trial 1 and 2 respectively. Technically, the figure illustrates the changes in the level of organic matter in the soil. Highly reduced soils show a slight decline in organic matter content over 12 weeks. Even though the organic matter of reduced soils was not as much as the others in the initial stage (1WAI) with organic matter content of 1.53 and 2.11 for soil 1 and soil 2 respectively, there was also a slight decline in organic matter content after 12 weeks. Rate of decline of organic matter content in moderately reduced and oxidized soils was high which is highest under oxidized soils, recording organic matter content as low as 0.81 and 1.33 for soil 1 and soil 2 respectively at 12 WAI. The same trend was observed during the second trial.

Table 2: Effect of Treatments on Soil Chemical Component on both soil˙(First Trial)

Factor	Field Capacity								Waterlogged							
PM (tha-1)	pH	OM	N	P	K	Ca	Mg	Na	pH	OM	N	P	K	Ca	Mg	Na
		…….g/kg…….		mg/kg	……………..cmol kg^{-1}……… ….....					…….g/kg…….		mg/kg	……… cmol kg^{-1}……………..			
0	5.98c	0.82c	0.04b	11.2c	0.04b	2.94c	1.16c	0.10b	6.12c	1.32c	0.05c	10.8b	0.07a	2.54c	1.02b	0.06b
6	6.02b	1.10b	0.06ab	14.0a	0.11a	3.33a	1.36b	0.12ab	6.81b	1.52b	0.08a	11.2a	0.05b	2.87b	1.13a	0.09ab
8	6.22a	1.37a	0.07a	12.2b	0.11a	3.32ab	1.43a	0.13a	6.86a	1.91a	0.06b	10.7c	0.06ab	3.00a	0.82c	0.10a
NPK (Kgha^{-1})																
0	5.98a	0.82b	0.04a	11.2b	0.04b	2.94a	1.16a	0.10a	6.12a	1.32b	0.05a	10.8a	0.07a	2.54a	1.02b	0.06a
200	5.90a	0.90a	0.05a	12.3a	0.15a	2.91b	1.06b	0.11a	6.00b	1.36a	0.02b	10.7a	0.06a	2.48b	1.06a	0.06a
P(F test)																
PM	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
NPK	NS	*	NS	*	*	*	*	NS	*	*	*	NS	NS	*	*	NS
PMxNPK	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
PMxNPKxWR	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
								Soil 2								
PM (tha-1)																
0	8.21a	1.34b	0.02b	15.22c	0.07c	3.45c	0.82c	0.07b	8.18a	1.87c	0.00c	15.10c	0.04c	3.50a	0.71c	0.07a
6	8.10b	1.82a	0.09a	17.42b	0.13b	3.52b	1.29b	0.09a	7.30b	2.49b	0.05b	17.64a	0.10b	2.85b	1.09b	0.07a
8	8.11b	1.83a	0.09a	17.62a	0.20a	3.81a	2.03a	0.08ab	7.10c	2.67a	0.07a	17.19b	0.14a	3.54a	1.92a	0.05b
NPK (Kgha^{-1})																
0	8.21a	1.34a	0.02b	15.22b	0.07b	3.45a	0.82a	0.07a	8.18a	1.87b	0.00a	15.10b	0.04b	3.50a	0.71a	0.07a
200	8.15b	1.30b	0.04a	17.24a	0.18a	3.51a	0.84a	0.07a	7.40b	1.95a	0.03a	16.82a	0.13a	3.42b	0.70a	0.06a
P(F test)																
PM	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
NPK	*	*	*	*	*	NS	NS	NS	*	*	NS	*	*	*	NS	NS
PMxNPK	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
PMxNPKxWR	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*

Means followed by the same letters are not significantly ($p<0.05$) different according to Tukey HSD,
NS= Not Significant, *= Significant

Table 3: Effect of Treatment on Soil Chemical Component on both soil (Second Trial)

Factor				**Field Capacity**								**Waterlogged**				
PM (tha^{-1})	pH	OM	N	P	K	Ca	Mg	Na	pH	OM	N	P	K	Ca	Mg	Na
		…….g/kg…….		mg/kg	…………..cmol kg^{-1}……… ….....					…….g/ kg…….		mg/kg	………. cmol kg^{-1}………… …..			
0	5.96c	0.82c	0.03b	11.30c	0.03b	2.97b	1.18b	0.10a	6.10b	1.80b	0.05b	10.60b	0.05a	2.42b	1.05b	0.07b
6	6.04b	1.12b	0.06a	14.20a	0.10a	3.30a	1.35a	0.12a	6.82a	2.42a	0.07a	11.10a	0.05a	2.96a	1.07a	0.08b
8	6.20a	1.38a	0.07a	12.32b	0.11a	3.20a	1.28a	0.12a	6.87a	2.52a	0.07a	10.70b	0.05a	2.94a	0.82a	0.10a
NPK (Kgha^{-1})																
0	5.96a	0.82b	0.03b	11.30b	0.03b	2.97b	1.18a	0.10a	6.10a	1.80b	0.05a	10.6a	0.05a	2.42b	1.05b	0.07a
200	5.91b	0.92a	0.06a	12.30a	0.12a	3.11a	1.05b	0.10a	6.02b	1.94a	0.02b	10.4a	0.06a	2.52a	1.07a	0.05a
P(F test)																
PM	*	*	*	*	*	*	*	NS	*	*	*	*	NS	*	*	*
NPK	*	*	*	*	*	*	*	NS	*	*	*	NS	NS	*	*	NS
PMxNPK	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
PMxNPKxWR	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
								Soil 2								
PM (tha^{-1})																
0	8.23a	0.72b	0.02b	15.31c	0.06c	3.42c	0.84c	0.08a	8.15a	1.25c	0.00c	15.26c	0.03c	3.54a	0.70c	0.07a
6	8.11b	1.01a	0.09a	17.40b	0.09b	3.55b	1.30b	0.08a	7.38b	1.69b	0.05b	17.61a	0.08b	3.19c	1.11b	0.07a
8	8.10b	1.12a	0.09a	17.60a	0.18a	3.82a	2.01a	0.07a	7.22c	2.00a	0.07a	17.20b	0.12a	3.51b	1.97a	0.05b
NPK (Kgha^{-1})																
0	8.23a	0.72a	0.02a	15.31b	0.06b	3.42b	0.84a	0.08a	8.15a	1.25b	0.00b	15.26b	0.03b	3.54a	0.70a	0.07a
200	8.15b	0.86b	0.03a	17.30a	0.15a	3.51a	0.81b	0.07a	8.16a	1.34a	0.02a	17.00a	0.10a	3.40b	0.72a	0.06a
P(F test)																
PM	*	*	*	*	*	*	*	NS	*	*	*	*	*	*	*	*
NPK	*	*	NS	*	*	NS	NS	NS	NS	*	*	*	*	*	NS	NS
PMxNPK	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
PMxNPKxWR	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*

Means followed by the same letters are not significantly (p<0.05) different according to Tukey HSD,
NS= Not Significant, *= Significant

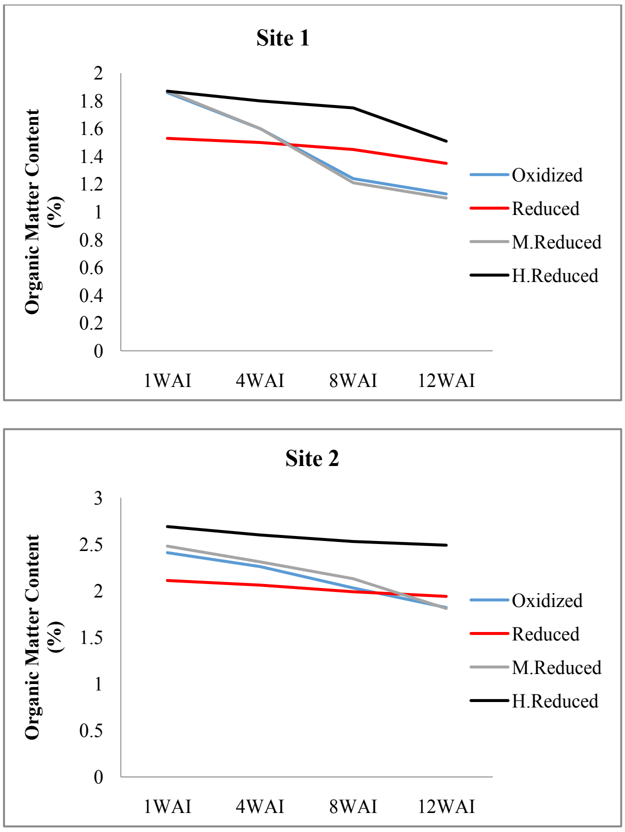

Figure 1: Trend of Organic Matter Content of Treatments Over 12 Weeks (First Trial)

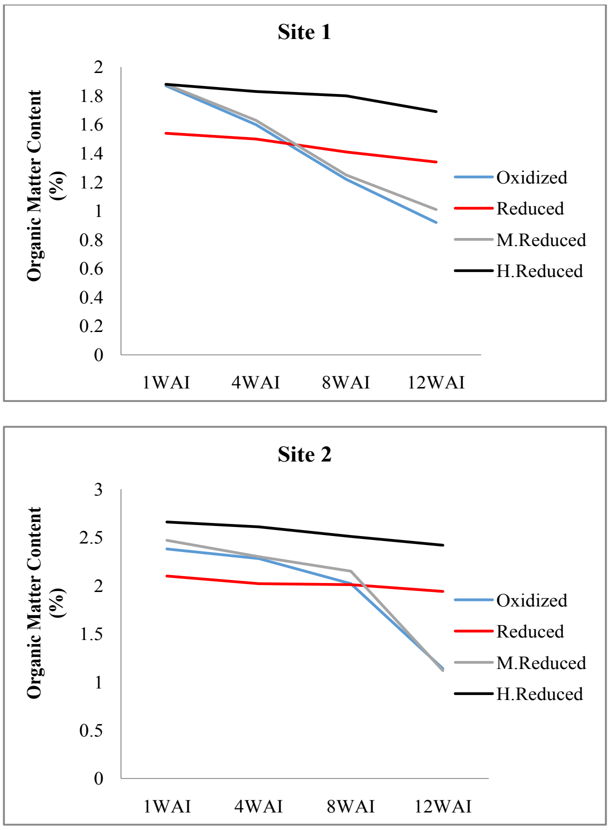

Figure 2: Trend of Organic Matter Content of Treatments Over 12 Weeks (Second Trial)

Wt and 8 t ha^{-1} PM+ 200 kg ha^{-1} NPK+ Fc were highest while treatment 8 t ha^{-1} PM+ 0 kg ha^{-1} NPK+ Wt had the lowest. The same trend was observed for the second trial.

DISCUSSION

Effect of Redox Potential on Soil Hydrogen Potential (pH)

Acid-base reaction also known as hydrogen potential or pH is a major reaction used in soil analysis. From the results obtained in this research, redox potential has significant ($p<0.05$) influence on soil pH. Highly reduced soils were found to be less acidic and less alkaline than the moderately reduced and oxidized soils. In a report on O_2, pH and Eh around pond weed by Dong *et al.* (2014), it was observed that an increase in pH of acid soil arose from a decrease in redox potential. According to Walstra and Jenness (1984) working on the redox potential of milk as related to its pH also concluded that the pH of milk was raise with a decrease in redox potential. However, redox potential under acidic condition is inversely proportional to pH, but directly proportional to pH under alkaline conditions. Ashenhurst (2012) mentioned that proton can be deprotonated and thereby become electron rich. When a free electron is present in a vacuum, a proton may pick it up and become a free radical or neutral. Also, Ojanuga *et al.* (1996) found out that reduction process consumes hydrogen ion which is an acid forming ion. This ion consumption could be responsible for the increase of pH in acidic soils and decrease in pH of alkaline soils. This finding agrees with that of Ojanuga *et al.* (1996) that submerged soils from Southern Nigeria clustered around 7.8.

Effect of Redox Potential on Soil Chemical Properties

Certain elements are considered essential elements, and their availability determines to a large extent if plant will complete their life cycle or not. Under different redox conditions, different transformations occur to these elements. Under reduced conditions, the oxidized forms of many substances are changed to their reduced counterparts (Ojanuga *et al.*, 1996) and these changes determine their availability to plant. It was demonstrated that nitrogen is highest under moderately reduced conditions (8 t ha^{-1} PM+ 200 kg ha^{-1} NPK+ Fc, 8 t ha^{-1} PM+ 0 kg ha^{-1} NPK+ Fc and 6 t ha^{-1} PM+ 0 kg ha^{-1} NPK+ Fc). Under completely oxidized conditions, nitrate is the major form of nitrogen in the soil (Prosser, 2007), however this form of nitrogen is highly mobile and can easily be lost through leaching, immobilization and uptake, hence retention in the soil will reduce, leading to an overall decline in soil nitrogen content. Reduced and highly reduced soils trigger a change in the oxidation state of nitrate (NO_3) reducing it to nitrous oxide (N_2O) or atmospheric nitrogen with the help of anaerobic organisms. Once the nitrogen volatilizes, the content in the soil reduces. This could account for the low nitrogen content observed at the end of the trial period for reduced and highly reduced soils. However, Prasad *et al.* (1986) reported that nitrogen in waterlogged soils is majorly in the form of ammonia (NH_4), volatilization of ammonia is rare, and the net effect of waterlogging is accumulation of ammonia (Philip and Greenway, 2008). This could account for the fact that reduced and highly reduced soils have more nitrogen contents than the oxidized soils. Moderately reduced soils recorded the highest nitrogen content, most likely because it has a combination of both nitrate and ammonia. Given that moderately reduced soil is an intermediary between oxidized and reduced, it still contains some packets of oxygen with which nitrifying bacteria can still carry out their activities, yet not too oxidized that it allows for some accumulation of ammonia. Phosphorus (P) has been found to exist in a valence states from +3 to -3and are highly reactive which makes it never found as a free element on earth (Greenwood and Earnshaw, 1997). It was also demonstrated that oxidized soils 6 t ha^{-1} PM+ 0 kg ha^{-1} NPK+ Wt and moderately reduced soil 8 t ha^{-1} PM+ 200 kg ha^{-1} NPK+ Fc had the highest content of phosphorus. This is most likely due to the addition of inorganic phosphorus to the treatments. According to Stumm and Morgan (1981) phosphorus in its oxidized form can form complexes with Iron (III) oxide or Aluminum oxide under acidic conditions or with Calcium to form Calcium phosphate under alkaline conditions. Soils that have these features will have more phosphorus on their adsorption sites. Ojanuga *et al.* (1996) however concluded that phosphorus under submerged soils is more stable in solutions making their content on exchangeable site to reduce. This accounts for highly reduced and reduced soils having low phosphorus content. Cations are essential plant nutrients and also contribute to the fertility and productivity of soil as well as determine the pH of soil. Some major ones are Calcium (Ca^{2+}), Magnesium (Mg^{2+}), Potassium (K^+) and Sodium (Na^+). They are basically positively charged. Results from this research show that soils subjected to highly reduced conditions had the highest Calcium, Magnesium and Sodium in solution. This could also be linked to the activities of facultative anaerobes on other soil components with higher valences like Iron (Fe^{3+}) and Manganese (Mn^{2+}).

Under reduced conditions, there is dissolution of Iron and Manganese oxide which leads to an elevation in the iron and manganese concentration in the soil. Lu *et al.* (2004) stated that the level of iron and magnesium was increased under waterlogged conditions. This elevation further triggers a competition for adsorption site and since these cations (Ca^{2+}, Mg^{2+}, K^+ and Na^+) have lower valences, their adsorption to CEC site becomes weak and can easily be released into solution being substituted by iron, manganese or aluminum.

The rate of decomposition of organic matter is affected by soil microbes among other things, these microbes are aerobic in nature and functions best under oxidized conditions. This research shows that at the expiration of the trial, Organic matter content was highest under highly reduced conditions. Also, the trend of organic matter over 12 weeks show that the rate of decomposition of organic matter was fastest under oxidized condition and slowest under reduced conditions. This could be attributed to the fact that soil microbes that carry out decomposition requires oxygen and since oxygen is absent under reduced conditions, decomposition rate will slow down. This could also be linked to the electrical charges generated by electron transfer. Gorny (2019) and Gall *et al.* (2013) found that when microbes are subjected to electrical charges, their functionality and attachment to surfaces becomes weak. Since the transfer of electron can generate electrical charge (Bhadra, 2015) then the functionality of decomposing microbes and their attachment to organic matter surfaces become weak. Hence, the progress of decomposition reduces.

CONCLUSION

The objectives of this research was to evaluate the effect of different redox potential on soil chemical properties. Redox potential initiated various chemical changes in the soil, reduction process slows down organic matter decomposition. Soil pH was greatly altered; reduction process tends to move pH towards neutral while oxidation process tends to move pH towards acidity or alkalinity. Nitrogen content was more in moderately reduced soils which is in the form of ammonia and nitrate. Cations are lower in reduced soils due to weak adsorption to CEC sites and phosphorus is highest under oxidized conditions.

Declarations

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