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SOIL ALKALINITY CONTROL USING THREE DIFFERENT BIO-MATERIALS (WASTES) FOR SOIL SUSTAINABILITY AND PRODUCTIVITY

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ABSTRACT
The study presents soil alkalinity control using three different bio-materials for soil sustainability and productivity. It has been noted that soils without balanced pH have trouble with nutrient solubility, thereby making soil nutrients unavailable for plants. 5kg soil sample was measured and put in five different containers. Thereafter, 450g of ash was added to four containers to induce alkalinity. Moreover, three samples were further mixed with 3 different treatments; treatment A, B and C. In all, five samples were set for the study, sample A (control or ordinary soil), B (soil + ash), C (soil + ash + poultry droppings), D (soil + ash + cassava peals) and E (soil + ash + dry grasses). pH tests' were conducted weekly on the samples and the results subjected to ANOVA test. Results obtained were 7.2, 11.5, 9.5, 8.7 and 9.2 for samples A, B, C, D and E respectively in week 1. Similarly, 7.2, 11.5, 8.4, 8.2 and 9.0; 7.2, 11.5, 7.8, 7.9 and 8.7; 7.2, 11.53, 7.4, 7.5 and 8.2 for samples A, B, C, D and E were obtained in 2nd, 3rd and 4th week respectively. The results showed that the treatments have significant effect in reducing alkalinity (p = 5%).
Keywords: poultry droppings; cassava peels; grasses; alkalinity; pH; soil.

INTRODUCTION

Interest in evaluating the quality and health of our soil resources has been stimulated by increasing awareness that soil is critically an important component of the earth's biosphere, functioning not only in the production of food and fiber but also in the maintenance of local, regional, and global environmental quality (Glanz, 1995). Soil quality is conceptualized as the major linkage between the strategies for agricultural conservation management practices and achievement of the major goals of sustainable agriculture (Parr et al., 1992; Acton and Gregorich, 1995). In short, the assessment of soil quality or health, and direction of change with time, is the primary indicator of sustainable land management (Karlen et al., 1997). Globally, the demand for good fertile soil is increasing daily because of increase in demand for food supply as a result of daily increase in the world's population. More recent estimates suggest that, by 2030, an additional 81 to 147 million ha of cropland will be needed compared to the 2000 baseline (Lambin et al., 2013). Soil cultivation requires considerable expense and high energy inputs to create favorable conditions for good stand establishment, growth and development of plant crop.

Productive soils are important for agriculture in order to provide the world with sufficient food. Several researches have shown that composting cassava peels eliminate the problem of waste disposal and increase the manurial value of the materials (Adediran*et al*., 2003; Akanbi*et al*., 2007). The decomposition of carbohydrates in the glycolytic pathway produces carboxylic groups which, after dissociation, may decrease soil pH. Furthermore, poultry manure contains nutrient elements that can support crop production and enhance the physical and chemical properties of the soil (Omisore *et al*., 2009; Iren *et al*., 2011b; John *et al*., 2011). Several soils have been contaminated because of human activities some are naturally acidic, saline, alkaline and even polluted by heavy metals thus, placing high demand on good soil for cultivation of food crops. This necessitated that alkaline, contaminated and poor quality soil within the reach of farmers should be remediated. Alkaline soils can be treated with gypsum and sulfur but these materials or chemicals are scarce and costly to acquire for poor native farmers and even for large scale commercial farmers because it will be required in large amount for treatment of hectares of land, thus, increasing cost of farm inputs and as well affecting profit. However, the primary aim of the study is to use some organic matters or materials (Poultry Droppings (PD), Mashed Cassava Peels (MCP), and Slightly Mashed Grasses (SMG)) to control soil alkalinity. In order to achieve this goal, some physical and chemical tests were conducted on the soil at its natural state. Again, the pH level of the soil samples amended with different organic materials was monitored in weekly intervals for the entire study period.

Soil pH and Alkalinity

Soil pH is a measure of acidity or alkalinity in the soil. It is an important indicator of soil health. It affects crop yields, crop suitability, plant nutrient availability, and soil micro-organism activity which influence key soil processes. Soil pH can be managed by measures such as applying the proper amount of nitrogen fertilizer, liming, and cropping practices that improve soil organic matter and overall soil health. In the natural environment, the pH of the soil has an enormous influence on soil biogeochemical processes. Soil pH is, therefore, described as the "master soil variable" that influences myriads of soil biological, chemical, and physical properties and processes that affect plant growth and biomass yield (Brady and Weil 1999, Minasny *et al*., 2016). Alkaline soils are soils with a high pH (> 9). Soil alkalinity is associated with the presence of sodium carbonates (Na_2CO_3) in the soil, either as a result of natural mineralization of the soil particles or brought in by irrigation and or floodwater. The sodium carbonate, when dissolved in water, dissociates into $2Na^+$ (two sodium cat ions, i.e. ions with a positive electric charge) and CO_3^{--} (a carbonate anion, i.e. an ion with a double negative electric charge). The sodium-carbonate can react with water to produce carbon-dioxide (CO_2), escaping as a gas, and sodium-hydroxide (Na^+OH^-), which is alkaline and gives high pH values (pH >10). This is associated with poor soil structure and a low infiltration capacity. They are not saline, i.e. the total amount of soluble salts, especially sodium chlorides is not excessive (ECe< 4 to 8 dS/m) (Oosterbaan, 2003) (. Alkaline soils are difficult to take into agricultural production. Often they have a hard calcareous layer at 0.5 to 1 m depth. Józefaciuk et al. (2002) investigated the effect of alkalization on the pore properties of the soil with sodium hydroxide solution of increasing concentration\\fr =; om 0.001 to 1 mol dm^3. The cause of soil alkalinity can be natural or induced by man. The natural development is due to the presence of soil minerals producing sodium carbonate upon weathering. The man-made development is due to the application of irrigation water (surface or ground water) containing relatively high proportion of sodium bicarbonates. Important research on alkaline soils has mainly occurred in Central Europe and North India (above the Ganges river), where alkaline soils occur frequently (Oosterbaan, 2003). Alkalinity problems are more pronounced in clay soils than in loamy, silt or sandy soils. Varieties of crops and plants cannot survive in soils that are highly alkaline because alkalinity causes deficiency of nutrients like iron in the soil and when plants are deficient of iron, they become chlorotic i.e. the leaves turns yellow with green veins.

Research Problem

Soil is a critical element of life support systems because it delivers several ecosystem goods and services such as carbon storage, water regulation, soil fertility, and food production, which have effects on human well-being (FAO, 2015; Jones *et al*., 2013). These ecosystem goods and services are broadly categorized as supporting, provisioning, regulating, and cultural services (Millennium Ecosystem Assessment, 2005). Cultivation of crops in Nigeria is mainly carried out by the rural dwellers and there are good percentages of unproductive lands as a result of high content of alkaline in them. These farmers usually do not have the idea of using sulfur and gypsum to alleviate lands affected by alkalinity or may not even be buoyant enough to purchase it, thereby leaving such lands uncultivated. Similarly, it was observed that increase in alkalinity affects the nutritional composition of the soil which can lead to poor growth and productivity in varieties of crops. Lots of species of crops and plants cannot survive in land or soil that is highly alkaline, hence resulting to low productivity and food insecurity. More so, Nigeria is the world largest producer of cassava (*Manihotesculenta*), Shachelford, (2018) cultivated in two thirds of her states mainly in the southern part of the country. About 90% of the total production is used for human consumption and processing of cassava generates about 14 million tonnes of by-products, comprising of peels, stumps, woody and under sized tubers currently disposed off as waste (Okike *et al*., 2015). More so, poultry droppings and mowed grasses are easily found not effectively utilized and managed in developing countries like Nigeria. However, the aforementioned problems posed by alkalinity prompted investigations on the use of some organic materials to alleviate alkaline affected soils in the study area.

MATERIALS AND METHODS

Study Area

The study was carried out in Agricultural and Bio-resource Engineering research farm, behind Faculty of Engineering complex, Independence Layout Enugu, Enugu North L.G.A. Enugu State, Nigeria. Enugu lies between latitude 6^0 21' North and 6^0 30' North and longitude 7^0 26' east and 7^0 37' east. Enugu is located in the South-East of Nigeria. Enugu spreads its borders to the states of Kogi and Benue to the north, Ebonyi to the east, Abia and Imo to the south and Anambra to the west, covering an area of around 8,730 km^2,(Environment, Resettlement and Social Unit (ERSU), 2017). Its landscape changes from tropical dense rain forest in the south to small round-topped hills covered by open grasslands with occasional clusters of woodland in the middle to sometimes almost sandy savannah in the north. Enugu is found within the tropics with high radiation all year round. Rainfall over Enugu is associated with the presence of moist tropical maritime (MT) and the location of inter tropical discontinuity (ITD). Rainfall in Enugu is of two major types, conventional and rainfall associated with disturbances. The mean annual rainfall is usually high, varying from 1200mm to 1800mm while temperature ranges from 27^oC to 29^oC and in severe cases is up to about 32^oC(Okechukwu and Mbajiorgu, 2020). Relative humidity of the study area ranges between 50% and 80% while surface pressure is about 985.5 hpa (Irem, 1999). Human activities in Enugu, the capital city of Enugu State are predominantly characterized by administrative workers (Ofomata, 2002). However, other forms of human activities can also be identified within the area such as; commercial, religious, hoteling, sporting and finally educational activities which can be justified by the number of higher institution in the state.

Materials and Equipment Used

The materials used for the study were soil, poultry droppings, mashed cassava peels, slightly mashed grasses and ash. Soil sample (10 Kg) used was collected from Nsukka town, Nsukka L.G.A. of Enugu State, South-East of Nigeria at 30cm depth. Poultry droppings used were collected from nearby poultry farm in Enugu urban area, Enugu State, Nigeria. Cassava peels and ash used were obtained from cassava processing farm in Ugwuaji Nike near Enugu while slightly mashed grasses were sourced from the environ of Enugu State University of Science and Technology, Faculty of Engineering , Enugu all in Enugu State. Figs. 1- 4 are the materials and treatments used for the study.

Plate 1. Ordinary Soil Sample

Plate 2. Treatment A, Poultry droppings

Plate 3. Treatment B (Cassava Peels)

Plate 4. Treatment C (Dry grasses)

The facilities, apparatus and equipment in soil and water laboratory unit of Agricultural and Bio-resource Engineering Department, Enugu State University of Science and Technology, Enugu- Nigeria were fully utilized. Such includes; Soil test kit, pH meter, auger, beaker, distilled water, plastic sampler, 2 mm diameter sieve and triple beam balance etc.

METHOD

Sample Preparation

Collected soil samples were aired and allowed to dry. It was properly sieved with a 2mm sieve to remove large stone particles and inorganic materials and other debris letting only the smaller soil particles to pass through the sieve. Similarly, particle size analysis of the soil was also carried out on the natural soil sample. The soil sample was air dried, pulverized and sieved using a set of sieve ranging from 9.5mm -75µm in size. The physical properties of the soil were determined and the soil was classified using AASHTO M 145. The colour was observed physically. Thereafter, 3kg of the soil sample was measured out from the sieved soil sample and put in three different containers. Each of these soil samples were mixed properly with 450g of sieved ash and water and were left for 24 hours in order to homogenize the mixture and induce alkalinity in the soil samples. Treatment A, poultry droppings was air dried to remove moisture in them and was ground with local pestle and mortar. This treatment was further sieved with 2mm diameter sieve to obtain fine particulate matter. Treatment B, Cassava peels was washed with clean water and allowed to drain the water in them before mashing with a clean pestle and mortar. Similarly, treatment C, mashed grasses was ground using a clean pestle and mortar to obtain a fine particle.

Experimental design

The design of the experiment was a 2-factorial combination (5×1) i.e. five different samples, A, B, C, D and E and a study condition i.e there was only laboratory study, no field study was set up and monitored. The experiment was carried out using three 10 liters' plastic buckets in which 3kg of soil sample were put in each bucket. Sample A (Ordinary or natural soil sample alone), sample B (soil sample + ash), sample C (soil + ash + poultry droppings), Sample D (soil +Ash + cassava peals), Sample E (soil + ash + dry grasses). However, sample A, normal soil sample was not mixed with any amendment and sample B was mixed with ash alone in order to obtain alkaline soil. Samples C, D and E were mixed with 450g of ash and 500g of the different treatments (A, B and C) respectively. These samples were kept in Soil and Water Laboratory Unit of Agricultural and Bio-resources Engineering Department, Enugu State University of Science and Technology, Enugu Nigeria. The samples were monitored for 4 weeks and analyzed for their alkaline content on weekly basis using digital pH meter. Figs. 5, 6 and 7 are samples C, D and E.

Plate 5. Sample C (Soil + Ash + Poultry droppings)

Plate 6. Sample B (Soil + Ash + Mashed cassava peels)

Plate 7. Sample E (Soil + Ash + Mashed Grasses)

Sample analysis

Ten grams (10g) of the treatments used (A = PD, B = MCP and C = SMG) were weighed into a beaker containing 10ml of distilled water and was allowed to stand for 24 hours before testing for their pH using a standard laboratory pH meter (Asghar and Kanehiro, 1980). Similarly, the same analysis was conducted on samples, A, B, C, D and E i.e ordinary soil sample, soil sample mixed with ash alone, soil sample mixed with ash and PD, soil sample mixed with ash and MCP and soil sample mixed with ash and SMG respectively on weekly intervals to ascertain the remedial effects of the treatments used on the soil samples. Nonetheless, samples A and B were set as control.

RESULTS AND DISCUSSION

The physical observation carried out on the natural soil showed that the soil is dark brown in colour with fine texture at feel and moderately plastic when wet. The dark brown nature of the soil is an indication of presence of organic matter in the soil. The plasticity is an indication of humus and clay in the soil sample. However, the physio-chemical analysis conducted classified the soil to be a sandy loam soil. From the potential hydrogen (pH) test of the soil sample used, it was observed that the natural soil recorded pH 7.2 but when mixed with wood ash the pH was raised to 11.5. This is because wood ash is high in calcium content which is capable of influencing pH level. The initial pH values of the treatments (A = PD, B = MCP and C = SMG) used were 7.4, 5.8 and 7.8 respectively as shown in Table 1.This showed that these organic materials can influence soil pH. Noble *et al*., (1996) stated that, plant materials and animal manure are very important in the treatment and control of acidic content of the soil, and they are the best when it comes to lowering or increasing pH value of the soil and should be used by farmers and agriculturists for maintenance of their agricultural soil as there is no negative effect attached to their use unlike the use of chemical treatments.

Table 1.pH Results of the Different Treatments before experimentation

S/n	Treatment	pH Value
1	Treatment A (PD)	7.4
2	Treatment B (MCP)	5.8
3	Treatment C (SMG)	7.8

Table 2 presents also potential hydrogen analysis of the samples (A, B, C, D and E). It was observed that the organic matters used for amendment of the soil have great potentials in remediation of alkaline soil. From Table 2, the natural soil sample (Sample A) used has its pH value to be 7.2 which was almost neutral and requires no treatment. But when mixed with ash (Sample B), the pH value was raised to 11.5 which indicated high alkalinity.

Table 2**.** Analyzed Weekly pH Result of the Samples (A, B, C, D and E) for the Period of Experiment

Sample	Quantity	pH values				Diff. in pH level
	(kg)	Wk 1	Wk 2	Wk 3	W4	(wk 1- w4)
A	1.000	7.2	7.2	7.2	7.2	00
B	1.450	11.5	11.5	11.5	11.53	0.03
C	1.950	9.5	8.4	7.8	7.4	2.1
D	1.950	8.7	8.2	7.9	7.5	1.2
E	1.950	9.2	9.0	8.7	8.2	1.0

The pH result for the experiment for the entire period of experimentation as given in Table 2 shows that there were significant decline in the alkaline content of samples used for the study. From the result of Table 2, it was observed that as the day progresses, the pH value of the soil decreases gradually. This can be attributed to increase in decomposition of the organic matter, chemical reaction in the soil and increased rate of micro- bacterial activities in them. Poultry droppings were observed to be most effective in ameliorating alkalinity in the soil within the period of study, which can be attributed to the presence of sulfur in the treatment used (poultry droppings). This is in agreement with a research conducted by Brigid *et al.* (2019), their study demonstrated that alkaline and sodic Coal Seams-water can be chemically ameliorated successfully within the soil profile by the addition of gypsum and sulfur amendments, although the efficacy of chemical amendment depends upon the method of incorporation and soil properties. It was followed by mashed cassava peels. The effectiveness of these organic matters can be attributed to their particle sizes (they were well grounded before use) that enhanced their decomposition rate, activities of micro-organisms of the soil, thereby increasing both chemical and biological reactions in the medium and lowering the alkaline content of the soil. The dry grasses were slightly mashed, thus, affecting its decomposition rate and efficacy of the treatment. However, this study is in agreement with the work done by Hue and Amien, (1989) that made use of chicken manure and green manures in treatment of a farm land that was highly alkaline. Fig. 8 is a graphical representation of results of Table 2 (analyzed weekly pH results of the samples for the entire period of experiment).

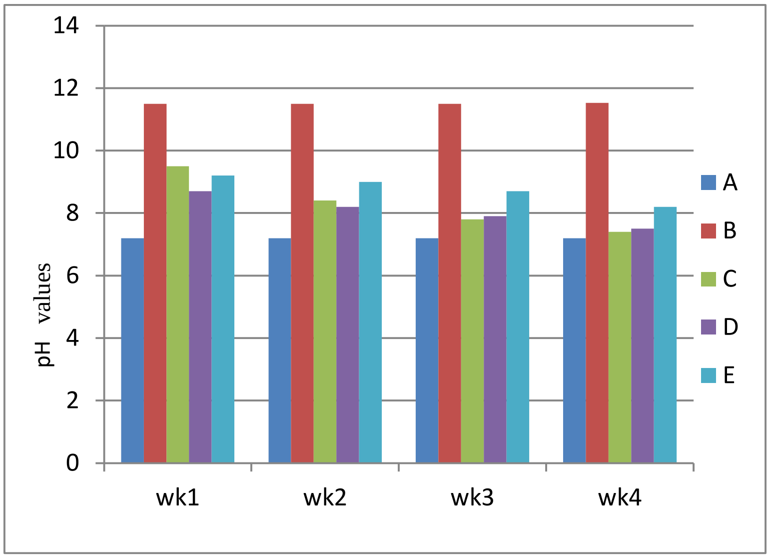

Fig. 8. Graphical representation of analyzed weekly results of the samples' pH values

The color legend represents the different samples (A, B, C, D and E) and Table 3 presents the ANOVA results for comparison of the effect of the three biomaterials and duration of study in control of soil alkalinity.

Table 3. Anova Comparing the Effect of Biomaterials and Duration af Study in Control of Soil Alkalinity

Source of Variation	SS	df	MS	F	P-value	F crit
Samples	1.04	2	0.52	6.24	0.034225	5.143253
Weeks	3.3425	3	1.114167	13.37	0.004578	4.757063
Error	0.5	6	0.083333			
Total	4.8825	11				

Table 3, the ANOVA results obtained on the effect of treatments on alkaline soil samples and duration on reduction of alkalinity on the soil showed that the treatment samples studied have high significant difference (F-test of 6.24 > F-crit. of 5.14) at < 0.5% probability level and the duration in weeks has very high significant difference (F-test of 13.37 > F-crit. of 4.7) at <0.1% probability level. Table 4 is the conducted ANOVA of the treatments used.

Table 4. ANOVA of the Treatments Used

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	3.3425	3	1.114167	5.787879	0.021048	4.066181
Within Groups	1.54	8	0.1925			
Total	4.8825	11				

Comparison of the variance of the sample treatment to the unaccountable variance (residuals) in Table 4 showed that it is 5.7 times larger. With this number of samples, that represents a significant difference (P = 0.05) thus we would reject the null hypothesis that the means for the three biomaterial are the same in controlling soil alkalinity.

CONCLUSION

The result showed that the soil used for the study has dark brown colour indicating the presence of organic matter, it also signaled that the soil is a fertile. At feel, the soil was a little bit plastic indicating the presence of humus and clay in it. The physio-chemical test conducted classified the soil to be a sandy loam soil and the potential hydrogen (pH) test of the soil sample before treatment was added (natural soil) gave 7.2 on mixing with wood ash, the pH was raised to 11.5 indicating that wood ash is high in calcium content which is capable of influencing pH level (Ohno and Erich, 1990). The bio-materials used for remediating alkalinity in the soil showed significant effort in reduction of alkaline content of the soil. This is in line with the study conducted by (Benites and Bos, 2005) who observed that organic matter and soil organisms play important roles in conserving and improving soil properties that are related to soil resilience. However, poultry droppings were observed to be most effective in ameliorating alkalinity in the soil within the period of study. The Anova result showed significant difference (P = 0.05) in using the bio-materials for control of alkalinity in the soil within the stipulated time period.

Finally, the use of organic matters has been noted to be suitable and effective in reducing alkalinity in the soil as seen from the results of this study. In addition to reducing alkalinity, organic matters have been observed to boost soil fertility and stabilize the soil for improved crop productivity and general well being of the soil.

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