KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY, KUMASI

COLLEGE OF ENGINEERING

DEPARTMENT OF MATERIALS ENGINEERING

TOPIC: COMPARATIVE STUDY OF COMPOSTED AND UNCOMPOSTED DIGESTATES, CHICKEN MANURE AND COW DUNG AS FERTILIZERS AND THEIR EFFECTS ON SOIL PROPERTIES

BY

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DECLARATION

I declare that this thesis is my own work. It is being submitted for the degree of Master of Science in Environmental Resources Management at the Kwame Nkrumah University of Science and Technology, Kumasi. It has not been submitted for any degree or examination in any other University.

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ABSTRACT

The problem of waste disposal due to the large volume of waste generated could be greatly reduced when organic components of waste are used as manure. A comparative study of composted and uncomposted digestates, chicken manure and cow dung as fertilizers and their effect on soil properties would help find solutions to some wastes and also determine which waste source offers the best soil improvement qualities to alleviate the burden on farmers due to the high cost of inorganic fertilizers.

The aim of the study was to determine the effects of Composted, Uncomposted dry fermented digestates, Chicken manure and Cow dung on soil properties and the specific objectives were to determine and compare the effects of these organic fertilizers on soil N, P, K and cation exchange capacity (CEC).

Digestate was developed from waste from the dump site with basically the organic parts by dry fermentation, as an effort to control waste management problems and also provide cheap and alternate source of fertilizer for farmers due to declining soil fertility problems, and this was also composted using three methods namely windrow, co-composting and vermi-composting. In order to test the efficacy of these digestates, they were compared with other common organic manures namely chicken and cow dung in an application for 3 months on the field and various soil parameters including N, P, K and CEC needed for plant growth were determined in a Randomised Complete Block Design (RCBD) on a sandy loam soil.

Initial laboratory analysis was conducted on the manures and the soil samples to characterise them. Final laboratory analysis was conducted on soil samples from the various treatments. The final soil analysis showed varied improvements in N, P, K and CEC. The vermi compost treatment was adjudged the best soil improvement treatment as it was the best in terms of soil N, both K and CEC in the 15-30 cm soil depth and second best for P and CEC in the top 15 cm soil depth.

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CHAPTER ONE

INTRODUCTION

1.1 PREAMBLE

Continuous use of cropping land is an important contributor to soil fertility decline. Harsh climatic conditions have also contributed to the declining soil fertility in developing countries (Henao and Baanante, 1999). Application of fertilizer, from both organic and inorganic sources, offers a solution to the decline in soil fertility by farmers under these conditions. Although inorganic fertilizers add the necessary nutrients to the soil, their regular use cause long-term depletion of organic matter, soil compaction and degradation of overall soil quality (Sullivan, 2004).

Traditionally in villages and rural areas, organic manure such as the droppings of domestic animals are used. According to Gupta and Gupta (2011), the use of organic manure is better for quality and yield of crops and this increased rapidly at the start of the green revolution. They added that, cow dung shows no or less adverse effect on crops and also on human health.The main advantage of cow dung is that it does not pollute the soil and does not give any negative effect to the environment whereas inorganic fertilizers, pesticides and chemicals, *etc*. contribute towards soil pollution when applied in excess. The excess amount of fertilizers affects the soil, crop characteristics and products from the crops. The use of manure improves the soil physical condition such as aeration and water transmission properties of the soil. Because of the slow release of ammonia and nitrogen and their slow conversion to nitrates, the leaching loss of nitrogen is low in the presence of organic manures. It provides a hygienic and useful way of disposal and utilization of waste.

Waste management in Ghana is becoming difficult due to the large amount of waste generated. An innovation of waste management is the generation of fuel (biogas) from waste. This process does not completely do away with the waste as the digestate left as residue after the production of the biogas needs also to be disposed off. An effective and efficient way of disposing off this waste is to use them as organic fertilizer. The process of producing biogas from waste involves an anaerobic process which could be dry or wet fermentation. Anaerobic fermentation with digestate as a result reduces the C:N ratio and increases the stability of organic matter and the content of NH_4^+ and so, it results in a product with a high content of directly available N (Gutser et al, 2005).

According to the Ghana News Agency (2010) and reported by the Ghana Business News on Wednesday, July 7, 2010, Naba Bosongo Dogumpoeya, a traditional ruler, appealed to the government to encourage farmers to use organic compost instead of relying on chemical fertilizers which had serious consequences on the soil and environment when applied in excess. He explained that the application of organic manure to farms made them more fertile than the application of inorganic fertilizers which contained more chemicals. Naba Bosongo Dogumpoeya stated that the continuous use of inorganic fertilizers on farms could have acidic effects on the soil which affected yield and that some farmers were experiencing this on their farms. He said that some chemicals in fertilizers applied on crops could also have serious health implications on the health of the people during harvesting and consumption. Naba Doqumpoeya said most often than not the fertilizers applied on the farms were washed away by rain into rivers, ponds and other sources of water thereby polluting those water bodies. He said organic compost was cheaper to prepare and improves yield and that farmers only needed technical support from the Ministry of Food and Agriculture to enable them to prepare the compost. This will be possible if the government could cut down of funds for importing fertilizers and rather provide technical and other logistical support to farmers to expand their production.

1.2 AIM AND OBJECTIVE

The aim of the study was to determine the effects of composted, uncomposted dry fermented digestate, chicken manure and cow dung on soil properties.

The specific objective as:

To determine and compare the effects of these organic fertilizers on soil N, P, K. and CEC.

1.3 PROBLEM STATEMENT

Waste generation in Ghana is increasing due to the increase in population and urbanization of cities and the disposal of the large volumes of waste generated has become a problem. The use of organic components of waste as fertilizer is a step in the right direction to reduce the problem of waste disposal. Continuous use of cropping land and the problem of harsh environmental condition have contributed to the fast decline of soil fertility. Improvement in soil fertility is by the application of organic and inorganic fertilizers. Inorganic fertilizers are expensive and problematic when applied in excess than organic fertilizers and hence the need for more sources of organic fertilizers.

1.4 JUSTIFICATION

The high cost of inorganic fertilizers and the low levels of income of farmers have led to the search for alternate fertilizers which are cheaper and hence the reliance on organic manure. According to Agyarko and Adomako (2006), the cheapness and effectiveness of organic manure are the reasons behind their use as organic sources of fertilizers. They can sometimes be obtained for little or no cost, add valuable organic matter to the soil and have slow release of nutrients, supply secondary and trace elements occasionally lacking in conventional farming systems that rely on primary or artificial sources of fertilizer, and have been shown to cause much less pollution than inorganic fertilizers (Tilman, 1998; Bailey, 2002). Also, the problem of waste disposal due to the large volumes of waste generated could be greatly reduced when organic components of waste are used as manure. A comparative study of composted and uncomposted digestates, chicken manure and cow dung as organic fertilizers and their effects on soil properties would help find solutions to some wastes and also determine which waste source offers the best soil improvement qualities.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

Agyarko and Adomako (2006) carried out a study on the use of organic manure among vegetable farmers in three districts of Ghana from April 2006 to May 2006. A total of 120 vegetable farmers, 40 respondents each from the three districts were picked for the study. Respondents cited the cheapness and effectiveness of organic manure as the reasons behind their use. This is supported by their results, where higher proportions of 82.1%, 64.0% and 83.3% of respondents within Shama, Birim and Sissala districts respectively who apply organic fertilizer cited the cheapness and effectiveness of the fertilizer as reasons behind their usage. Farmers in the districts apply solely more organic fertilizer in vegetable production than inorganic fertilizer or a combination of the two fertilizers. 25 (83.3%) out of 30, 20 (76.9%) out of 26 and 19 (55.9%) out of 34 respondents within Shama, Birim and Sissala districts respectively who responded 'Yes' to the use of fertilizer in vegetable production apply only organic fertilizer. In similar studies, vegetable farmers were also found to apply more organic fertilizers than inorganic fertilizers in the Philippines (Joshi et al, 2001).

Generally, the application of inorganic fertilizers is considered very low in developing countries (Reardon *et al.* 2001). The high cost of inorganic fertilizers and low levels of income of farmers might explain why farmers use more organic manure than inorganic fertilizers. It was observed that many of the farmers, 53.6% and 72.0% within Shama and Birim districts respectively responded using more poultry manure as organic fertilizer than cow dung, pig manure or poultry manure + cow dung. More cow dung (83.3%), however, was found to be used by the vegetable farmers in the Sissala district than the other manures. They added that farmers might not be familiar with the combinations of manure as fertilizer for farming as only 3.6% of farmers within Shama District and none within Birim or Sissala districts responded using poultry manure + cow dung as fertilizer. The kind of organic fertilizer used by the farmers in the districts might be related to the availability, culture or the religious background of the farmers. Cattle farming is more practiced in the northern part of the country than in the southern part, and intensive poultry production is more practiced in the southern part than in the northern sector of the country. Most of the farmers, 17 (60.7%), 22 (88.0%) and 19 (79.2%) from within Shama, Birim and Sissala districts respectively responded obtaining their organic manure from other people's farms with only a few of them getting the manure from their own farms or homes.

The problems associated with the use of organic fertilizer as revealed by the respondents included, damage to crops from heat if not applied properly, non availability of organic fertilizers, attraction of insects by the fertilizers, enhancement of weed growth and the bulkiness and the associated problem of transporting the fertilizer from the source to the point of application. The major conspicuous problem within the districts was the bulkiness and the associated problem of transportation (32.1%, 56.0% and 58.3% responses within Shama, Birim and Sissala respectively). The bulkiness and transportation difficulties associated with the use of organic manure can be a serious limitation to the widespread recommendation of the use of organic manure. Kihanda (1998) found these same factors as barriers regarding the use of organic sources of fertilizers.

From the Soil Research Institute of Ghana's Annual Report of 1997, poultry manure on the average contains the following percentages by weight, 2.20, 1.80, 1.10, 2.40 and 0.70 for N,

P_2O_5, K_2O, CaO and MgO respectively. Also cattle manure on the average contains the following percentages by weight, 1.20, 0.17, 0.11, 0.35 and 0.13 for N, P_2O_5, K_2O, CaO and MgO respectively.

Some experiments have been conducted on digestates and they have shown improvements in soil and plant qualities. Bermejo et al. (2010), researched on the use of dry and wet digestates from biogas plant as fertilizers in plant production and the digestates showed some improvements to soil and plant qualities. They investigated the effect of wet and dry digestates in direct comparison to conventional fertilizers such as mineral fertilizer (Calcium ammonium nitrate), liquid manure, and farmyard manure in a field experiment carried out within a randomised complete block design. In this experiment an amount of fertilizer corresponding to 120 kg N ha^{-1} for each variant was applied. Therefore, the amounts of the organic and mineral fertilizers varied according to their nitrogen content. The corresponding amount of fertilizers were 25.81 t ha^{-1} fresh weight (FW) (7.95% DM) for wet digestate, 22.43 t ha^{-1}FW (17.04% DM) for dry disgestate, 27.71 t ha^{-1} FW (9.86% DM) for liquid manure and 16.64 t ha^{-1} FW (28.63% DM) for farmyard manure. An untreated control was used as a reference.

2.2 Soil

According to Prince (2008), generally most plants grow by absorbing nutrients from the soil and their ability to do this depends on the nature of the soil. Depending on its location, a soil contains some combination of sand, silt, clay, and organic matter. The makeup of a soil (soil texture) and its acidity (pH) determine the extent to which nutrients are available to plants.

2.2.1 Soil Texture

The amount of sand, silt, clay, and organic matter in the soil is soil texture. Soil texture affects how well nutrients and water are retained in the soil. Clays and organic soils hold nutrients and water much better than sandy soils. As water drains from sandy soils, it often carries nutrients along with it. This condition is called leaching. When nutrients leach out of the soil, they are not available for plants to use.

An ideal soil contains equivalent portions of sand, silt, clay, and organic matter. Soils vary in their texture and nutrient content, which makes some soils more productive than others. Sometimes, the nutrients that plants need occur naturally in the soil. Other times, they must be added to the soil as lime or fertilizer.

2.2.2 Soil pH

pH is a measure of the acidity or alkalinity of the soil. Soil pH is one of the most important soil properties that affect the availability of nutrients. Macronutrients tend to be less available in soils with low pH and micronutrients tend to be less available in soils with high pH (Prince, 2008). Lime can be added to the soil to make it less sour (acid) and also supply calcium and magnesium for plants to use. Lime also raises the pH to the desired range of 6.0 to 6.5. In this pH range, nutrients are more readily available to plants, and microbial populations in the soil increase. Microbes convert nitrogen and sulphur to forms that plants can use. Lime also enhances the physical properties of the soil that promote water and air movement. It is a good idea to have the soil tested. This way, how much lime and fertilizer your crop needs can be found.

According to Tucker (1999), nutrients are essential for plant life. Nutrients are essential because a plant deprived of any one of these elements would cease to exist. . . ." He reported about the term "law of the minimum," which states that "plants will use essential elements only in proportion to each other, and the element that is in shortest supply—in proportion to the rest—will determine how well the plant uses the other nutrient elements."

Again, Tucker (1999) added that knowing the nutrients required to grow plants is only one aspect of successful crop production and that optimum yield also requires knowing the rate to apply, the method and time of application, the source of nutrients to use, and how the elements are influenced by soil and climatic conditions.

2.3 Plant Nutrients

According to Prince (2008) and Tucker (1999), sixteen chemical elements are known to be important to a plant's growth and survival. The sixteen chemical elements are divided into two main groups: non-mineral and mineral. The non-mineral nutrients are hydrogen (H), oxygen (O), and carbon (C). These nutrients are found in the air and water. Since plants get carbon, hydrogen, and oxygen from the air and water, there is little farmers and gardeners can do to control how much of these nutrients a plant can use. The 13 mineral nutrients, which come from the soil, are dissolved in water and absorbed through a plant's roots. There are not always enough of these nutrients in the soil for a plant to grow healthily. This is why many farmers and gardeners use fertilizers to add the nutrients to the soil. The mineral nutrients are divided into two groups: macronutrients and micronutrients.

2.3.1 Macronutrients

Macronutrients can be broken into two more groups: primary and secondary nutrients. The primary nutrients are nitrogen (N), phosphorus (P), and potassium (K). These major nutrients usually are lacking from the soil first, because plants use large amounts for their growth and survival.

The secondary nutrients are calcium (Ca), magnesium (Mg), and sulphur (S). There are usually enough of these nutrients in the soil and so fertilization is not always needed. Also, large amounts of calcium and magnesium are added when lime is applied to acidic soils.

Sulphur is usually found in sufficient amounts from the slow decomposition of soil organic matter, an important reason for not throwing out grass clippings and leaves.

2.3.2 Micronutrients

Micronutrients are those elements essential for plant growth which are needed in only very small (micro) quantities. These elements are sometimes called minor elements or trace elements. The micronutrients are boron (B), copper (Cu), iron (Fe), chloride (Cl), manganese (Mn), molybdenum (Mo) and zinc (Zn). Recycling organic matter such as grass clippings and tree leaves is an excellent way of providing micronutrients (as well as macronutrients) to growing plants.

Macro nutrients

Nitrogen (N)

According to Lines-Kelly (2004), nitrogen is a key element in plant growth and it is found in all plant cells, in plant proteins and hormones, in chlorophyll and as part of metabolic processes involved in the synthesis and transfer of energy. It helps plants with rapid growth, increasing seed and fruit production and improving the quality of leaf and forage crops.

It was added that atmospheric nitrogen is a source of soil nitrogen and that some plants such as legumes fix atmospheric nitrogen in their roots; otherwise fertiliser factories use nitrogen from the air to make ammonium sulphate, ammonium nitrate and urea. When applied to soil, nitrogen is converted to mineral form, nitrate, so that plants can take it up.

Soils high in organic matter such as chocolate soils are generally high in nitrogen. Nitrate is easily leached out of soil by heavy rain, resulting in soil acidification. Nitrogen needs to be applied in small amounts often so that plants use all of it, or in organic form such as composted manure, so that leaching is reduced (Lines-Kelly, 2004).

Phosphorous (P)

Like nitrogen, phosphorus (P) is an essential part of the process of photosynthesis. Phosphorus helps transfer energy from sunlight to plants (transformation of solar energy into chemical energy), stimulates early root and plant growth, hastens maturity, encourages blooming, withstanding stress and involved in the formation of all oils, sugars, starches, etc. The most common phosphorus source is superphosphate, made from rock phosphate and sulphuric acid. All manures contain phosphorus and manure from grain-fed animals is a particularly rich source.

Potassium (K)

Prince (2008) commented that potassium is absorbed by plants in larger amounts than any other mineral element except nitrogen and, in some cases, calcium. Lines-Kelly (2004) also added that potassium increases vigour and disease resistance of plants, helps form and move starches, sugars and oils in plants, and can improve fruit quality. Heavy potassium removal can occur on soils used for intensive grazing and intensive horticultural crops (such as bananas and custard apples). Potassium is supplied to plants by soil minerals, organic materials and fertilizers. Muriate of potash and sulphate of potash are the most common sources of potassium.

Calcium (Ca)

Calcium, an essential part of plant cell wall structure, provides for normal transport and retention of other elements as well as strength in the plant. It is also thought to counteract the effect of alkali salts and organic acids within a plant. Calcium is essential for root health, growth of new roots and root hairs, and the development of leaves. Lime, gypsum, dolomite and superphosphate (a mixture of calcium phosphate and calcium sulphate) are sources of calcium. Lime is the cheapest and most suitable option and dolomite is useful for magnesium and calcium deficiencies, but if used over a long period will unbalance the calcium/magnesium ratio. Superphosphate is useful where calcium and phosphorus are needed.

Magnesium (Mg)

Magnesium is a key component of chlorophyll, the green colouring material of plants, and is vital for photosynthesis (the conversion of the sun's energy to food for the plant). It also helps activate many plant enzymes needed for growth. Deficiencies occur mainly on sandy acid soils in high rainfall areas, especially if used for intensive horticulture or dairying. Heavy applications of potassium in fertilisers can also produce magnesium deficiency, so banana growers need to watch magnesium levels because bananas are big potassium users. Soil minerals, organic material, fertilizers, and dolomitic limestone, dolomite (a mixed magnesium-calcium carbonate), magnesite (magnesium oxide) and epsom salts (magnesium sulphate) are sources of magnesium for plants.

Sulphur (S)

Sulphur is a constituent of amino acids in plant proteins and is involved in energy-producing processes in plants. It promotes activity and development of enzymes and vitamins, helps in chlorophyll formation and improves root growth and seed production. It is responsible for many flavour and odour compounds in plants such as the aroma of onions and cabbage. Sulphur deficiency is not a problem in soils high in organic matter, but it leaches easily. Sulphur may be supplied to the soil from rainwater. It is also added in some fertilizers as an impurity, especially the lower grade fertilizers. Superphosphate, gypsum, elemental sulphur and sulphate of ammonia are the main fertiliser sources.

Trace or Minor elements

Boron (B)

Boron helps with the formation of cell walls in rapidly growing tissue. Helps in the use of nutrients and regulates other nutrients, aids production of sugar and carbohydrates, essential for seed and fruit development. Deficiency reduces the uptake of calcium and inhibits the plant's ability to use it. Sources of boron are organic matter and borax.

Copper (Cu)

Copper is an essential constituent of enzymes in plants and it is important for reproductive growth, aids in root metabolism and helps in the utilization of proteins. Toxicity can be a problem for horticulturists who regularly use Bordeaux mixture or copper oxychloride sprays to control diseases on horticultural crops.

Chloride (Cl)

Chloride is found in the soil and aids plant metabolism.

Iron (Fe)

Iron is essential for the formation of chlorophyll. Iron is a constituent of many compounds that regulate and promote growth. Sources of iron are the soil, iron sulphate and iron chelate.

Manganese (Mn)

Functions with enzyme systems involved in breakdown of carbohydrates and nitrogen metabolism. Manganese helps with photosynthesis. It is often in toxic amounts in very acid soils, but can be deficient in sandy soils. Toxicity is remedied with lime. Soil is a source of manganese.

Molybdenum (Mo)

Molybdenum helps bacteria and soil organisms convert nitrogen in the air to soluble nitrogen compounds in the soil and also helps in the use of nitrogen, so is particularly needed by legumes. It is also essential in the formation of proteins from soluble nitrogen compounds. Molybdenum deficiency can be remedied easily with applications of Mo super, molybdenum trioxide (applied during inoculation and lime pelleting of legume seed), or sodium molybdate (sprayed on young emerging plants). Soil is a source of molybdenum.

Zinc (Zn)

Zinc helps in the production of a plant hormone responsible for stem elongation and leaf expansion and therefore regulates plant growth. It is readily available in acid soils. It is essential for the transformation of carbohydrates and regulates consumption of sugars. Sources of zinc are soil, zinc oxide, zinc sulphate and zinc chelate.

2.4 Cation Exchange Capacity (CEC)

From Cowan (2008), cation is an ion with a positive electrical charge and CEC is a measure of the soils capacity to exchange ions. Cation-exchange capacity can also be defined as the degree to which a soil can adsorb and exchange cations (Annon, 2004). Cowan (2008) explained that, the clay and organic matter of the soil supplies the negative charges, opposites attract so any element with a positive charge is attracted and held. Cations have the ability to be exchanged for another positively charged ion from the surfaces of clay minerals and organic matter. In general, the more clay and organic matter in the soil, the higher the CEC. Soils with organic matter greater than 17% are classified as muck or organic soils. Clay content is important because these small particles have a high ratio of surface area to volume. Different types of clays also vary in CEC. Smectites have the highest CEC (80-100 millequivalents 100 g^{-1}), followed by illites (15-40 meq 100 g^{-1}) and kaolinites (3-15 meq 100 g^{-1}).

According to Annon (2004), in general, the CEC of most soils increases with an increase in soil pH and two factors determine the relative proportions of the different cations adsorbed by clays. Firstly, cations are not held equally tight by the soil colloids. When the cations are present in equivalent amounts, the order of strength of adsorption is $Al^{3+} > Ca^{2+} > Mg^{2+} > K^{+} = NH_4+ > Na^{+}$. Secondly, the relative concentrations of the cations in soil solution help determine the degree of adsorption. Very acid soils will have high concentrations of H^+ and Al^{3+}. In neutral to moderately alkaline soils, Ca^{2+} and Mg^{2+} dominate. Poorly drained arid soils may adsorb Na^+ in very high quantities.

Another term that is used in conjunction with CEC is base saturation which refers to elements that are basic or alkaline in their reaction. These basic elements are largely potassium, magnesium and calcium. Small amounts of sodium and ammonium may also be present. Hydrogen is an element with a positive charge and acts like a cation. However, soils with significant saturation of hydrogen are acidic, or have a lower pH. It is best to refer to cation exchange capacity rather than base exchange. The unit of measure is expressed as milligramme equivalents per 100 grammes of soil or shortened to "me". The atomic weight and valence of the element are taken into account. One milli equivalent can be exchanged for another milli equivalent.

Most soils that are used in plant production have a CEC or exchange capacity per 100 grammes of soil in the range from 5 to 30 (Cowan, 2008). A soil with a CEC of 20 will have 20 milligrammes per 100 grammes of soil in total cation exchange capacity.

Table 2.1 Milli Equivalents of Some Ions

Element	Atomic Weight	Valence	ppm to equal one milli equivalent
Hydrogen	1	1	20
Potassium	39	1	390
Magnesium	24	2	120
Calcium	20	2	200

Source: Cowan (2008)

2.4.1 Calculating CEC and Saturation Percentage

According to Cowan (2008), saturation percentage is an expression of the number of sites occupied by potassium, magnesium, calcium and sodium mainly. Hydrogen and other smaller amounts of cations are also present but extremely small at neutral pH. Some high pH soils can be 98% saturated with base elements. Typically, soils could be saturated with potassium at 1 to 5%, magnesium at 5 to 25 % and calcium 50 to 85 %. Ideally soils that are productive will range realistically in the 1 to 5 % potassium, 10 to 15 % magnesium and 65-75 % on calcium and less than 1 % of sodium.

Annon, (2004) also puts it that the proportion of CEC satisfied by basic cations (Ca, Mg, K, and Na) is termed percentage base saturation (BS %) and that his property is inversely related to soil acidity. As the BS % increases, the pH increases and the availability of nutrient cations such as Ca, Mg, and K to plants increases with increasing BS %. Base saturation is usually close to 100% in arid region soils. Base saturation below 100 % indicates that part of the CEC is occupied by hydrogen and/or aluminum ions which form the exchangeable acidity. Base saturation above 100 % indicates that soluble salts or lime may be present, or that there is a procedural problem with the analysis. To determine the CEC of a soil with 390 ppm of potassium, magnesium at 240 ppm and calcium at 3000 ppm.

CEC determination is calculated based on the extracted soil test values converted to milliequivalents from Table 2.1 and entered into the formula:

CEC = Milliequivalents of Potassium + Magnesium + Calcium + 1.2

The individual milliequivalents

Potassium at 390 ppm 1

Magnesium at 240 ppm 2

Calcium at 3000 ppm 15

Total base milli equivalents 18

CEC = 18 plus 1.2 for a total CEC of 19.2

Saturation is calculated as follows:

Potassium (K) saturation 1/19.2 x 100 = 5.2

Magnesium (Mg) 2/19.2 x 100= 10.4

Calcium (Ca) 15/19.2 x 100= 78

This soil has a CEC of 19.2 with saturations of K, Mg, and Ca of 5.2%, 10.4% and 78% respectively. The total saturation adds up to only 93.6 the difference between this and 100 is 6.4%. The difference is assigned to hydrogen. Soils can still be productive up to 20% saturation of Hydrogen and it just means that pH is likely to be 6.5 to 6.9.

2.4.2 Sodium (Na)

Sodium in some soils can be problematic. One milliequivalent of sodium is 230 ppm and can be included in the summation of CEC and saturation percentage the same way as K, Mg and Ca.

Na saturation percentages greater than one can cause soil quality problems and interfere with normal plant growth. Apart from being phyto-toxic to roots, it can destroy soil structure by causing flocculation or dispersal of soil aggregates into a blocky mass with limited porosity, thereby limiting water movement and restricting root growth.

2.4.3 CEC and Availability of Nutrients

Exchangeable cations, as mentioned above, may become available to plants. Plant roots also possess cation exchange capacity. Hydrogen ions from the root hairs and microorganisms may replace nutrient cations from the exchange complex on soil colloids. The nutrient cations are then released into the soil solution where they can be taken up by the adsorptive surfaces of roots and soil organisms. They may, however, be lost from the system by drainage water. Additionally, high levels of one nutrient may influence uptake of another (antagonistic relationship). For example, K uptake by plants is limited by high levels of Ca in some soils. High levels of K can in turn, limit Mg uptake even if Mg levels in the soil are high.

Table 2.2 Practical Relationship/Interpretation of CEC to Soil Texture

Cation Exchange Capacity range	**Texture**	**Characteristics**
< 10 meq	Sand	Low organic matter, low moisture holding capacity
10 to 15	Sandy loam	More desirable, higher clay content, improved moisture capacity, well structured
15 to 20	Loam	Ideal soil from a texture standpoint and likely higher organic matter content, structure and moisture holding capacity
20 to 25	Clay loam	Higher clay content may restrict drainage and have tight structure, may need additional organic matter to improve aggregation
> 25	Clay	Tight soil structure due to high clay content, poor internal drainage. May need large amounts of organic matter to improve structure, and plant available water

Source: Cowan (2008)

CHAPTER THREE

MATERIALS AND METHODS

3.1 The Study Area

The study was conducted at the Agricultural Engineering farm at the Kwame Nkrumah University of Science and Technology campus. The area is located in the northern part of the humid forest zone and has a mean temperature of 22-30 °C with a relative humidity between 69-95% and a mean annual rainfall ranging between 1250-1500 mm. The area has a bimodal rainfall regime, the first of which is between March and mid-July and the second, between mid-September and November. The total dry season is about two months.

3.2 Source of Materials

Chicken and cow dung manures were obtained from the Animal Science Farm of the Faculty of Agriculture at KNUST. The composted and uncomposted dry fermented digestates were taken from a colleague's (Miss Francisca Emefa Kukah's) project products.

3.3 Experimental Design and Treatment Application

Randomised Complete Block Design was used. Three blocks with seven plots each of 2 m x 1 m size per plot were constructed and amounts of manure with each corresponding to 90 kg of N / ha from poultry manure (4 t / ha), cow dung manure (7.5 t / ha), 3 types of dry fermented digestate composted (17 t / ha each), dry fermented digestate uncomposted (17 t / ha) or no treatment (as a control) was applied to each plot per block in a randomized design.

Treatments:

T1 – Control

T2 – Chicken Manure

T3 – Cow Dung

T4 – Uncomposted Dry Fermented Digestate

T5 – Windrow Composted Dry Fermented Digestate

T6 – Co-composted Dry Fermented Digestate

T7 – Vermi-composted Dry Fermented Digestate

Table 3.1 Arrangement of Blocks and Treatments

BLOCKS	TREATMENTS						
I	T4	T3	T6	T1	T2	T5	T7
II	T2	T7	T4	T1	T3	T6	T5
III	T2	T6	T5	T4	T3	T7	T1

The randomization of the plots for the blocks was done by picking randomly from seven pieces of papers numbered T1 to T7 representing the treatments and which were roundly folded. The folded papers were put in a bowl and swirled for some seconds and one picked to represent the first plot in block one and this was recorded on a table as shown in Table 3.1. The bowl was swirled again and another paper picked to represent the second plot in block one. This process was repeated till the last paper remained for the last slot in block one. The full process was repeated for blocks two and three.

The dry fermented digestate and the composts were prepared at the Kwame Nkrumah University of Science and Technology Sewage Treatment Plant site (by Miss Francisca Emefa Kukah). Samples of the fresh digestate were taken to the Agroforestry Soil and Plant Laboratory of the Faculty of Renewable Natural Resources - KNUST for analysis of the quality parameters that characterize the usefulness of compost in agricultural applications. These parameters included pH, organic matter content, organic carbon, nitrogen, phosphorus, potassium, magnesium, calcium, sodium, aluminium and hydrogen.

The rest of the fresh digestate was divided into three portions for post-treatment (composting) for three months.

Experimental Design: Completely Randomized Design (CRD)

Treatments (post treatment composting methods)

1. Windrow composting
2. Co-composting
3. Vermicomposting

Replications – 3

Table 3.2 Arrangement of Composting Replicates

Co-composting	Windrow composting	Vermicomposting
Windrow composting	Vermicomposting	Co-composting
Vermicomposting	Co-composting	Windrow composting

For the open windrow system, three heap piles of fresh digestate, about 1.5 metres diameter and 0.5 metres high with a more or less conical shape were made. These were turned manually to allow aeration throughout the composting period. During the first and second weeks, three turnings weekly were done and two turnings done in the third week. Turning was done once in the fourth, fifth and sixth weeks. Measurement of temperature (by inserting a thermometer into the windrows) was used to gauge the need for turning to stimulate or control heat production. One kilogramme of each of the three piles was taken to the Agroforestry Soil and Plant Laboratory of the Faculty of Renewable Natural Resources - KNUST for physico-chemical analysis.

With vermicomposting, earthworms were used to convert the fresh digestate into worm castings. The earthworms were obtained from surrounding waste dump sites and placed in a bedding made of loose materials such as coconut husk and shredded paper in a shallow box and fed with the fresh digestate. The temperature of the worm castings being produced was taken every two days. One kilogramme of each of the three piles was taken to the laboratory for physico-chemical analysis.

Co-composting was done by mixing the fresh digestate with kitchen waste (basically food waste). The waste pile was then left under a shed to allow for composting. One kilogramme of each of the three piles was taken to the laboratory for physico-chemical analysis.

3.4 Land Preparation

The land was ploughed and harrowed with a tractor. The Blocks and the Plots were done across the gentle slope of the land. The weeds, mostly guinea grass, were removed when making the beds. The beds were heaped 15 cm off the ground.

3.5 Initial Sampling of Organic Manures and Soil and Preparation for Laboratory analysis

The chicken manure was collected from one of the battery cages of the poultry section of the Animal Science Department Farm of the Faculty of Agriculture, KNUST. The chicken manure was collected in a polythene bag from the droppings collected separately beneath the cage. A spade was used to collect 5 kgs of the droppings and this was thoroughly mixed and one kg of the droppings was taken for laboratory analysis. The cow dung was collected from the livestock section of the farm from the kraal. The stacks of cow dung on the floor of the kraal was collected with a shovel and placed in a polythene bag. Eight (8) kg of the cow dung was collected and thoroughly mixed and one kg taken for laboratory anlysis. The laboratory samples were spread on a cardboard and placed in an airy room to air dry. The air dried samples were ground to powder and sieved with a 2 mm sieve. The sieved powders were stored and used for the analysis. The anlyses were done for the following parameters: pH, organic matter content, organic carbon, nitrogen, phosphorus, potassium, magnesium, calcium, sodium, aluminium and hydrogen. One kg of the uncomposted digestate was taken, air dried, blended and sieved and also stored and used for analysis for the same parameters. One kilogramme composite sample each was taken for the 3 replicates of each composted digestate later and was prepared for laboratory analysis for the same parameters.

A 15 cm hand auger was used to sample soil from each plot and mixed together in a bucket and 2 kg taken, put in a plastic bag, labelled 0–15 cm and sealed for laboratory analysis for the same parameters as the manures. The holes for the 0-15 cm were cleared of loose soil particles and the hand auger put into the holes to sample soil from the 15-30 cm portion of the soil horizon. These were also mixed together thoroughly and a composite sample of 2 kg taken and put in a plastic bag, labelled 15-30 cm and sealed for laboratory analysis. The soils were dried on cardboards in an airy room for 2 days (powdery when felt), pounded in a mortar to fine particles and sieved with a 2 mm sieve and stored for the analysis. The parameters determined for the organic manures were done in addition to bulk density and particle sizes for the soil. A 5 cm core sampler was used to sample soil from each plot and these were put in plastic bags, labelled with the block and plot numbers and taken to the laboratory for bulk density determination for the various plots and an average bulk density calculated as a representative initial bulk density for the plots.

3.6 Laboratory Analyses

3.6.1 Determination Of Soil Bulk Density (ρ_b) Using The Metal Core Sampler Method

Dry bulk density is a measure of the weight of the soil per unit volume expressed as g cm^{-3} (usually given on an oven-dry (105 °C) basis). The samples for the bulk densities were poured into labelled weighing cans and the can labels recorded against the respective soil samples in a tabular form and the cans and contents dried in the oven at 105 °C to a constant weight (after 48 hours). The cans with the soils were removed from the oven and allowed to cool and the weights of cans with the contents measured and recorded and the cans were also emptied and weighed and the results tabulated against the others respectively. The volume of the soil was determined by measuring the internal volume of the core sampler from the height and internal radius of the core sampler.

Calculation:

$$\text{Dry Bulk Density, } \rho_b\ (gcm^{-3}) = \frac{W_2 - W_1}{V}$$

Where:

W_2 = Weight of can + oven dried soil

W_1 = Weight of empty can

V = Internal volume of soil or core cylinder ($\pi r^2 h$),

where:

Π = 3.142

r = Internal radius of the core cylinder

h = Height of the core cylinder

3.6.2 Determination of pH

The determination of hydrogen ion activity or pH of soil is by far the most commonly made soil test. The pH value has long been used to evaluate the acidity of soil and has long been accepted as one of the standard criteria for characterizing soils. The pH value of a solution is defined, by the Sorenson Equation as the negative logarithm (to base 10) of the hydrogen ion (H^+) activity (concentration), or the logarithm of the reciprocal of the H ion concentration in a given solution.

i.e. $pH = -\log [H+] = \log 1/ [H^+] \longrightarrow [H^+]$

Or $H^+ = 10^{-pH}$ molar

The electrometric method was used and the soil: solution ratio used was 1:2.5 which means that l0g of air-dried soil to 25 ml distilled water. The soil : solution ratio and the presence of electrolytes are two of the several factors that affect the value of pH of soils and which are of utmost importance here. The apparatus and the reagents included a pH meter, glass electrode, beakers (100 ml, 150 ml, 250 ml) stirring rods, spatula and distilled water.

For the soil samples, 10 g air- dried soil was weighed into a 100 ml beaker and 25 ml of distilled water was added and the suspension was stirred vigorously for 20 minutes and allowed to stand for about 30 minutes by which time most of the suspended clay had settled out from the suspension. The pH meter was calibrated with a blank at pH of 4 and 7 respectively. The electrode of the pH meter was inserted into the partly settled suspension and the pH value was read and the results recorded. The same procedure was used for the organic manures.

3.6.3 Determination of Organic Matter

Soil organic matter represents the remains of roots, plant material, and soil organisms in various stages of decomposition and synthesis, and is variable in composition. Though occurring in relatively small amounts in soils, organic matter (OM) has a major influence on soil aggregation, nutrient reserve and its availability, moisture retention and biological activity.

The ashing method was used. Ash is the inorganic residue obtained by burning a sample at 550 ^{o}C. Ashing of the sample burns off all organic constituents (OM), leaving behind the non-volatile mineral elements. The difference between the original sample and the residue after ashing gives the organic matter content of the sample. The apparatus included a muffle furnace, porcelain crucibles and a desiccator with magnesium perchlorate desiccant. 5 g of the sample was weighed (W) and put into porcelain crucible and the weight of the sample and crucible (W1) noted. It was then put into a furnace for 4 hours at 550^{o}C and the furnace was allowed to cool below 200^{o}C and maintained for 20 minutes and the sample was then removed and placed in a desiccator with stopper top to cool and then weighed (W_2).

<u>Calculations</u>

$$\% \text{ Organic Matter} = \frac{(W_1 - W_2)}{W} \times 100$$

Where

W_1= weight of the sample and crucible

W_2= weight of the ashed sample and crucible

W= weight of the sample taken

3.6.4 Determination of Percent Total Nitrogen By Micro Kjeldahl's Method

Almost all of the soil nitrogen is bound up in the organic matter (O.M), and the basic principle involved in assessing or estimating the quantity held up in this manner is to boil a weighed quantity of the soil with concentrated sulphuric acid. The nitrogen is thus converted into sulphate of ammonia [$(NH_4)_2SO_4$] and at the same time, the carbonaceous matter is oxidized to carbon dioxide (CO_2) with the sulphuric acid being reduced to sulphur dioxide (SO_2). This is essentially a wet–oxidation process which involves two main steps:

1. Digestion of the soil sample to convert organic N to ammonium – N by sulphuric acid and
2. Determination of the ammonium in the acid digest.

Much of the nitrogen in soil (organic matter and plant tissue) exists in the form of protein in which nitrogen is present primarily as the amino group (– NH_2) attached to the carbon (– C – NH_2). The procedure is summarized as follows:

$2\ [-C-NH_2] + 2\ H_2SO_4 \longrightarrow (NH_4)_2SO_4 + 2\ CO_2 + SO_2$ – Digestion

$(NH_4)_2SO_4 + 2\ NaOH \longrightarrow 2\ NH_3 + Na_2SO_4$ } Steam

$2\ NH_3 + 2H_2O \longrightarrow 2\ NH_4OH$ Digestion

$NH_4OH + HCl \longrightarrow NH_4Cl + H_2O$ – Titration

The reagents and equipment were:

1. Conc. H_2SO_4 (ammonia – free grade)
2. 40% NaOH
3. 4% Boric acid solution (H_3BO_3)
4. Catalyst: Selenium : 1

   : Copper sulphate ($CuSO_4$) : 10

   : Potassium or sodium sulphate (K_2SO_4/Na_2SO_4) : 100

5. Mixed indicator or Bromocresol green and methyl red in ethyl alcohol
6. 0. l N Standard HCl
7. Kjeldahl flask, 500ml
8. Steam Distillation system unit
9. Volumetric flask
10. Conical flask, 200ml.

For soil, 10 g of the sample was used and for the organic manure (plant tissues), 5 g of the sample was used. For the soil digestion, 10 g of air dry soil was weighed into a 500ml long – necked kjeldahl flask. 10ml distilled water was added and allowed to stand for 10 minutes to moisten. One spatula full of kjeldahl catalyst [mixture of l part Selenium + 10 parts $CuSO_4$ + 100 parts Na_2SO_4] was added and then 20 ml conc. H_2SO_4. The mixture was then digested for about 2 hours until clear and colourless or light greenish colour was obtained and the flask was allowed to cool. The fluid was decanted into a 100 ml volumetric flask and made up to the mark with distilled water.

For the distillation, 10 ml of the aliquot was transferred by means of pipette into the kjeldahl distillation apparatus provided. 90 ml of distilled water was added and then 20 ml of 40% NaOH. The distillate was collected over 10 ml of 4% Boric acid and 5 drops of mixed indicator in a 500 ml conical flask for 4 minutes. The colour change from pink to a light blue showed the presence of Nitrogen.

100 ml of the collected distillate was titrated with 0.l N HCl till the blue colour changed to grey and then suddenly flashed to pink. A blank was carried out without the soil sample. The same procedure was used for the organic manure.

Calculation

Weight of soil sample used, considering the dilution and the aliquot taken for distillation =

$$\frac{(10g \times 10\,ml)}{100\,ml} = 1g$$

Thus, the percentage of Nitrogen in the soil sample is,

$$\%\,N = \frac{14 \times (A - B) \times N \times 100}{1000 \times 1}$$

Where:

A = volume of standard HCl used in the sample titration

B = volume of standard HCl used in the blank titration

N = Normality of standard HCl

<u>NB</u>:

When N = 0. l and B = 0

% Nitrogen = A x 0.14

3.6.5 Determination Of P In Soil/Manure Extracts

The method used was based on the production of a blue complex of molybdate and or thiophoshate in acid solution. Chloromolybdic acid was added to the soil/manure extract and molybdophosphoric acid was formed. The intensity of the blue colour formed when the molybdophosphoric acid was reduced using Amino – naphthol – sulphuric acid was a measure of the amount of P present.

Thus:

$H_3 PO_4$ + $12 H_2 M_o O_4$ ⟶ $H_3 P (Mo_3 O_{10})_4$ + $12 H_2O$

(Soluble P in Soil Extracts) (Molybdic acid) (Molybdo Phosphoric acid)

$H_3 P (M_{03} O_{10})_4$ —Reduction using Amino–naphtho – sulphuric Acid or stannous chloride⟶ Blue colour

The reagents were: 0.1 N HCl, Bray P1 Extractant (0.025N HCL + 0.03N NH_4F), Ammonium molybdate and a reducing agent (Ascorbic acid).

First, 2.0g of soil/manure was weighed into a 50 ml shaking bottle and 20 ml of Bray P1 extracting solution (Extractant) was added. This was put on a mechanical shaker for one minute and then filtered into a 100 ml conical flask. 10 ml of filtrate was transferred into a 25 ml volumetric flask with a pipette and then 1.0 ml of molybdate reagent followed by 1.0 ml of the dilute reducing agent were added and the solution developed blue colour. It was topped up with distilled water to the 25 ml mark, shaken vigorously and the solution allowed to stand for 15 minutes. The percentage transmission at 600 nm wavelength was measured on a colorimeter and the % transmittance (T) values obtained were recorded.

Calculation

% T values were converted to 2 – Log T and a graph was plotted using P Standard solutions to obtain actual concentration of P.

The concentration of P in the extract was obtained by comparing the results with a standard curve plotted. From the standard curve, this equation was obtained:

Y=AX ………………………….. (1)

Therefore available phosphorous (P) ppm or mg/Kg

X=Y/A x10

Where

Y= 2- log T of the sample

A = a constant obtained from the graph

3.6.6 Exchangeable Bases Determination (K and Na)

Exchangeable metallic cations are those cations on colloid surfaces that are replaceable by other cations from the soil solution. For instance, when a sample of soil is treated with a salt solution such as ammonium acetate, ammonium ions are adsorbed by the soil and equivalent amount of cations are displaced from the soil into the solution. This reaction is termed "cation exchange, and the cations displaced from the soil are referred to as "exchangeable". The surface active constituents of soil that have cation – exchange properties are collectively called the "exchange complex".

Exchangeable metallic cations or bases most frequently found in soils include Ca^{2+}, Mg^{2+}, K^{+} and Na^{+}. All of these exchangeable cations are easily extracted and determined in 1.0 N NH_4OAc extract of soil.

First, 10 g of soil (5 g for manure) was weighed into an extraction bottle and 100 ml of 1.0 N NH_4OAc solution was added. The bottle with its contents was placed on a mechanical shaker and shaken for 2 hours. The supernatant solution was filtered through No 42 whatman filter paper and a 10 ml aliquot was taken and K or Na was read on a Flame Photometer after calibration of photometer with prepared standards. The flame photometer reading for soil was determined and using the meter reading standard curve, the concentration of K in the soil extract was determined.

Calculation

From the curve, this equation was obtained

Y= BX

Therefore Potassium (K)cmol/kg=

$X=(Y/B)\div 39.1$

X= Potassium (K)cmol/kg

Y= flame photometer reading of the sample

B= constant value from the curve

39.1= atomic weight of K

Atomic weight of Na is 23

3.6.7 Determination of Calcium and Magnesium in the Samples

10 g of soil was weighed into an extraction bottle and 100 ml of 1.0 N NH_4OAc solution added. The bottle with its content was placed on a mechanical shaker and shaken for one hour. The supernatant solution was filtered through No 42 Whatman filter paper.

Aliquots of the filtrate (extract) were used for the determination of Ca and Mg.

Titration of Calcium (Ca)

10 ml aliquot of the sample solution extracted and filtered above was taken and 10 ml of 10 % KOH solution was added followed by 1 ml of 30 % Triethanolamine. 3 drops of 10 % KCN solution and a few crystals of Cal-red indicator were added and shaken vigorously for a uniform mixture. The mixture was titrated with 0.02 N EDTA solution from a red to blue end point.

Titration of Calcium Plus Magnesium (Ca+Mg)

To a 10 ml aliquot of the same sample solution above in a 100 ml conical flask, 5 ml of ammonium chloride-ammonium hydroxide buffer solution was added followed by 1ml of triethanolamine. 3 drops of 10 % KCN solution and a few drops of EBT indicator were added to the solution and shaken vigorously for a uniform mixture. The mixture was titrated with 0.02 N EDTA solution from a red to blue endpoint.

Calculation

To obtain Mg value:

Subtract value for Ca from that of Ca +Mg

I.e. Titre value for [(Ca+Mg) – Titre value for (Ca)] x 2 = Mg Cmo//kg

NB: Ca = Titre value of Ca x 2 in Cmol/kg or Me/100g soil

3.6.8 Soil Particle Size (or Mechanical) Analysis - Hydrometer Method

The particle size analysis of soils estimate the percentage sand, silt and clay contents of the soil and is often reported as percentage by weight of oven-dry and organic matter-free soil. The analyses are usually performed on air-dry soil. Based on the proportions of different particle sizes, a soil textural category may be assigned to the sample.

The first stage in a particle size analysis is the dispersion of the soil into the individual particle. These are the sand (0.05–2.00 mm) silt (0.002–0.05 mm) and clay (< 0.002 mm) fractions. Individual soil particles are often bound into aggregates hence the requirement for dispersion.

The hydrometer method of silt and clay measurement relies on the effects of particle on the differential settling velocities within a water column. The settling velocity is also a function of liquid temperature, viscosity and specific gravity of the falling particle. Theoretically the particles are assumed to be spherical and of specific gravity of 2.65. If all other factors are constant then the settling velocity is proportional to the square of the radius of the particle (Stoke's law). In practice, therefore, we must know and make correction for the temperature of the liquid. Greater temperatures result in reduced viscosity due to liquid expansion and a more rapid descent of falling particles.

The reagents and equipment include, 5% sodium hexametaphosphate (calgon) solution, hydrogen peroxide (30 %), distilled water, Amyl alcohol (or methanol, 95 %), mechanical shaker, sedimentation cylinder (tube) – 1000 ml, stop clock, thermometer, hydrometer and screw lid bottle, 1000 ml (for shaking).

51.0 g air–dried soil was weighed into a one–litre screw lid shaking bottle and 100ml distilled water was added and the mixture swirled to wet the soil thoroughly. 20 ml of 30 % H_2O_2 and 50ml of 5 % sodium hexametaphosphate solution were added. A drop of amyl alcohol or methanol (95 %) was added and gently swirled to minimize foaming. The mixture was then shaken on a mechanical shaker for about 2 hours or more. The content was transferred to a 1000 ml sedimentation cylinder. Water from the washings of all soil particles were added to the sedimentation tube and was made up to the 1000 ml mark with distilled water. The first hydrometer reading was recorded and the first temperature reading also with the help of a thermometer after 40 seconds. The sample was allowed to stand undisturbed for 3 hours. Second hydrometer and temperature readings were again taken after this duration. H_2O_2 destroys soil organic matter and hence frees the individual classes of soil.

Calculation (1)

% Sand = 100 – [H_1 + 0.2 (T_1 - 20) – 2] x 2

% Clay = [H_2 + 0. 2 (T_2 – 20) – 2] x 2

% Silt = 100 – (% Sand + % clay)

Where

H_1 = 1st Hydrometer reading at 40 seconds

T^1 = 1st Temperature reading at 40 seconds

H_2 = 2nd Hydrometer reading at 3 hours

T_2 = 2nd Temperature reading at 3 hours

– 2 = Salt correction to be added to hydrometer reading

0.2 (T – 20) = Temperature correction to be added to hydrometer reading, and T = degrees celcius.

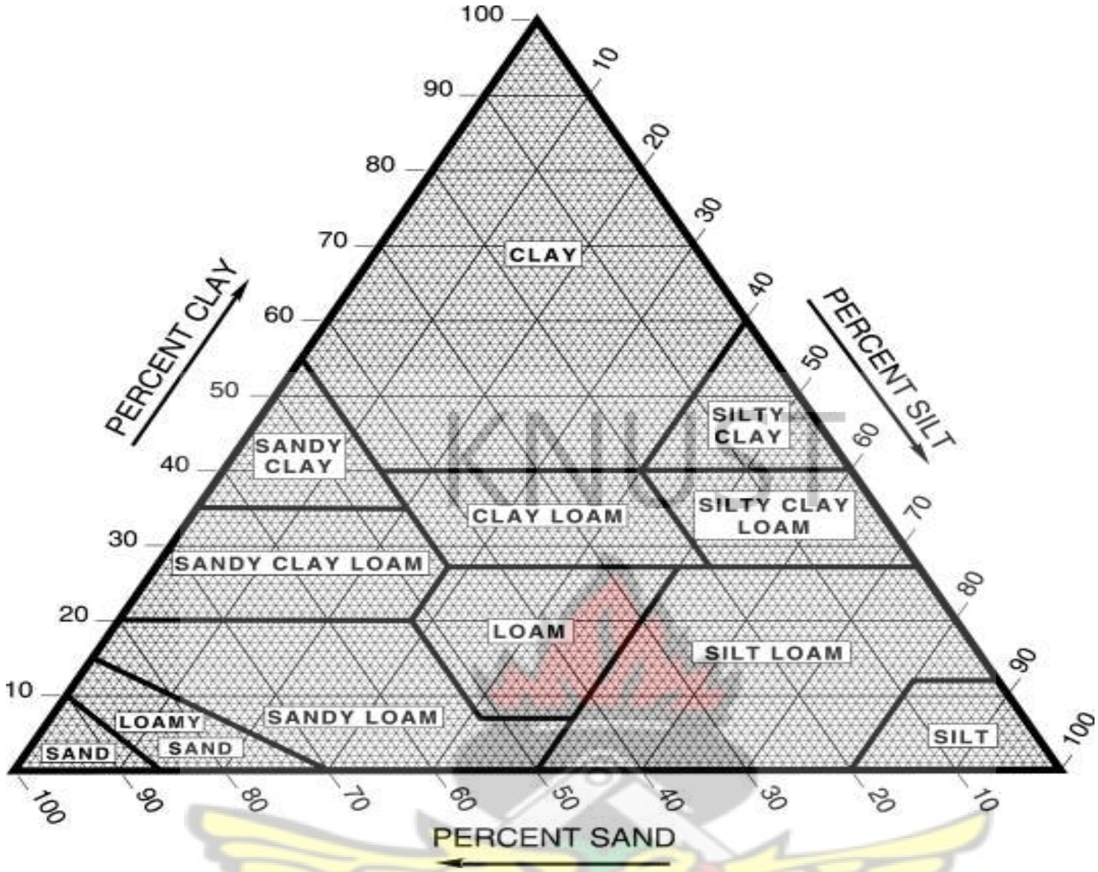

Figure 3.1 Textural Triangle

Once the sand, silt and clay distribution was measured, the soil was assigned to a texture class based on the soil textural triangle in Figure 3.1. Within the textural triangle are various soil textures which depend on the relative proportions of the soil particles.

3.6.9 Determination of Aluminium and Hydrogen

The reagent included 1.0 N KCl, 0.05 N NaOH std, 0.05 HCl std, 1.0 N NaF solution and phenolphthalein indicator.

5 g of the soil / manure was weighed into a 50 ml shaking bottle and 100 ml of 1 N KCl was added and shaken on a mechanical shaker for 2 hours. The mixture was filtered and 25 ml of

the sample solution was measured into a 250 ml conical flask and 150 ml of distilled water added. 4 drops of phenolphthalein indicator was added and the solution titrated with 0.05 N NaOH to obtain a pink colour. Few drops of 0.05 HCl was added to change the pink colour back to colourless and 10 ml of 1N Sodium flouride (NaF) also added to change the colour to pink again. The solution was then titrated again to a colourless condition with 0.05N HCl. This gave Al and H titre value. The titre value of Al was subtracted from that of H to give H titre value alone. Thus, the first titrate of 0.05 N NaOH gave the value for Al only and the second titration of 0.05 N HCl gave Al + H.

Calculation

The value for the titration of 0.05 N NaOH gives the amount of Extractable Al. This value is subtracted from the titre value of total acidity from the titration of 0.05 N HCl (Al + H) to obtain the extractable H value.

Express the extractable H and Al in meq per 100 g of soil

$$\text{Meq KCl} = \frac{(\text{ml NaOH sample} - \text{ml NaOH blank}) \times N \times 100}{\text{Wt of sample}}$$

N = Normality of NaoH = 0.05 N

$$\text{Meq KCl exchangeable Al} = \frac{\text{ml HCl} \times N \times 100}{\text{Wt of sample}}$$

N = Normality of HCl = 0.05 N

Meq H = KCl acidity – KCl exchangeable Al

3.7 Application of Treatments

The chicken manure, cow dung, the uncomposted dry fermented digestate and the composted dry fermented digestates were applied (by spreading and incorporation) after initial soil samples had been taken for laboratory analysis. One kg of the chicken manure was applied as a treatment per plot, 1.5 kg of cow dung was applied per plot and 3.5 kg of the uncomposted and 3.5 kg each of the composted dry fermented digestates (windrow, co-compost and vermi-compost) were applied per plot for 3 months. A chemical balance was used to weigh the fertilizers. The measured amounts of the various fertilizers were spread on the plots and a hoe was used to incorporate them into the soil (about 10 cm depth). The soils on the various plots were turned over (about 10 cm deep) when the surfaces became hard to allow for aeration and infiltration of water.

3.8 Watering

Each plot was watered three times in a week with a total of 20 litres of water.

3.9 Weed Control

Weeds that appeared on the beds were controlled by weeding with a hoe and machette as well as those between the plots at about 2 week intervals to prevent any reduction of nutrients and also reduce any effects that the weeds might have on the soil. The weeds were cleared away from the plots to prevent them from decomposing on the plots to affect the fertility.

3.10 Final Sampling of Soil and Preparation for Laboratory analysis

The final soil sampling was similar to the initial but here, two points on each plot were sampled and the soils mixed thoroughly before a final sample was taken for the laboratory analysis. The two points were selected by dividing the plot into three sections and using the middle of the two dividing lines as the sampling points. The two points were sampled for the 0-15 cm and 15-30 cm sections of the soil horizons. The two samples for each plot (0-15 cm and 15-30 cm) were packaged in plastic bags and labelled appropriately. The samples were prepared as the initial samples and the same parameters determined as the initials. Samples for the bulk densities were taken for individual plots and determined as the initials were done.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 Introduction

Initial and final data on soil samples from each plot for the following soil parameters were determined: bulk density, particle size analysis, soil pH, organic matter content, N, P, K, Na, Ca, Mg, Al, and H ions. Cation exchange capacity (CEC) was calculated from the results of K, Ca, Mg and Na. The same parameters with the exception of particle size analysis and dry bulk density were determined for the manures. The results are presented in tables. Results from the data collection were analysed using ANOVA and LSD was used to separate the values.

4.2 Initial Soil and Manure Test And analysis

Table 4.1 Initial Soil Test Results

SAMPLE	pH	N (%)	P (cmol/kg)	K (cmol/kg)	O.M (%)	O.C (%)
SOIL (0-15)	5.79	0.15	0.088	0.48	7.14	4.14
SOIL (15-30)	5.51	0.14	0.026	0.45	6.12	3.55

SAMPLE	Ca (cmol/kg)	Mg (cmol/kg)	Al (cmol/kg)	H (cmol/kg)	Na (cmol/kg)
SOIL (0-15)	3.40	1.00	0.20	4.40	0.30
SOIL (15-30)	4.00	0.40	0.20	4.40	0.94

4.2.1 Discussion Of Initial Soil Test Results

In terms of pH, the soil was slightly acidic (5.79 and 5.59 for the top 15 cm and 15-30 cm respectively). From the results, most of the parameters measured for the top 15 cm of the soil had slightly higher values than the 15-30 cm depth of the soil except for the Ca and Na which were higher in the 15-30 cm depth (3.4 and 0.3 cmol/kg in the top 15 cm respectively and 4 and 0.94 cmol/kg in the 15-30 cm respectively). From the data obtained, the cation exchange capacity (CEC) calculated from the following elements K, Ca, Mg and Na for the 0-15 and 15-30 cm portions of the soil were 6.38 and 6.99 cmol/kg respectively which fell in the range of 5-30 cmol/kg for soils used in plant production (Cowan, 2008). The percentage saturations of the elements K, Ca, Mg and Na for the 0-15 cm and 15-30 cm portions of the soil were 7.52, 53.29, 15.67, 4.70 and 6.44, 57.22, 5.72, 13.45 respectively which are within the ranges for these elements in the soil except for Na in the 15-30 cm portion.

Table 4.2 Manure Parameters

SAMPLE	pH	N (%)	P (%)	K (%)	O.M (%)	O.C (%)
CHICKEN	8.92	2.80	2.05	5.69	58.68	34.03
COW DUNG	8.61	1.40	0.51	3.45	41.13	23.86
UNCOMPOSTED DIGESTATE	9.17	1.5	0.0001	0.0002	58.16	33.73
WINDROW COMPOST	8.46	2.03	0.0009	0.0017	53.17	30.84
CO-COMPOST	8.61	2.1	0.0004	0.0015	50.77	29.45
VERMI-COMPOST	7.96	1.93	0.0005	0.0013	44.4	25.75

SAMPLE	Ca (%)	Mg (%)	Al (%)	H (%)	Na (%)
CHICKEN	5.30	25.80	40.00	2.40	1.10
COW DUNG	3.60	19.00	46.00	2.80	0.40
UNCOMPOSTED DIGESTATE	15.80	1.94	40.40	4.00	0.41
WINDROW COMPOST	1.36	7.97	28.00	5.60	0.49
CO-COMPOST	0.92	12.26	30.80	10.00	0.42
VERMI-COMPOST	1.80	1.46	38.00	1.60	0.52

4.2.2 Discussion of Manure Nutrients Test Results

In terms of pH, the manures were basic in character with the uncomposted digestate having the highest value followed by chicken manure and then cow dung and co-compost which were the same and the vermi-compost having the least value.

The nitrogen in the chicken manure was the highest followed by the composts in the order co-compost > windrow > vermi-compost, followed by the uncomposted digestate and then the cow dung. All these were greater than that of the soil. The higher compost N over the uncomposted was as a result of the composting with nitrifying bacteria causing the mineralisation of N. Gale (2005) attests to this fact that composting of organic residues permits the breakdown of the residues to occur without competition of micro organisms and higher plants for the mineral nitrogen and also reduces the C:N ratio of the resulting mass to a C:N value of less than 20:1.

The chicken manure had the highest P content (characteristic of it) followed by the cow dung with the digestates having negligible amounts in the order windrow compost > vermi compost > co-compost > uncomposted digestate.

Potassium had a similar trend in terms of its values recorded but the difference here was that the co-compost had higher potassium than the vermi compost.

The laboratory analysis showed organic matter and carbon were highest in the chicken manure followed by the digestates in a decreasing order of uncomposted digestate > windrow compost > co-compost > vermicompost and this could be supported with the argument that the organic matter and organic carbon decreased as the post-treatment method became specialised from uncomposted form to windrow type where only turnings were done to co-

compost type where fresh waste was added, to the vermi type where earthworms were added. This might have resulted in increasing faunal and chemical activities from the uncomposted digestate through to the vermi-compost type and therefore an increase in the use up of carbon by fauna in their breakdown activities. Cow dung recorded the least. The chicken manure and the uncomposted digestate had almost the same value as the difference between them was very small.

From Table 4.2, the manures did not show a particular trend for Ca, Mg, Al, H and Na but chicken manure, cow dung and the uncomposted digestate were mostly among the top three highest values for these nutrient elements. Chicken manure had the highest content of Mg and Na and had the second highest content of Ca and the third highest content of Al. The cow dung had the highest content of Al, second highest content of Mg and the third highest content of Ca and H. The uncomposted digestate had the highest content of Ca, the second highest content of Al and the third highest content of H. These nutrient elements was what was going to affect the the CEC and pH.

Table 4.3 Initial Particle Size Analysis of the Soil

SAMPLE	SAND (%)	SILT (%)	CLAY (%)	SOIL TYPE
SOIL (0-15)	70.80	10.00	19.20	SANDY LOAM
SOIL (15-30)	74.80	8.00	17.20	SANDY LOAM

Table 4.3 shows the percentages of the various particles in the soil with sand having the highest amount followed by clay and silt being the least. This confirms why it is a sandy loam soil as read from the textural triangle for depths up to 30 cm.

Table 4.4 Initial Dry Bulk Densities of Plots

SAMPLE	B1P1	B1P2	B1P3	B1P4	B1P5	B1P6	B1P7
DRY BULK DENSITY (g/cm^3)	0.95	0.87	1.05	0.83	0.83	1.29	1.28
SAMPLE	**B2P1**	**B2P2**	**B2P3**	**B2P4**	**B2P5**	**B2P6**	**B2P7**
DRY BULK DENSITY (g/cm^3)	0.95	0.87	0.87	0.8	1	1.2	1.32
SAMPLE	**B3P1**	**B3P2**	**B3P3**	**B3P4**	**B3P5**	**B3P6**	**B_3P_7**
DRY BULK DENSITY (g/cm^3)	0.79	0.91	0.85	1.08	0.97	1.26	1.3

Table 4.4 shows the dry bulk densities of the various plots which were almost around 0.8 to 1.32 gcm^{-3}. The average bulk density was about 1.01 gcm^{-3} and this is good for plant growth.

4.3 Final Soil Test Results and Analysis

Table 4.5 Final Soil Test Results and Analysis of Dry Bulk Density, pH, N and P

SAMPLE	BULK DENSITY	pH (0-15)	pH (15-30)	N (%) (0-15)	N (%) (15-30)	P (cmol/kg) (0-15)	P (cmol/kg) (15-30)
T1-Control	1.32	5.34 a	5.29 a	0.17 a	0.17 a	0.042 a	0.051 a
T2-Chkn	1.28	5.14 b	5.40 b	0.17 a	0.18 a	0.116 b	0.091 b
T3-Cow dung	1.27	5.48 c	5.26 a	0.14 b	0.15 b	0.081 cd	0.051 a
T4-Uncmpstd D.	1.33	5.43 cd	5.26 a	0.17 a	0.14 b	0.086 cd	0.088 bd
T5-Windrow C.	1.30	5.43 cd	5.45 b	0.17 a	0.17 a	0.086 cd	0.059 c
T6-Co-compost	1.30	5.39 ad	5.33 a	0.15 b	0.15 b	0.072 c	0.091 b
T7-vermi Comp.	1.32	5.55 e	5.53 c	0.18 a	0.21 d	0.088 d	0.083 d
CV	5.34	0.69	0.69	7.75	5.68	10.38	4.84
LSD		0.07	0.07	0.02	0.02	0.015	0.006
F RATIO (TREATMENT)	0.32ns	36.78*	24.07*	3.82*	17.51*	20.95*	85.69*
F RATIO (BLOCKS)	0.83ns	4.55*	0.34ns	0.21ns	3.45ns	0.40ns	1.98ns

* - Significant at 5% ns – Not Significant

In terms of dry bulk density (from Table 4.5), the treatments and the block design were not significant and this means they did not affect the bulk densities of the soil.

The treatments and the block design affected the pH and thus were significant at $P<0.05$ with the final pH value reducing further than the initials making the soil more acidic except the vermi compost treatment for the 15-30 cm which increased. This increase in acidity could be attributed to the increase in exchangeable acidity from Al and H ions. Al ions could be attracted to the exchangeable sites or OH ions and release more H ions into the soil solution and Al ions could be difficult to remove from the exchangeable sites. Also, other cations could have exchanged H and more H ions could have been released from the exchangeable sites into the soil solution and thereby increasing the pH as the final soil test results for Al and H ions recorded were higher than the initials except for the vermi-compost treatment for the 15-30 cm. The treatments produced different values of pH in the soil except for the cow dung and uncomposted digestate treatments for the 15-30 cm portion of the soil which were the same (5.26).

From the LSD (0.07 for both soil depths), the control and co-compost treatments for the top 15 cm soil depth were not different from each other and therefore had the same pH effect. Similarly, the cow dung, uncomposted digestate and the windrow compost treatments were not different from each other for the top 15 cm soil depth. The co-compost treatment was again not different from the uncomposted digestate and the windrow compost treatments for the top 15 cm soil depth. The chicken manure and vermi compost treatments had different pH effects from each other and from all others for the top 15 cm soil depths. For the 15-30 cm soil depth, the control, cow dung, uncomposted digestate and the co-compost were not different from each other and therefore had the same pH effect. Similarly the chicken manure and windrow compost treatments were not different from each other. The vermi compost treatment was different from all the other treatments. Comparatively, the chicken manure treatment produced the most acidic soil (5.14) for the top 15 cm portion of the soil and the control, cow dung, uncomposted digestate and the co-compost treatments produced the most acidic soils for the 15-30 cm depth (5.29, 5.26, 5.26 and 5.33 respectively) and the vermi compost treatment produced the least acidic soils for both depths (5.55). Vermi-compost was the lest basic manure (7.96) but eventually produced the most basic soil.

The treatments were significant at P<0.05 for N at both depths of the soil and thus were affected by the treatments whereas blocking did not affect the various treatments. The N levels in both depths increased except for co-compost and uncomposted digestate treatments for the top 15 cm and 15-30 cm respectively which remained the same and the cow dung treatment for the top 15 cm which reduced. From the LSD of 0.02 for both depths, the vermi compost, the windrow compost, the uncomposted digestate, the chicken manure and the control treatments produced the highest N content of 0.18 or 0.17 cmol/kg for the top 15 cm and for the 15-30 cm depths, the vermi compost treatment produced the highest N content of 0.21 cmol/kg. The high increase in the N content of the vermi compost treated soil could be due to increased microbial populations (Maerere et al., 2000) from the introduction of earthworms in preparing the compost and this could have aided in the mineralization of N in the soil. Also, cow dung and co-compost treated soils produced the least N content (0.14 or 0.15 cmol/kg) for the top 15 cm of the soil while uncomposted digestate treated soils in addition to these soils produced the least N content (0.14 or 0.15 cmol/kg) for the 15-30 cm soil depths. This low N content from cow dung and uncomposted digestate treated soils were due to the low N content in their respective manures compared to the others and this might have affected the microbial activities and the further mineralization of N or caused the immobilization of N in soils with these treatments. The uncomposted digestate treated soil was, however, higher (0.17 cmol/kg) in the top 15 cm compared to its value (0.14 cmol/kg) in the 15-30 cm depth and this could be attributed to the attenuation of N in the top 15 cm portion of the soil. The N in the control plots also increased and this could be attributed to natural mineralization processes in the soil and this could explain why other treatments could match the effect of the vermi compost when the LSD is used.

The treatments had an effect on the P content. For the top 15 cm, the uncomposted digestate and the windrow compost treatments had the same P content of 0.086 cmol/kg and from the LSD (0.015) their P content were not different from that of cow dung (0.081 cmol/kg), co-compost (0.072 cmol/kg) and vermi compost (0.088 cmol/kg) treatments. The co-compost and the vermi compost treatments, however, were different from each other. The chicken manure treatment gave the highest P content (0.116 cmol/kg) and the control treatment being the least (0.042 ccmol/kg). For the 15-30 cm portion of the soil with LSD 0.006, the control and cow dung treatments produced the least and same P contents (0.051 cmol/kg) while the chicken and co-compost treatments produced the highest and same P content (0.091 cmol/kg).). The chicken manure treated soils producing the highest P content could be attributed to the high P content in chicken manure which might have caused increased microbial decomposition and release of organic forms of P as reported by Maerere et al. (2000), Bomke and Lavkulich (1975) and Schegel (1992). Co-compost and chicken manure treatments producing the same P content could be attributed to similar soil conditions that might have occurred in both treatments at this depth. The uncomposted digestate treatment had the same effect on P content or was not different from the chicken manure, co-compost and the vermi compost treatments but the chicken manure and co-compost treatments were different or had different effect (higher) on P content compared to the vermi compost treatment.

Table 4.6 Final Soil Test Results and Analysis of K, O.M and O.C

SAMPLE	K (cmol/kg) (0-15)	K (cmol/kg) (15-30)	O.M (%) (0-15)	O.M (%) (15-30)	O.C (%) (0-15)	O.C (%) (15-30)
T1-Control	0.35 a	0.24 a	5.47 a	5.87 a	3.17 a	3.40 a
T2-Chkn	0.76 b	0.58 b	6.80 b	9.80 b	3.94 b	5.71 b
T3-Cow dung	0.61 c	0.45 c	5.57 c	7.59 c	3.23 c	4.40 c
T4-Uncmpstd D.	0.37 d	0.63 d	4.50 d	7.50 c	2.61 d	4.35 d
T5-Windrow C.	0.61 c	0.46 c	6.55 e	7.05 d	3.80 e	4.09 e
T6-Co-compost	0.55 e	0.49 e	6.24 f	6.65 e	3.62 f	3.85 f
T7-vermi Comp.	0.53 e	0.63 d	6.34 g	6.66 e	3.68 g	3.86 f
CV	5.07	3.84	0.55	0.32	0.55	0.32
LSD	0.05	0.03	0.06	0.04	0.03	0.02
F RATIO (TREATMENT)	85.15*	151.93*	1815.19*	8302.39*	1800.84*	8485.89*
F RATIO (BLOCKS)	1.75ns	0.17ns	2.74ns	0.95ns	2.74ns	0.95ns

* - Significant at 5%   ns – Not Significant

The treatments had an effect on the K content and for the top 15 cm of the soil, the cow dung and windrow compost treatments produced the same K content (0.61 cmol/kg) and this could be due similar soil conditions while all the others gave different K contents and from the LSD (0.05) the co-compost and vermi compost treatments were not different from each other. Chicken manure treatment produced the highest K content (0.76 cmol/kg) while the control treatment produced the least (0.35 cmol/kg) and this could be due to the levels of K in their respective manures and the resultant microbial activities generated. For the 15-30 cm portion of the soil, the uncomposted digestate and the vermi compost treatments produced the same and highest K content (0.63 cmol/kg) and this could be due to similar soil conditions and highest level of microbial activities, followed by the chicken manure treatment (0.58 cmol/kg) and the control treatment (0.24 cmol/kg) produced the least.

The treatments had an effect on the organic matter content in both depths of the soil sampled but the block design did not. For the top 15 cm and from the LSD (0.06), the different treatments had different effects on the organic matter content. The chicken manure produced the highest organic matter content of 6.80 % followed by the windrow compost treatment with 6.55 % and these amounts could be due to the higher organic matter content in these manures than the others. The vermi composts and co-compost treatments produced 6.34 % and 6.24 % respectively and the uncomposted digestate treatment produced the least organic matter content of 4.50 % and these could be as a result of different usage rates of carbon from organic matter by microbes in these treated soils as they did not follow the level of organic matter in their respective manures. For the 15-30 cm depth of the soil and with the LSD of 0.04, the chicken manure treatmtent produced the highest organic matter content of 9.80 % followed by the cow dung treatment (7.59 %) and the uncomposted digestate treatment (7.50 %) which were not different from each other. The vermi compost and the co-compost treatments were also not different from each other when the LSD was used; producing 6.65 % and 6.66 % respectively and the control treatment produced the least (5.87 %) and the reasons are as happened in the top 15 cm depth . The C content produced for both depths followed the same trend as the organic matter as they were determined by the combustion method which derives carbon from the organic matter content by multiplying the organic matter value by a factor of 0.58. The cow dung and the uncomposted digestate treatments for the 15-30 cm depth, however, were different from each other with respect to the LSD as opposed to their organic matter content and this is as a result of approximations in calculations.

Table 4.7 Final Soil Test Results on Na, Ca and Mg

SAMPLE	Na (cmol/kg) (0-15)	Na (cmol/kg) (15-30)	Ca (cmol/kg) (0-15)	Ca (cmol/kg) (15-30)	Mg (cmol/kg) (0-15)	Mg (cmol/kg) (15-30)
T1-Control	0.31	0.30	5.20	4.80	0.60	1.00
T2-Chkn	0.35	0.32	3.80	5.20	1.40	1.00
T3-Cow dung	0.39	0.34	5.80	5.60	0.60	0.20
T4-Uncmpstd D.	0.35	0.35	4.80	4.80	0.20	1.40
T5-Windrow C.	0.30	0.32	5.60	7.40	3.60	1.20
T6-Co-compost	0.32	0.41	5.00	7.00	0.80	0.40
T7-vermi Comp.	0.41	0.51	6.80	8.80	0.40	2.60

From Table 4.7, the Na levels in in the top 15 cm depth of the soil went up marginally but in the 15-30 cm depth, they decreased very well when compared to their initial levels. Na content might have been moderated by the addition of the manures. Ca levels in both depths of the soil went up for all treatments especially the composted manure treated soils with the vermi-compost treated soil producing the highest. The windrow composte treated soils followed and then the co-composted treated soils. The uncomposted digestate treated soil and the chicken manure treated soils had the least Ca content especially in the 15-30 cm depth and the top 15 cm depth respectively in spite of their manures having higher Ca content than the others and these inidicate that other factors such as the level of faunal activity affects Ca availabilty as was clearly seen with the vermi-compost treated soil. Mg levels in the top 15 cm depth of the soil were lower after the final soil analysis compared to their initial values except for windrow compost and chicken manure treated soils. They were up for the 15-30 cm depth of the soil except for cow dung and vermi-compost treated soils. This could have been due to the leaching out of Mg from the top 15 cm soil depth to the 15-30 cm soil depth.

Table 4.8 Final Soil Test Results on Al, H and CEC

SAMPLE	Al (cmol/kg) (0-15)	Al (cmol/kg) (15-30)	H (cmol/kg) (0-15)	H (cmol/kg) (15-30)	CEC (cmol/kg) (0-15)	CEC (cmol/kg) (15-30)
T1-Control	0.20	0.20	6.60	6.00	7.66	7.54
T2-Chkn	0.40	0.40	6.60	6.00	7.51	8.30
T3-Cow dung	0.40	0.40	6.20	5.80	8.60	7.79
T4-Uncmpstd D.	0.40	0.40	5.80	6.60	6.92	8.38
T5-Windrow C.	0.20	0.20	6.80	6.80	11.31	10.58
T6-Co-compost	0.60	0.80	6.60	6.80	7.87	9.50
T7-vermi Comp.	0.20	0.60	6.20	6.60	9.34	13.74

Al and H ion concentrations represent the exchangeable acidity which affects the H ions in the soil solution thereby affecting the soil pH. From Table 4.8, Al contents in the soil increased from the application of most treatments except windrow treatments in both depths of the soil and vermi compost treatments in the top 15 cm portion. H ion content in the soil increased in all treatments including the control and this means some natural processes in the soil might have also contributed to the increased adsorption of H ions onto the exchangeable sites.

K, Ca, Mg and Na values were used for the calculation of the CEC. For the top 15 cm, windrow compost treatment produced the highest CEC (11.31 cmol/kg) followed by vermi compost treatment (9.34 cmol/kg) and chicken manure treatment produced the least CEC (7.51 cmol/kg). For the 15-30 cm portion, the vermi compost treatment produced the highest CEC (13.74 cmol/kg) followed by the windrow compost treatment (10.58 cmol/kg) and the control treatment produced the least CEC (7.54 cmol/kg). The high CEC values mean that nutrient could be easily made available for plant uptake and vice versa.

Table 4.9.1 Final Soil Test Results on Particle Size Analysis (0-15 cm)

SAMPLE (O-15 cm)	SAND	SILT	CLAY	SOIL TYPE
T1-Control	74.80	9.60	15.60	sandy loam
T2-Chkn	70.80	9.60	19.60	sandy loam
T3-Cow dung	80.60	3.80	15.60	sandy loam
T4-Uncmpstd D.	80.80	5.60	13.60	sandy loam
T5-Windrow C.	74.80	9.60	15.60	sandy loam
T6-Co-compost	78.80	7.60	13.60	sandy loam
T7-Vermi Comp.	76.40	10.00	13.60	sandy loam

From Table 4.9.1, the sand proportion (for the top 15 cm soil depth) of the various treated soils increased compared to the initial values except for the chicken manure treatment which remained the same. The silt and clay proportions decreased except for the silt in the vermi compost treated soil which remained the same. The increase in the sand proportions and the decrease in the silt and clay proportions could be attributed to some amount of erosion on the various plots as the land had a gentle slope. The textural class of the various treated soils did not change from the sandy loam.

Table 4.9.2 Final Soil Test Results on Particle Size Distribution (15-30 cm)

SAMPLE (15-30 cm)	SAND	SILT	CLAY	SOIL TYPE
T1-Control	74.40	8.00	17.60	sandy loam
T2-Chkn	74.80	5.60	19.60	sandy loam
T3-Cow dung	78.80	5.60	15.60	sandy loam
T4-Uncmpstd D.	76.80	7.60	15.60	sandy loam
T5-Windrow C.	76.60	7.80	15.60	sandy loam
T6-Co-compost	78.80	5.60	15.60	sandy loam
T7-vermi Comp.	80.60	3.80	15.60	sandy loam

From Table 4.9.2, the sand proportion (for the 15-30 cm soil depth) of the various treated soils increased compared to the initial values except for the control treatment which decreased and chicken manure treated soil which remained the same. The silt proportions decreased except for the control treatment which remained the same. The sand proportions also decreased except for the chicken manure treated soil. The increase in the sand proportions and the decrease in the silt and clay proportions could be attributed to some amount of erosion on the various plots as the land had a gentle slope. The textural class of the various treated soils did not change.

CHAPTER FIVE

CONCLUSIONS AND RECOMMENDATION

5.1 Conclusions

From the analyses, the following conclusion could be drawn:

1. Vermi compost from dry fermented digestate increased soil pH and therefore made the soil more basic than the chicken manure, cow dung, the uncomposted dry fermented digestate and its windrow and co-composts. On the other hand, chicken manure reduced the pH of the top 15 cm making it more acidic while cow dung, uncomposted digestate and co-compost reduced the pH of the 15-30 cm portion of the soil more than the other organic manures used.

2. Vermi compost again increased soil N more than chicken, cow dung, fresh digestate and its windrow and co-compost as was clearly seen in the 15-30 cm soil depth and relatively in the top 15 cm of the soil. Chicken manure, uncomposted digestate and windrow compost were the next alternatives to vermi compost for N improvement.

3. Chicken manure showed the best improvement for soil P compared to the other organic manures. The next manures for P improvement in the soil were vermi compost and co-compost.

4. For soil K, chicken manure was the best in the top 15cm followed by cow dung and windrow composts. For the 15-30 cm portion of the soil, vermi compost and the uncomposted digestate gave the best in terms of K improvement in the soil.

5. Windrow compost was the best for CEC improvement for the top 15 cm of the soil followed by vermi compost and for the 15-30 cm portion, vermi compost was the best for CEC improvement, followed by windrow compost.

6. Chicken manure improved soil organic matter better than all the other types of organic manures. The next manures for the top 15 cm was windrow compost and those for the 15-30 cm portions were cow dung manure and uncomposted digestate.

5.2 Recommendation

Overall, vermi-compost is the best of the manures used as it was the best in terms of soil N, both K and CEC in the 15-30 cm soil depth and second best for both P and CEC in the top 15 cm soil depth. To help in making a definitive conclusion about the efficacy of vermi-compost, I would recommend a further study to compare these organic manures with inorganic manure.

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