EFFECT OF SPENT MUSHROOM SUBSTRATE ON SELECTED SOIL PROPERTIES AND PERFORMANCE OF UPLAND RICE IN OWERRI, IMO STATE, NIGERIA

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CERTIFICATION

This is to certify that this work **"Effect of Spent Mushroom Substrate on selected Soil Properties and Performance of Upland Rice (*Oryza sativa*) in Owerri, Imo State, Nigeria"** was carried out by I, MGBEAHURU, CHIBUIHEM .I. (20174079818) in partial fulfillmentfor the award of the degree of Master of Science (M.Sc) in Soil Physics, Degradation and Conservation in the Department of Soil Science and Technology of the Federal University of Technology, Owerri.

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DEDICATION

This thesis is dedicated to God my everlasting Father, the King of Kings and the Lord of Lords who makes ways where there seems to be no way; Lord, I am grateful for your goodness, sustainance, protection, provisions, surpassing love, mercies and grace. To you Lord, be all the Glory.

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ABSTRACT

Spent Mushroom Substrate (SMS) is a type of organic amendment found to be a good nutrient source for crop production mainly because of its rich nutrient status and slow mineralization rate which retains its rich nutrient as an organic amendment. This research work was carried out at the Centre for Agricultural Research and Extension, Federal University of Technology, Owerri (FUTO).It investigated the effect of spent mushroom substrate (SMS) on some selected soil properties and performance of upland rice in Owerri, Imo State, Nigeria. The experiment was evaluated using five treatments at rates of SMS 0 t/ha (control 1), NPK 300 kg/ha (control 2), SMS 5 t/ha, SMS 10 t/ha and SMS 15 t/ha and were incorporated into the soil two weeks before planting; the treatments were replicated three times in a Randomized Complete Block Design (RCBD).The field measured 13 m by 6.5 m; each plot measuring 2 m by 1.5 m with a 0.5 m alley between plots.The SMS treatment was sourced from a mushroom farm located at Aba in Aba North Local Government Area, Abia State and at Irete in Owerri West Local Government Area, Imo State while NPK was sourced from the Imo State Agricultural Development Project (ADP).The test crop used was FARO 56/NERICA 2 upland rice variety sourced from the Imo ADP; rice plants were sown at spacing of 30 cm ×30 cm. Soil samples were collected at depth of 0-20cm using soil core attached to soil auger; a sample was collected from each plot and analysed for physico-chemical properties of moisture content, bulk density, total porosity, particle size distribution, pH, organic carbon and matter, total nitrogen, available phosphorus, exchangeable aluminum, hydrogen, calcium, magnesium, sodium, potassium, total exchangeable bases, total exchangeable acidity, effective cation exchange capacity, percentage base saturation, C/N, Ca/Mg and Na/K and the presence of chromium, lead, cadmium and mercury. Samples were analyzed at pre-planting, at the end of vegetative growth (100 days after planting) and at harvest. The growth parametersmeasured were: plant height, root weight, leaf area and number of tillers; yield parameters include: filled grain, unfilled grain, total grain yield, percentage unfilled grain and percentage filled grain. Data collected was subjected to both laboratory and statistical analysis. Laboratory analysis was carried out in the Soil Science Laboratory of the Federal University of Technology, Owerri while statistical analysis was carried out using Analysis of Variance (ANOVA) and means separated with the Fisher's Least Significance Difference (F-LSD) at (p=0.05). Results obtained revealed that soil of the study area was predominantly sandy. Moisture content (9.33%) was highest in SMS 15 t/ha and varies significantly from moisture content values of control plot (7.40) and NPK treated plots (7.49). Bulk Density was lowest in NPK treated plots (1.40 g/cm^3). Basically, SMS treated plots recorded significant increase in soil physico-chemical properties with increase in application rate when compared with control and NPK treated plots, except in exchangeable acidity where it significantly reduced with increased rate of application of SMS. Similar trend on physico-chemical properties were observed in values at harvest, but values at harvest recorded a decline in value compared with values at the end of vegetative growth (100 days after planting) except in total porosity which increased due to the relationship with bulk density on the soil. Lower values obtained at harvest could be attributed to nutrient uptake by plants during vegetative growth. Spent Mushroom Substrate recorded negligible values of mercury, lead, chromium and cadmium which were below permissible limits of heavy metals in the soil both at the end of vegetative growth and at harvest; hence, will not limit soil productivity. The application of SMS positively affected the growth and yield of the test crop used when compared with control and NPK plots, except in root weight where SMS 15 t/ha was statistically equal to control plots; other SMS rates were also statistically equal to NPK treated plots; this could be attributed to high content of sodium (salt) which may have inhibited good root development. All rates of SMS applied during the experiment significantly improved soilphysico-chemical properties and the performance of upland rice.Spent Mushroom Substrate 10 t/ha was seen as the best application rate suitable for the performance of upland rice; hence, it is recommended to farmers in the study area for yield improvement of upland rice production without adversely affecting human health-both farmers and consumers.

KEY WORDS: Growth, Nitrogen Phosphorus Potassium (NPK), Owerri, Soil Properties, Spent Mushroom Substrate (SMS),Upland Rice and Yield.

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background Information

Southeastern Nigeria is a humid tropical rainforest characterized by high precipitation which causes runoff, leaching of nutrient elements and soil erosion (Onweremadu, Ihem, Onwudike, Ndukwu, Idigbor & Asiabaka, 2011); thus lowering soil fertility and increasing soil degradation. Research has shown that anthropogenic activities on the natural terrestrial ecosystem have resulted to variations in physical, chemical and biological properties of the soil (Conant, Six & Paustian 2003). Some land use and cropping systems like cultivation and deforestation have been reported to cause significant variations in soil physical and chemical properties and reduction of output (Conant *et al*., 2003; Saraswathy, Siganya & Singarain, 2007). This has led to decline in soil fertility and degradation, which in turn is considered as a major constraint facing agricultural productivity. Soil degradation is the lowering of soil physical and chemical fertility to a level that limits maximization of agricultural productivity (Ezeaku & Davidson, 2008). Soil degradation is particularly serious in Nigeria, where the effects of anthropogenic activities are compounded by the problems caused by periods of drought and intense rainfall.

In Southeastern Nigeria, the predominating Ultisols suffer from a combination of "very low" organic matter content and an unfavourable clay mineralogy dominated by kaolinitic clays. These soils have a number of soil related constraints to agricultural productivity, poor structural stability and high susceptibility to erosion and drought (Opara-Nadi, 2000). The soils have low mineral reserve, are highly weathered and leached and have low fertility status. Yet, a common agronomic feature of the region is the continuous cropping of small holder farms and the associated debilitating effect, without adequate efforts towards replenishment and conservation to ensure sustainability of the soil resources (Ogoke, Ibeawuchi, Ngwuta, Tom & Onweremadu, 2009). Soil productivity and reduced crop yield has become a major problem in agriculture due to reduced organic matter contents and increased soil salinity along with much use of dense fertilizers in agriculture (Abak & Celikel, 1996). The increasing dependence on the use of inorganic fertilizers in the growth of cereal and food crops like rice has been found to have negative impacts and long term detrimental effects on the structure of the soil and excessively high farmer's expenditure (Orluchukwu & Okosa, 2018). Due to the high cost of fertilizers and not being accessible to farmers, there is need for alternative methods for development of an efficient and quality soil improvement approach (Ozguven, 1998). Bodruzzaman, Meisner, Sadat and Hossain (2010) pointed out the need to improve soil fertility levels with the use of organic wastes as nutrient sources. This will aid in the reduction of the poverty level of farmers that threatens their productivity. Useni, Chukiyabo, Tshomba, Muyambo and Kapalanga (2013) stated that improvements in soil fertility levels of rice fields require considerable inputs of organic waste materials, like Spent Mushroom Substrate (SMS), especially in impoverished soils for agricultural production. In order to overcome these problems, there is need for soil amendment. Soil amendment includes all inorganic and organic substances added to the soil to achieve a better soil condition for plant productivity. Soil amendments promote aeration, nutrient holding capacity and drainage.

Spent Mushroom Substrate (SMS) is the soil-like material remaining after a crop of mushrooms have been harvested, It adds nutrient to the soil, improves acidic soils and adds organic matter and structure to the soil by improving soil properties. Application of SMS to the soil is important for soil improvement and safe for human consumption; it provides a balanced nitrogen and carbon source for plant growth (Orluchukwu & Okosa, 2018).The recomposted spent mushroom substrate has been found to be a good medium for majority of the vegetables and cereal crops and has shown multifacet utilities in improving the yield and quantity of crop, and management of diseases. Hence, SMS can be used in organic farming to improve soil water infiltration, water holding capacity, permeability and aeration. Research carried out by The Irish State Agriculture and Food Development Authority in

1997, showed that total nutrient level along with the dry matter content indicates an average content of 8.0 kg (nitrogen), 3.9 kg (phosphorus) and 7.9 kg (potassium) per 1000 kg of fresh SMS.

Rice is a staple food and currently the most staple food after maize in Nigeria with increased consumption as a result of urbanization and population growth (Ekpe *et al*., 2020). It is also the world's most important wetland crop. It grows across all agro-ecological zones in Nigeria (African Rice Centre (AfricanRice), 2011). In Owerri, the actual yield of rice and in Nigeria at large is not up to its expected potential; this has led to the importation of rice into the country at an alarming rate (Babatunde, Salami & Mohammed, 2016). In order to increase the yield of upland rice in Owerri, there is need for improved technologies like good irrigation water, improved seed variety and incorporation of appropriate quantities of organic and inorganic fertilizers (Ekpe *et al*., 2020). These amendments have been used to improve soil physico-chemical properties; decreasing acidity and improving soil humus content (Olanikan, 2006). These organic fertilizers/amendments like spent mushroom substrate are environmentally safe, highly effective and justified biologically in most degraded soils (Ojobor, Obiazi & Egbuchua, 2014) while inorganic fertilizers adversely affect soil chemical properties when excessively and frequently used uncontrollably (Ekpe *et al*., 2020).

1.2 Problem Statement

Ultisols of SouthEastern Nigeria, have many soil related constraints to agricultural productivity, poor structural stability and high susceptibility to erosion and drought as a result of low organic matter content, low cation exchange, low base saturation, poor aeration, high acidity and decrease in Cation Exchange Capacity (CEC). Decrease in cation exchange capacity suggests decrease in buffering capacity and is a cause for concern as soil with low to medium CEC can have decline in soil organic matter, total nitrogen, total porosity, aggregate stability and low pH due to reduction in biological activities that could adversely affect productivity of soils (Lee, Lee, Jung, Park, Lee & Kim 2009). High weathering, leaching and rainfall also contribute to the poor fertility and productivity of the soil. Anthropogenic activities such as continuous cropping, tillage practices, over grazing, e.t.c are also causes of poor fertility and low productivity of the soil. Decline in soil fertility and soil degradation has been considered as the major constraint facing agricultural productivity in Southeastern Nigeria (Onwudike, 2015). Rice is a crop that requires sufficient supply of water for growth and yield; the rainforest zone of SouthEast Nigeria does not have an even distribution of rainfall throughout the year; hence, the need for irrigation practices. Due to the high cost of inorganic fertilizers like NPK, it is important to assess the use of spent mushroom substrate (SMS) in improving soil properties since it is less economical and can improve productivity, even better than inorganic fertilizers.

1.3 Objectives of the study

The main objective of this study was to determine the effect of Spent Mushroom Substrate (SMS) on selected soil properties and performance of upland rice in Owerri, Imo State, Nigeria while **the specific objectives** were to:

a) determine the effect of the treatment (SMS) on selected soil physico-chemical properties

b) determine the effect of treatment on rice growth parameters

c) determine the effect of treatment on the yield and yield components of rice

d) determine the effect of treatment on some selected heavy metals

1.4 Justification of the study

The study of the effect of Spent Mushroom Substrate (SMS) on soil properties and performance of upland rice is important because of its ability to replenish the lost soil plant nutrient and increase grain yield of rice as an organic amendment. Soil of the study area, which is an Ultisol has characteristics of poor aggregate stability, low CEC, low organic matter, low base saturation, high acidity, poor aeration, e.t.c. Spent Mushroom Substrate has been reported to contain nutrients which could be used for the growth of useful crops. These nutrients are non-toxic to cultivated crops and crops are biosafe for consumption; therefore, it should be employed as soil amendment for different crops (Orluchukwu & Okosa, 2018). Spent mushroom substrate is readily available where there is a mushroom farm and saves cost (economical) compared to other sources of amendment; hence, it is accessible to anyone irrespective of class and financial status. It is odourless, non-hygroscopic, has little transportation hitches and does not pose threat to human health. At the end of this study, it is expected that there will be improvement in productivity: soil properties and grain yield of upland rice after amendment with SMS. It is therefore imperative that information on the use of spent mushroom substrate (SMS) in improving soil properties and performance of upland rice in Owerri, Imo State, Nigeria be made available to farms and this will be done through the outcome of this research; this will aid farmers in the study area; the research work being an exploratory study.

1.5 Scope of the study

This research work focused on the effect of spent mushroom substrate (SMS) on soil properties and performance of upland rice. Due to constraints in soil productivity as a result of reduction in soil properties: low CEC, low organic matter, poor aggregate stability, poor aeration, high acidity, e.t.c, it is important to treat the soil with an organic amendment such as SMS to improve productivity. This study was carried out and completed for a period long enough for rice production (from late October, 2019 through early February, 2020). Constraints to this study include inadequate capital/finance, termites attack, and unstable academic calendar (industrial unrest).

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Mushroom Substrate

According to the American Dictionary (2015, version 4.3), a substrate is the surface on which an organism (such as a plant, fungus, or animal) feeds on or lives on. A substrate can include biotic or abiotic materials and animals. Agricultural wastes serve as potential substrates for Mushroom cultivation. These wastes are rich in various types of nutrients and their disposal is difficult to manage as excess of nutrients in them can cause leaching if left in the field, as a compost. Mostly, they are disposed by means of incineration which causes pollution (Udayasimba & Vijayalakshmi, 2012). Hence, there is always a high demand of discovering an agricultural waste management method which is cost effective and contributes less in environment pollution. Mushroom cultivation in agricultural wastes fulfills these requirements (Nicolcioiu, Popa & Matei, 2016).Some of the agricultural wastes commonly used include wheat straw, paddy straw, rice straw, rice bran, molasses, coffee straw, banana leaves, tea leaves, cotton straw, saw dust, etc.

Various edible mushroom strains are cultivated worldwide. Some of them include:Button-Agaricus, Oyster-Pleurotus, Shiltake-*Lentinula edodes*, Straw- *Volvallela volvacea*, Chinese mushroom-Ganoderma.

2.1.1Nutrient compositions of substrates.

For high yield mushroom cultivation, it is necessary that the entire nutritional requirement should be fulfilled in optimum concentration as various researches have reported low yield when nutrients in a medium are either in low or high concentration. Banana stalk and Bahia grass are used for the cultivation of *Pleurotus sajor-caju* with biological efficiency of 74.4 % and 74.12 % respectively, but there is a low yield when they are supplemented with other components. This can be due to high nitrogen concentration which hinders its yield (Thongklang & Luangharn, 2016).

Table 2.1: Nutrient Composition of some substrates

SUBSTRATE/NUTRIENT	COMPOSITION
1. Wheat straw	1 % Protein, 13 % Lignin, 39 % Hemicellusose, 40 % Cellulose. Dry Matter: Calcium 4.5 g/kg, Phosphorus 0.7 g/kg, Potassium 12 g/kg, Sulphur 1.1 g/kg, Magnesium 1.1 g/kg
2. Rice straw	41 % Cellulose, 14 % Lignin, pH 6.9, 0.8 % Total nitrogen, 6 % Silicon oxide(SiO_2), 0.3 % K_2O, 0.25 % P_2O_5, Calcium(0.25-0.55 %), Phosphorus(0.02-0.16 %), Nitrogenous matter(2-7 %).
3.Sugarcane bagasse	35-40 % Cellulose. 1-4 % Ash, <1 % Waxes, 0.7 % Nitrogen, 20-25 % Hemicellulose, 18-24 % Lignin.

(Elahe, Mehrdad & Shahin, 2016)

2.2 Soil Amendment

Soil amendment includes all inorganic and organic substances mixed into the soil for achieving a better soil constitution regarding plant productivity. Both organic and inorganic substances can be added into the soil. Organic substances consist of materials derived from living things e.g plants, while inorganic substances are mined or man-made. Soil amendment does not include mulching, which includes substances lying on top of the soil. There are different substances for different soils and plants to optimize the soil conditions. A very common amendment is the addition of organic matter like compost due to its low production costs. By use of soil amendment, almost every type of soil can be made fertile (West Coast Seeds, 2011).

2.2.1 Inorganic Amendments

Inorganic sources include vermiculite, tire chunks, sand and pea gravel. They are expensive because they must be bought. Additionally, the industrial production process needs a great deal of energy. Therefore, they do not have the same degree of sustainability as organic amendments. Most are relatively sterile (with regard to plant pathogens) and many are relatively inert. Inorganic amendments are used to:

- Increase aeration
- Increase drainage
- Decrease excessive water holding capacity
- Decrease or increase weight (Reed, 2007).

2.2.2 Organic Amendments

Organic amendments are derived from plants or plant produce e.g. spent mushroom substrate (SMS) that occur naturally or are the by-products of processing plants or mills (saw dust, rice hurls, cedar chips, etc.) or waste disposal plants (compost, processed sewage sludge, biosolids, etc.). The main purpose of using organic amendments is to loosen the soil and create large pores to increase:

- Aeration
- Drainage
- Usable water holding capacity
- Nutrient holding capacity
- Decrease growing medium weight (compared to soil). (Reed, 2007).

2.3 Effect of Spent Mushroom Substrate (SMS) on Soil Physical Properties.

Soil texture is the proportional distribution of soil particles into sand, silt and clay components according to size and mineral fractions. Texture is the result of weathering, the physical and chemical breakdown of rocks and minerals, because of compositional and structural differences (Forth, 1999). Root production can be affected by soil structure and texture. Bigger roots have greater potential in elongation; hence, enhances water and nutrient uptake (Fugen, Junel, Rodante, Tabien & Kun, 2016).The arrangement of soil particles into larger clusters called aggregates is called soil structure (Nichols, Wright, Liebig & Pikul(Jr), 2004). Aggregation is important for increasing stability against erosion, maintaining porosity of soil water movement and improving fertility and carbon sequestration in the soil (Nichols *et al*., 2004). Finer soils usually have stronger, more defined structure than coarser soils due to shrink and swell process predominate in clay rich soils and more cohesive strength between particles. The ability of the soil to allow passage of water and air through it is called porosity (Donahue *et al*., 1990). It is that part of a soil volume that is not occupied by soil organic matter; but filled with air, other gases or water (Brady & Weil, 2002). Long term cultivation lowers porosity because of reduction in soil organic matter and peds (Brady & Weil, 2002). Increase in soil organic matter levels will improve soil porosity, structure and reduce soil compaction and erosion. Moisture content is the available amount of water contained in a unit mass or volume of soil (Hillel, 1982). Low moisture content can be improved by amendment with organic matter e.g. SMS, either as mulch or by incorporating into the top layer of the soil (Brady & Weil, 1996). Bulk density is the weight of soil per unit volume of soil; pore spaces and solids inclusive, while particle density involves only the mineral solids. Hunt and Gikes, (1992) postulated that it is desirable to have soil with low bulk density (< 1.5 g/cm^3) for optimum movement of air and water through the soil. High bulk density indicates low soil porosity and soil compaction while low bulk density indicates high soil porosity and soil compaction. This is the ease with which a fluid, usually water moves through pore spaces, It is dependent on soil structure and varies in both space and time. Variations of hydraulic conductivity could be caused by agricultural activities e.g tillage practices, shrinking and swelling (Ankeny, Kaspar & Horton, 1990; Bagarello, Iovino & Reynolds, 1999).

Soil Degradation is the lowering of soil physical and chemical fertility to a threshold that limits maximization of agricultural productivity (Ezeaku & Davidson, 2008). It is a particularly serious problem in Africa, where the effects of anthropogenic activities are compounded by the problems caused by periods of drought and intense and irregular rainfall. Soil physical degradation in agricultural areas occurs mostly as a consequence of a decrease in soil organic matter caused by excessive soil cultivation (Grandy, Porter & Erich 2012). Intensive soil cultivation can lead to a decrease in aggregate stability and a greater risk of soil erosion (Annabi, Le Bissonnais, Le-Villio & Honot 2011). Loss of organic matter is generally associated with a decrease in soil porosity and a wet aggregate stability (Seker & Karakplan, 1999).

Organic materials are important soil additives that help to improve soil physical, chemical, biological properties and overall soil fertility (Wu, Xu & Shao 2014). Hence, organic materials like spent mushroom substrate (SMS) can be applied to soils to improve their organic matter contents and restore their physical properties, including soil aggregate stability (Annabi et al.,2011). Anikwe (2000) reported that organic materials can modify soil physical and chemical properties; including those important for soil structure. Among different and many characteristics and possible applications, SMS has shown to be a source of enzymes, enabling its use in animal nutrition, energy production and even bioremediation (Phan, Zeng, Tu, Huang & Chen, 2015). Reports have shown that SMS was used in agriculture to increase the organic content of the soil and to improve its structure. Spent mushroom substrate has also shown to be characterized by good sorption properties (Chen, Zeng, Tu, Huang & Chen, 2005).

Spent Mushroom Substrate has high content of nutrients that are generally harmless to plants. Application of spent mushroom substrate, which is an organic amendment reduced bulk density as stated by Mbagwu (1992); this also agreed with Ogbodo, Ekpe and Ulobo (2009) who stated that organic amendments reduced soil bulk density in ascending order of treatment rate application. Total porosity increased on addition of SMS compared to control (Mbagwu, 1992). Soil amendments with organic wastes like SMS improve soil aggregate stability (Lee *et al*., 2004), hydraulic conductivity also increased on addition of SMS.

Application of organic amendments in increasing rate increased soil moisture (Ogbodo *et al*., 2009). Gupta and Jaggai (1979) stated that higher soil moisture content could be attributed to favourable soil-water relation that was able to improve with the organic amendment addition. Mbagwu and Piccolo (1990) also stated that the improved soil structure from reduction in soil bulk density, and increased porosity played a role in increasing soil water holding capacity. Organic materials have the characteristics of absorbing and retaining water; increasing soil water storage capacity (Ogbodo *et al*., 2009). Mbagwu and Ekwealor (1990) pointed out that soil water content in an Ultisol increased by increasing the rate of application of organic amendment. Organic materials also loosen soils, reduced water loss due to erosion, reduced evaporative water loss and reduced soil temperature. Jeff-Michael *et al* (1996) reported that soil organic matter facilitates infiltration of water and air into the soil, maintains soil tilt and also increased water retention by the soil.

Increase in porosity and reduction in bulk density were noted as a result of promotion of aggregation of soil properties when the soil was amended with an organic material (Ogbodo *et al*., 2009), hence adopting the practice of regular use of organic amendment in crop production could aid in ameliorating the problem of high bulk density. This reduction in bulk density could be due to the binding effect of organic amendment on soil particles into aggregates. Additions of organic amendment to the soil has been found to add significant amounts of carbon to the soil and generally associated with increased water infiltration, reduced bulk density and improved soil tilt (Greg & Robert, 2000). Organic amendments reduce soil bulk density ($<1.5 g/cm^3$), which is desirable for optimum movement of air and water through the soil (Hunt & Gikes, 1992).

2.4 Effect of Spent Mushroom Substrate (SMS) on Soil Chemical Properties.

Soil pH is the negative logarithm to base 10 of hydrogen ion (H^+) concentration in a solution (Forth, 1999). It indicates the acidity or alkalinity of a soil. The pH ranges from 0-14; where pH value of 7 is said to be neutral, below pH 7 is acidic and values above 7 alkaline (Brady & Weil, 2002). The optimum soil pH for rice growth in dry conditions is 5.5-6.5; a pH range of 6.0-6.8 is ideal for most crops (Howeler, 2002). Aluminum and hydrogen are dominant exchangeable cations in acidic soils; as the acidic cations (Al^{3+} and H^+) increases, basic cations ($Mg^{2+,}$ Ca^{2+}, K^+, Na^+) decreases; giving rise to acidic soils while as basic cations increase(occupies the exchange site), acidic cations decrease; giving rise to alkaline soils. (Howeler, 2002).Any material derived from tissues of organisms (animals or plants) whether dead or alive is referred to as organic matter. Hence, soil organic matter is any material derived from organic residues which varies in their stability and susceptibility to further degradation. It is rich in nutrients and closely linked with soil productivity which is important for soil structural improvements, favourable soil-water relationship and nutrient mineralization (Gupta & Jaggi, 1979). These are essential plant nutrients for increasing crop yield (Dastan *et al*., 2012). Nitrogen deficiency results in stunted growth and chlorosis. Application of different types and rates of amendments may have effect on tiller number and application of nitrogen and phosphorus nutrients resulted to increased tiller number and panicle, panicle length, number of spikelet and increased grain yield (Fairhurst, Will, Buresh & Dobermann, 2007). Application of both phosphorus and potassium increases rice grain yield, although the effect is more pronounced under favourable rainfall or adequate irrigation conditions (Barbosa & Yamada, 2002). The recommended rate for application is 300 kg/ha of NPK 20-10-10 for rice production (Aduayi, Chinde, Adebusuyi & Olayiwola, 2002).

Carbon(C) and Nitrogen(N) in soils are the main component of organic content which is known as soil fertility; both play a key role in regulating soil organic matter (SOM) mineralization (Johanna & Kuzyakov, 2012). C/N is an indicator of the decomposition rate of organic matter which leads to mineralization or immobilization of soil nitrogen. Deng *et al* (2013), stated that the greatest Soil Organic Matter (SOM) mineralization would occur at C/ N of 25. At ratio less than 20, nitrogen is released at the early stage of decomposition. Carbon and Nitrogen ratio shows the degradation rate of organic matter which is the major source of carbon in the soil. For agricultural soil, low C/N (20:1 or less) is sufficient. The values of C/N in cropping systems is important for practical farming by adding organic materials to reduce immobilization or an increase in soil nitrogen (Xiong, Grunwald, Myers, Ross, Harris & Comerford, 2014).C/N range from < 8(very low) to > 30(very high); the SOM active fraction C: N typically exceeds 15, while the slow fraction C/N ranges between 10 and 25 and the passive fraction C/N ranges between 7 and 10 (Brady and Weil, 2002). A C: N in the range 15-30 indicates a good energy supply for soil microbes, with a C/N of 25 being optimal for SOM mineralization (Brady & Weil, 2002; Deng *et al*; 2013 and Swangjang, 2015). High C/N can slow down the decomposition rate of organic matter and nitrogen; the higher the soil C/N, the slower the decomposition rate of organic matter and nitrogen because it can limit the ability of soil microbial activity (Wu *et al*., 2016). Swangjang (2015) stated that ratio of less than 20 is classified as nutrient poor due to the faster release of nitrogen during the decomposition process.

Calcium and Magnesium are both basic cations with two valence electrons in their outermost shells. Soil Calcium and Magnesium ratios between 2 and 8 have no influence on crop yield (Jim, 2016). Ca/Mg of 6:1 brought about optimum maize yield (Osemwota, Omueti & Ogboghodo, 2007). The recommended ratio for good plant growth is Ca/Mg of 2:1 (Schulte & Kelling, 1993).Sodium and Potassium have almost identical chemical properties; both are basic cations and have one valence electron in their outermost shells. Plants like grains, cereals and tomatoes absorb high levels of sodium (Wybenga, 1975). The medium fertility range of Na/K is 1:3 (Akintunde, Obigbesan, Kim & Akinrinde, 2000).

Addition of organic amendments like spent mushroom substrate (SMS) in increasing rate, improved soil chemical properties. Organic manure serves as a slow-release reservoir for macro-nutrients, especially nitrogen and also helps in plant micro-nutrient nutrition. It has been reported that nitrogen is the most important nutrient element in rice production. Spent mushroom substrate also increased percentage nitrogen content (Unal, 2015). Organic amendments have buffering capacities and hence, buffer soil pH; making the soil more resistant to pH changes in the soil and improves soil cation exchange capacity (Ogbodo *et al.*, 2009). Ekpe *et al* (2017) noted that mineralization of organic wastes resulted in the release of organic bound nutrients in the soil; significantly nitrogen, phosphorus, potassium and organic matter. The spent mushroom substrate from different mushrooms varies in their physical, chemical and biological properties. It has been found to be nutritionally rich with respect to its nitrogen, phosphorus and potassium contents and having high cation exchange capacity. It has the ability to replace farmyard manure for the purpose of raising cereal and horticultural crops (Ahlawat & Sagar 2007).

Wisniewska and Pankiewirz (1989) observed that SMS treatment in soil increased the phosphorus, calcium and magnesium contents in the soil. Medina, Paredes, Perz-Murcia, Bustamante and Moral (2009), observed that pH values, salt contents and macro and micro nutrients concentrations increased due to addition of SMS to growing media. Mushroom compost generally limes soils and increases the availability and uptake of nutrients, especially nitrogen, potassium and phosphorus. However, negative growth responses have been reported occasionally owing to high salinity or metal concentration

(Stewart, Cameron, Cornforth & Sedcok, 1998). Spent mushroom substrate is an organic substrate rich in nutrients, especially nitrogen, which has a considerable agronomic value when used as soil improver (Medina *et al*., 2009). Addition of spent mushroom substrate (SMS) to the soil significantly increased organic matter content (Adeli, Tewolde, Sistani & Powe 2009). Total nitrogen also had a significant increase when SMS was added to the soil (Bitzer & Sims, 1988). Soil pH will also improve; become slightly acidic when amended with SMS. This agrees with Ogbodo *et al*., (2009) who reported that addition of organic amendment to the soil improved soil pH, soil organic matter content, exchangeable bases and cation exchange capacity (CEC). Unal (2015) observed that soils treated with spent mushroom substrate (SMS) recorded increases in potassium (K_2O), calcium, phosphorus (P_2O_5) and magnesium contents as the rate of application increased; hence, SMS increased exchangeable bases with increased rate of application. Application of spent mushroom substrate also increased the zinc, copper and manganese content while iron content was reduced. The pH was observed to range from 6.5-7.5 when SMS was applied (Unal, 2015). This pH value is said to be suitable for growing seedlings and also for the availability of various macro and micro nutrients (Aktas, 2004). High pH values affect root development (Gunes, Alpasian & Inal 2004). Unal (2015) also reported that application of spent mushroom substrate increased electric conductivity values, but no salinity issue was recorded.

Moral, Perez-Murcia, Perez-Espinosa, Moreno-Caselles, Paredes and Rufete (2008) stated that organic amendments had high sodium contents and addition of organic amendments to the soil increased soil sodium content; this increase could be toxic in the long term usage because it could lead to soil salinization. Micronutrient malnutrition causes serious diseases in both plants and animals and even in humans. Deficiency of micronutrients is the main reason of so-called hidden hunger, characterized by the lack of the appropriate balance of nutrients (Murgia, Arosio, Tarenitino & Soave, 2012). One of the methods for the combaction of micronutrient deficiency is the macronutrient fertilization. Popular nutrient fertilizers are majorly cheap inorganic salts and are highly leached from the soil to ground water and expensive and non-biodegradable organic chelates (Jie, Raza, Xu & Shen 2008). There is need for new fertilizer materials that are cheap, have high bioavailability of nutrients and biodegradable (Michalak, Tuhy, Saeid & Chojnacka, 2013). The potential use of spent mushroom substrate (SMS) in agriculture makes it a promising micronutrient fertilizer; overcoming micronutrient deficiency in soils and plants. Spent mushroom substrate is a rich source of Iron and can be classified as an organic-mineral fertilizer because of its organic character of the biomass micro and macronutrient content. Spent mushroom substrate is a promising new organic fertilizer material with advantageous properties, such as the preferred C/N ratio, assimilable forms of nutrients and high content of organic matter (Garrrido *et al*., 2012). It contains macronutrients in high concentrations, especially Phosphorus (P), Sulphur (S), Calcium (Ca) and Potassium (K).

Wisniewska-Kadzajan and Jankowski (2013), observed a high concentration of Calcium and low heavy metal content of Zinc (Zn), Manganese (Mn), Copper (Cu) in spent mushroom substrate. Application of spent mushroom substrate improves soil fertility (Medina *et al*., 2012). Hairu, Li, Zhang, Ghangming, Zhao and Meishan (2016) stated that spent mushroom substrate increased the organic matter content and exchangeable cations in the soil; it was found that on application of spent mushroom substrate, the content of the organic matter and exchangeable cations were higher than in soils without application of spent mushroom substrate. Hairu *et al* (2016) also observed increase in pH and higher contents of total nitrogen, total potassium, available nitrogen and total phosphorus on application of spent mushroom substrate; this increased rice growth. Sanchez (1976) stated that on sites that have a tendency to iron, aluminum or hydrogen toxicity, humifying organic matter works to combat toxic metal concentrations by forming complexes with high molecular weight; where there is absence or little presence of organic matter, aluminum or hydrogen toxicity cannot be combated.

2.5 Effect of Spent Mushroom Substrate on Rice Production

Rice (*Oryza sativa*) is an edible starchy cereal grain. It is eaten as a staple food in many parts of Asia. It is grown in warm parts of the world; mainly Asia, Africa, Northern Italy and the coast of North

America. It is usually cooked. In some areas, such as Spain, rice is first fried in olive oil or butter, and then cooked with water or soup. In other areas, such as India, rice is eaten with sauce, curry or soup. Rice can also be used to make alcohol such as Japanese sake rice wine. It is an annual grass of the family Gramineae and the genera Oryza. Oryza has about twenty (20) different species, of which two are culticated. They are *Oryza sativa L.* (Asian rice) and *Oryza glabemina stend* (African rice). It has long, wide to narrow, light green leaves, usually long and thin grains.

Rice is believed to have been first grown in ancient Southern China and India around 2500 BC. Rice growing was brought to Japan possibly in the first century BC, and became popular during the second century and the third century. From India, rice spread to Southern Europe and Africa. Rice is a monocot; it is usually grown as an annual crop, although in tropical areas it can survive as perennial and can produce a ration crop for up to thirty years. Alluvial loamy and clayey soil is ideal for growing rice. The rice crop needs about 24^0C or above with minor variations during sowing, growing and harvesting seasons. It grows well in the areas where rainfall is above 100cm. Deltas, river valleys, coastal plains and terraced fields in mountainous regions are ideal for its cultivation. Rice contains a lot of carbohydrates. The leaves are long and flattened, and its panicle or inflorescence is made up of spikelets bearing flowers that produce the fruit or grain.

In 2016, the Food and Agricultural Organization rated Nigeria as the 18th largest producer of rice in the world with a production output of 2.7 million metric tonnes; having China as the first, producing 146.5 million metric tonnes, followed by India which produced 106.5 million metric tonnes (FAO, 2016). The President of the Rice Farmers Association of Nigeria, Aminu Goronyo stated in May 17th, 2017 that rice production in Nigeria has increased from 5.5 million tonnes in 2015 to 7.5 million tonnes in 2017; being one of the leading producers in the world and leading producer in the African continent. Ebonyi State produces more than 50 % of the total Nigerian output of rice. Through improved technology, rice production can be increased (Ekpe & Alimba, 2013). In Nigeria, it is estimated that the average man consumes approximately 24.8 kg of rice per year, which accounts for nine percent (9%) of their annual calorie intake or requirement. Rice consumption in developing countries of the world had been on the rise due to changes in demographic profile of the populace (Bamidele, Abayomi & Esther 2010) and the ease of its preparation (Ojogho & Erhabor, 2011).

Rice production is constrained by biotic and abiotic factors, especially among resource challenged farmers in Africa, where rainfall pattern was observed to be more erratic than before (Lafitte, Courtois & Arrandeau 2002), likely to be caused by changes in global climate. Today, rice is no longer a luxury food to millions of Nigerians, but has become the cereal that constitutes a major source of calories for the rural and urban poor with demand growing at annual rate of 5 %. Urbanization, changes in employment patterns, income levels and rapid population growth have significantly contributed to widening the gap between supply and demand for rice in Nigeria. Nigeria has the potential and suitable agro-ecologies (upland, rainfed, lowland, irrigated lowland, deep water and mangrove swamp to attain self-sufficiency in rice production. The potential land area for rice production in Nigeria is estimated at 4.6 to 4.9 million hectares, but only about 1.7million hectares of this land is presently being cropped to rice. The rain fed rice ecology represents 25 % of the 1.7million hectares.

The spent substrate from different mushrooms varies in its physical, chemical and biological properties and each one has its own specific utility. It has been found to be nutritionally rich with respect to its Nitrogen, Phosphorus and Potassium content and having high cation exchange capacity; it has the ability to replace farm yard manure for the purpose of raising cereal and horticultural crops (Ahlawat & Sagar, 2007). Spent mushroom substrate amendment on loamy soil produced significantly greater plant height, stem girth, number of leaves and total leaf area than compared to loamy soil without spent mushroom substrate (SMS) treatment in the growth of Cowpea and Tomato (Mustapha & Kadiri, 2010). Harris (1992) stated that application of SMS to a Potato crop soil improved the moisture holding capacity of the soil and this resulted to increased plant uptake of nutrients. Stewart *et al* (1997) reported that SMS application to the soil resulted to increased yield of potato. As a soil conditioner which has no economic value, SMS increases the yield of vegetables.

Application of SMS brought about significant increase on growth attributes and yield of maize (taller maize plants and better nutrient supply), leaf area index also increased with SMS amendment (Zhao, Reddy, Kakuri, Reddy & Carter 2003). Zhao *et al*., (2003) also stated that nutrients, especially nitrogen, increases leaf area index in maize plots treated with nitrogen source like SMS and decreased leaf area index of plants without application of nitrogen source as a result of nutrient deficiency; specifically nitrogen. Greater grain yield was observed when SMS was applied to the soil. Hussaini, Ado and Mani (2002) stated that lack of application of fertilizer in poor soils like ultisols resulted to zero yield of plants. Ogbodo *et al* (2009) reported that there was significant increase in plant height when organic amendment was added. Grain yield also increased significantly with increasing rate of organic amendment application. Such significant increases were attributed to improvement in soil physical properties when organic amendment was added. Recent findings showed that higher amount of salt in SMS negatively affected SMS treatments. This problem can be overcome by keeping the SMS outside for longer time. This however, could lead to loss of nutrient values of SMS. According to Maher (1991), keeping the SMC outside longer time led to 94 % potassium, 33 % phosphorus and 15 % nitrogen loss. Addition of SMS to the soil showed an increase in cucumber nitrogen content and total cucumber yield and quality; increasing with increase in rate of application (Polat, Uzun, Topcuoglu, Onal, Onus & Karaca 2009). Unal (2015) stated that application of SMS increased the seedling length of tomato and also growth and yield qualities.

Application of spent mushroom substrate enhanced grain yield of rice and tuber yield of potato in the field. Further, there was higher uptake of Calcium, Magnesium, and Iron by rice and potato tuber (Ranganathan & Selvaseelan, 1997). Liang and Siu-Wai (2007) reported that spent mushroom substrate not only served as the sole fertilizer to produce normal growth and grain yield of wheat and rice, but also improved the soil quality after harvest to increase the soil organic matter, maintain the soil alkalinity and increase field capacity unlike the synthetic amendment. Significant increase in the plant height of rice (taller plants) was observed when organic amendment was applied as a result of improved fertility; larger leaf index was also reported (Ogbodo *et al.*, 2009). There was also a significant increase in grain yield on addition of organic amendment; this increase could be in response to growth performance of the rice crop. Decrease in soil bulk density which led to an improvement in soil physical properties of the crop environment for improved aeration, root growth, improved soil porosity, e.t.c could have brought about increase in grain yield of rice with the application of organic amendment like spent mushroom substrate (SMS) (Ogbodo *et al.*,2009). Ogbodo *et al*, (2009) also stated that at rates 15 t/ha of SMS and above, low level of rice grain yield was observed. Higher grain yield was observed at 10 t/ha than at 15 t/ha; the low level of grain yield in plot treated with 15 t/ha of SMS compared with the high yield obtained in plots with 5 t/ha and 10 t/ha might be attributed to excess supply of nutrients (especially nitrogen) to the soil which favours more vegetative growth increase which was detrimental to grain yield. Agba *et al,* (2012) had similar finding in maize where there was a decrease in yield beyond optimum level of SMS of 20 t/ha. Alegre, Cassel and Maderman (1989) stated that there is a positive correlation between yield and porosity. Increase in soil moisture with the incorporation of organic materials could also contribute to improvements in grain yield as a result of improvement in the moisture economy of the soil (Bashir & Bubenzer, 2000). Due to the buffering capacity of organic amendments, increased soil cation exchange capacity, etc., there will be improvements in rice growth and grain yield.

2.6 Effect of Spent Mushroom Substrate (SMS) on some selected Heavy Metals

In the recent past, the management of hazardous materials like heavy metals has received a great deal of attention (Umrania, 2006). The presence of heavy metals in the soil brings serious environmental and agricultural pollution that threatens crop growth, human health and the ecosystem (Marina, Ana, Elisco & Fernando, 2019). Spent Mushroom Substrate has been found to reduce, even remove heavy metals present in the soil and in industrial waters (Marina *et al*., 2019). Hence, the use of SMS as a bioremediation agent is supported by its properties of a nearly neutral pH and notable content of organic carbon and calcium (Jordan, Mullen & Murphy, 2008). Since Spent Mushroom Substrate is a valuable source of organic matter and nutrients, it has potential uses in agriculture, horticulture, livestock feeding and bioremediation of various types of pollutants (Kwack, Song, Shinohara, Maruo & Chun, 2012). Xu, Chen, Huang, Liu and Yang (2012) stated that Spent Mushroom Substrate was used to reduce lead and cadmium from the soil and also remove them from aqueous solutions. Marina *et al*, (2017) reported that Spent Mushroom Substrate was used to drastically reduce copper and aluminum in the soil. They further stated that SMS was found to be useful as a low-cost bioremediation agent for the removal of different heavy metals from polluted soil and water.

CHAPTER THREE

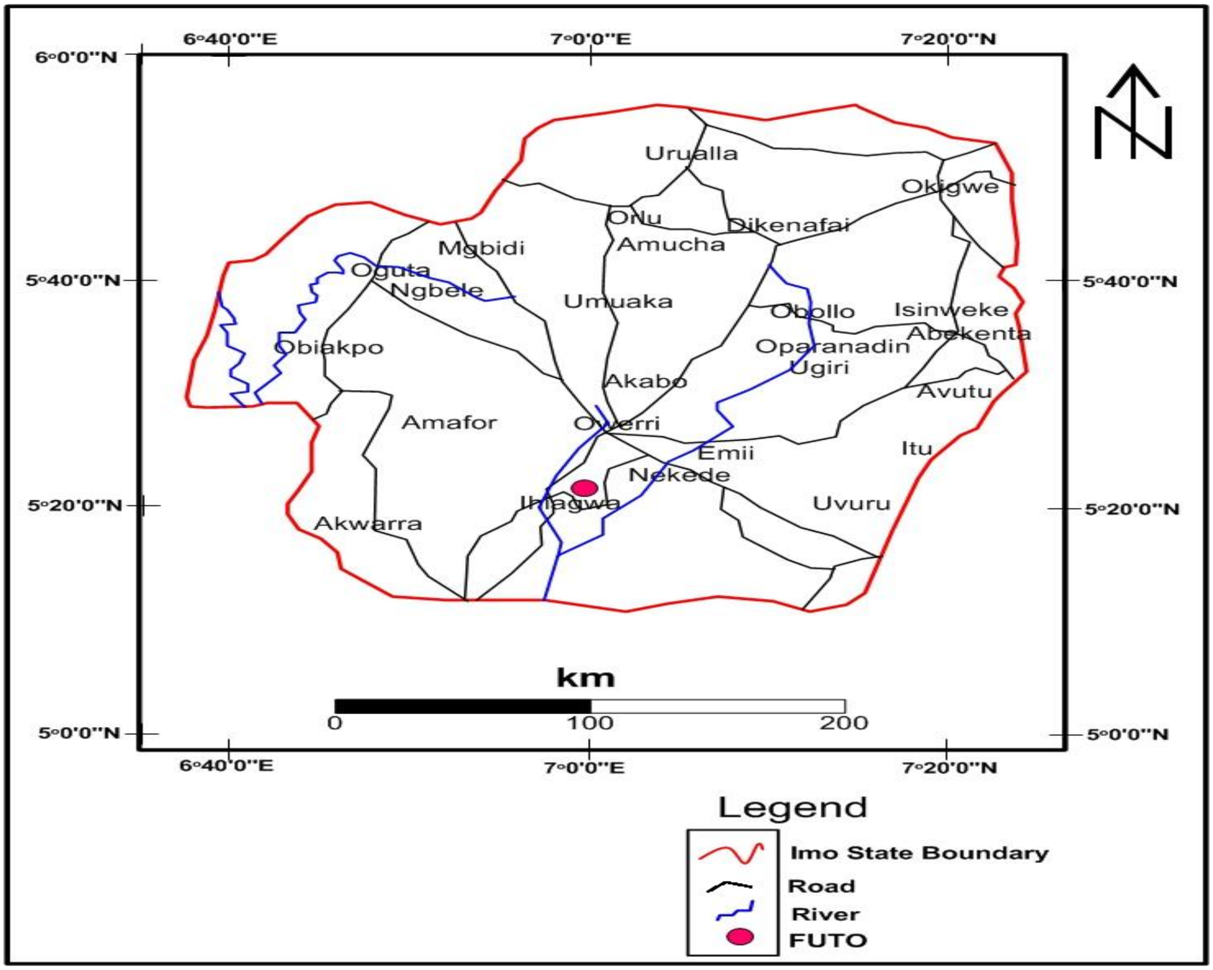
3.0 MATERIALS AND METHOD

3.1 Site Description

The study was carried out at the Centre for Agricultural Research and Extension field of the Federal University of Technology, Owerri, Imo State, Nigeria. The site was geo-referenced using hand held global positioning system with coordinates at latitude $5^{o}22^{l}52.75^{ll}$N and longitude $6^{o}59^{l}34.6488^{ll}$. Owerri is in the tropical rainforest zone of Southeast Nigeria. It is located between Latitude $05^{\circ}25^{1}$ and $05^{\circ}32^{1}$North and Longitude $06^{\circ}57^{1}$ and $07^{\circ}71^{1}$East.The climate of Owerri is typical of humid tropics with fairly even and uniform temperature throughout the two seasons (dry and raining) seasons each year. The raining season (March-October), is characterized by clouds, driven by light wind from the ocean, relatively constant temperature, frequent rains and high humidity from May to October. Rainfall peaks are in July and September; mean annual rainfall ranges between 2000-2500mm, high relative humidity of about 80 % and mean annual temperature of about 27 °C. Rainfall distribution is bimodal (March-July and Mid-August-October). Dry season sets in from November; the wind becomes dusty,"Hamathan" bringing in drier air from the Sahara Desert. It is notable with very little rainfall, hotter days, cooler nights and lower humidity ending in February. The area is characterized by a variety of vegetal forms, although there is presence of trees and shrubs with mostly grasses such as Guinea grass (*Panicum maximum*), Elephant grass (*Penisetum purpureum*), Siam weed (*Cromolina odorata*),Wire weed (Sidacuta), Star grass (*Cynodon nlemfuensis*), e.t.c. Its agroecology is the tropical rainforest.

3.2Soil Type/Land Use

Soil of the study area is an Ultisol and it is derived from coastal plain sand (Onweremadu, 2016). Soil of the study area is majorly used for arable production; crops grown include cassava, maize, vegetables like cucumber, telfera, yam, plantain and plantation crops like oil palm.



Map of Imo state showing study area (FUTO)

Source: Geology Department, FUTO.

Fig 3.1 Map of Imo State showing FUTO

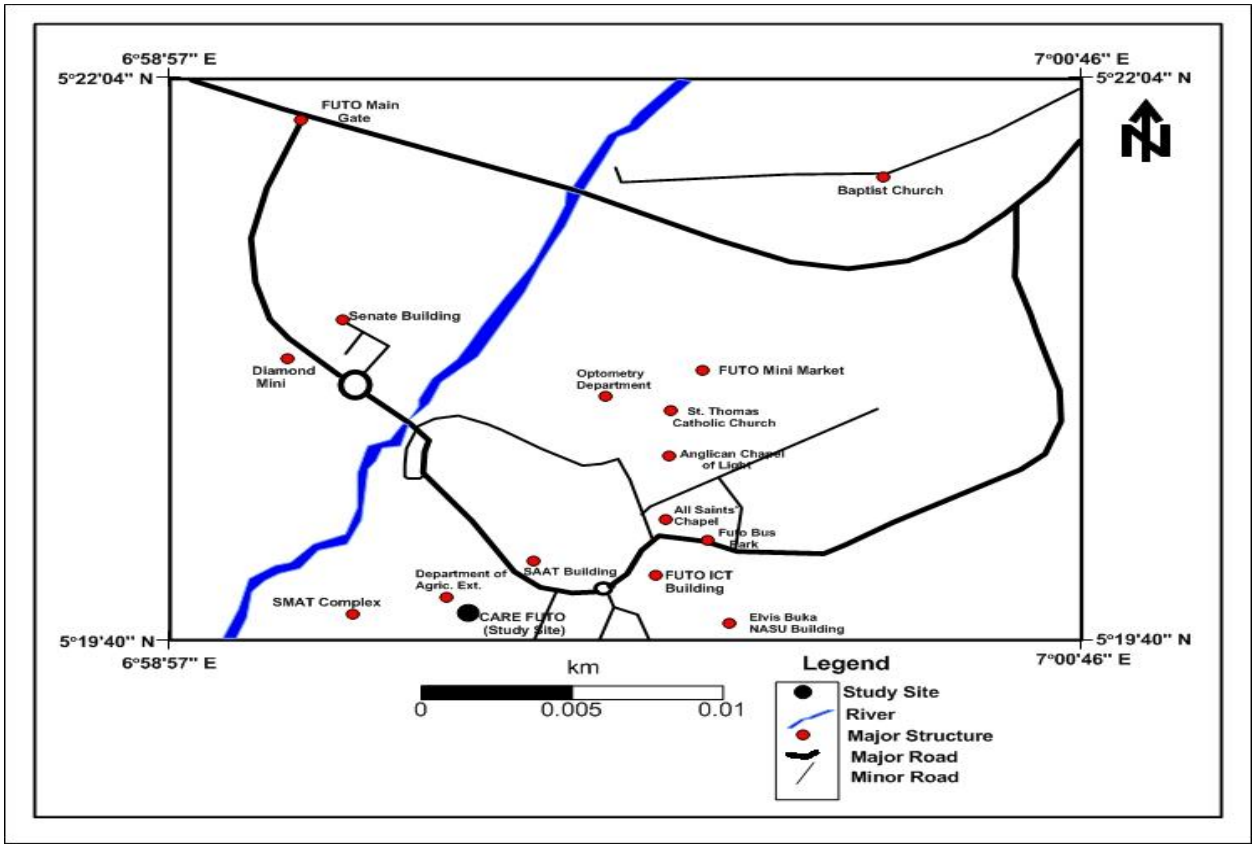


Fig 3.2: Map of the study area (FUTO), showing the study site Centre for Agricultural Research and Extension (CARE) Field.

Source: Geology Department, FUTO.

3.3 Human/Economic Activities

The study area is located in Ihiagwa town and bounded by Eziobodo and Obinze towns, all in Owerri West Local Government Area of Imo State. Natives of the study area are primarily farmers and traders. The presence of the institution of higher learning- Federal University of Technology, Owerri has led to development and migration of people to the area. This development and migration/settlement of people has led to creation of job opportunities (white collar jobs).

3.4 Land Preparation/Field Work

Field of the study area was mapped out using tape rule, ropes and pegs. The field was manually cleared with the use of cutlass and spades. The cleared field was mapped out into plots using tape, ropes and pegs and beds made, using spade. There were fifteen (15) plots; each plot measured 2m × 1.5m with a 0.5m alley between plots. The irrigation system was reinstalled and treatment incorporated into the soil.

3.5 Field Layout

The layout consisted of fifteen (15) plots, each measuring 2m × 1.5m with a 0.5m alley between blocks and plots. The total area of the field layout was 84.5m^2 (0.00845 hectare) as shown in figure 3.1.Treatments consisting of SMS 0t/ha, 5 t/ha, 10 t/ha, 15 t/ha and NPK 300 kg/ha were applied and properly incorporated into the soil. The plots were laid out in a randomized complete block design with five treatments replicated three times.

3.6 Soil Sampling

The pre-treatment and post-treatment application soil samples were collected from 0-20cm surface soil depth. Fifteen (15) samples were collected; one sample from each plot using soil auger attached with core samplers for bulk density, porosity and moisture content determination. Soil samples were collected randomly from several spots in a plot. These samples were air dried, sieved using a 2mm diameter mesh and fine earth particles labeled and stored, then transported to the laboratory for analysis.

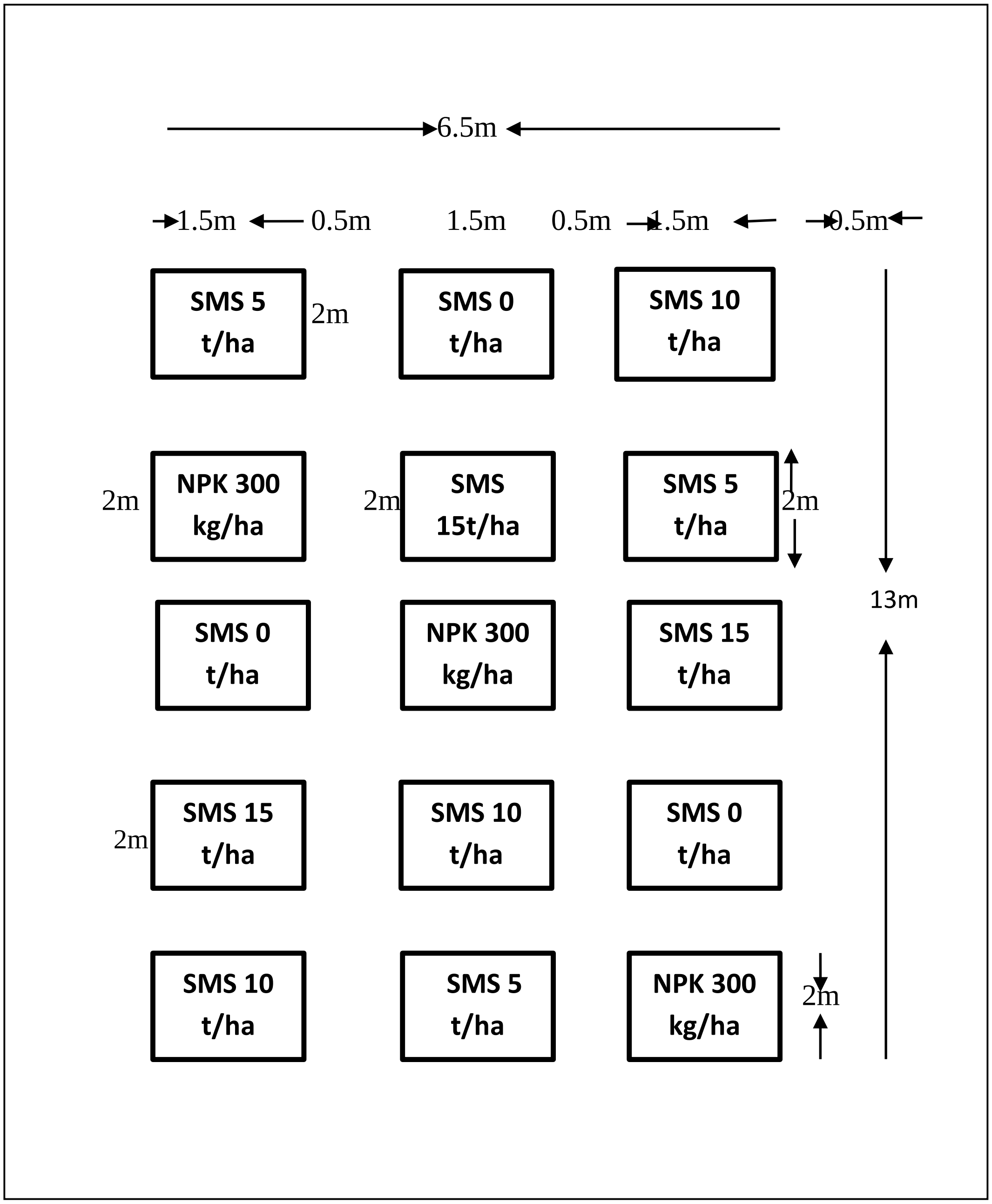


Fig 3.3: Field layout of the experimental site

3.7 Treatment

Spent Mushroom Substrate (SMS) was sourced from farms located at Irete, Owerri West Local Government Area of Imo State and Aba in Aba North Local Government Area of Abia State. The treatments consisted of the following:

SMS 0 t/ha - SMS 0 kg/plot

NPK 300 kg/ha - NPK 0.09 kg/plot

SMS 5 t/ha - SMS 1.5 kg/plot

SMS 10 t/ha - SMS 3.0 kg/plot

SMS 15 t/ha - SMS 4.5 kg/plot

Each plot measured $3m^2$. NPK and rice seeds were sourced from Imo Agricultural Development Programme (ADP), Owerri. Nitrogen Phosphorus and Potassium (NPK) fertilizer and SMS 0 t/ha (no treatment application) was used as the farmer's control. Spent mushroom substrate was treated by leaving it in the open under the sun for two weeks before incorporating it into the soil.

3.8 Handling of Treatment

Spent Mushroom Substrate was collected from the mushroom farms using shovel and bagged in jute/beans bags. They were transported home and left in the open (under the sun) for two weeks to be treated; being turned over within intervals. They were transported to the field after treatment and incorporated into the soil after weighing.

3.9Planting/sowing methods

Rice seeds were planted directly into the soil after four days of treatment application by dibbling. Dibbling is the opening up of a spot in the soil and sowing seeds; four to five seeds were sown at a depth of 2-3cm.

3.10 Spacing/plant population

Rice seeds were dibbled at 30 × 30 cm. Four to five seeds were planted per hole and at two weeks after planting, the seedlings were tined down to three seeds per hole to give a plant population of 333,333 seedlings per hectare.

3.11 Weed Control

This was done by rouging. Weeding was done regularly as the need arose.

3.12 Pest and Disease control

Scare crows were used on the farm to prevent birds. Insecticide (Termi Dust) was applied two times in an interval of two weeks.

3.13 Harvesting

The rice grains were harvested when the grains became hard and started turning yellow/brown at four months after planting; at maturity, 30-45 days after flowering.

3.14 Agronomic characteristics

Agronomic parameters determined were plant height, leaf area, root weight and tiller number. These were determined at the end of vegetative season (100 days after planting).

- **Plant height (cm):** this was obtained by measurement, using a tape. Plant height of the tallest leaf and the shortest leaf from a plant stand collected from the middle of each plot was taken; the mean plant height was then used.
- **Leaf Area (cm^2):** this was determined by taking a rice plant from the middle of the plot;

  Leaf Area = $L \times W \times 0.75 \times number\ of\ leaves$ equation 1

  Where L = Leaf Length and W = Leaf Width. As recommended by Gomez (1972).
- **Tiller numbers:** this was determined by counting the number of tillers from the plants on a hole from each plot and mean values computed.
- **Root weight:** root weight was determined by using a weighing balance.

3.15 Grain yield and yield components

Parameters determined were weight of filled grain, weight of unfilled grain, total grain yield, percentage unfilled grain and percentage filled grain. Weight of rice grains was measured using a weighing balance.

- **Weights of filled and unfilled grains:** Weights of filled and unfilled grains were determined by weighing them with a weighing balance and converted to tonne per hectare.

- **Total grain yield:** this was obtained by weighing the harvested rice grains. The paddy was adjusted to 12 % moisture content using the formula below,

Adjusted grain yield = $A \times W$ equation 2

Where A is the adjustment coefficient and W is the weight of the harvested grains. Adjustment Coefficient (A) = $\frac{100-M}{88}$ equation 3

The grain yield per hectare was adjusted to tonnes per hectare.

- Percent filled and unfilled grains were calculated thus:

% filled grains = $\frac{weight\ of\ filled\ grains}{total\ weight\ of\ grains} \times 100$ equation 4

% unfilled grains = $\frac{weight\ of\ unfilled\ grains}{total\ weight\ of\ grains} \times 100$ equation 5

3.16 Laboratory Analysis

This was carried out in the Soil Science laboratory of Federal University of Technology (FUTO), Owerri and in two phases: pre-planting and post-planting (after vegetative growth and at harvest) analysis. Pre-planting analysis will include determination of soil physico-chemical properties. Soil properties determined include: total porosity, bulk density, particle size distribution, soil texture, moisture content, total exchangeable bases-Na^+, Ca^{2+}, Mg^{2+}, $K^{+,}$ exchangeable acidity-Al^{3+}, H^+, pH, percentage carbon and organic matter, C/N ratio, effective cation exchange capacity (ECEC) and base saturation.

3.16.1 Particle size distribution

This was determined by the Hydrometer method according to the procedure of Gee and Or (2002).

3.16.2 Soil Texture

This was determined by reading the value of the particle size on the soil textural triangle according to Bouyoucos (1936).

3.16.3 Bulk Density

Bulk density was determined using core method (Grossmans & Reinsch, 2002).

$$\text{Bulk density} = \frac{\text{weight of wet soil} - \text{weight of dry soil (g)}}{\text{weight of wet soil (g)}} \times \frac{100}{1} \qquad \text{equation 6}$$

3.16.4 Total Porosity

This was calculated using results of bulk density and particle size distribution.

$$\text{Thus, Total Porosity} = 1 - \frac{B.D}{P.D} \times 100. \qquad \text{equation 7}$$

Where B.D is Bulk Density and P.D is Particle size distribution, where particle density (P.D)=2.65g/cm^3

3.16.5 Gravimetric Moisture Content

This was determined by the gravimetric method, calculated as follows:

$$\text{GMC} = \frac{W2 - W3}{W3 - W1} \times 100 \qquad \text{equation 8}$$

Where, W1= weight of the core, W2= weight of wet sample + core, W3= weight of oven-dried sample + core. W1 was determined by weighing the core in a weighing balance. W2 was determined by weighing the wet sample in the core in a weighing balance and W3 was determined by oven-drying the wet sample in the core and weighing the dried sample and core in a weighing balance.

3.16.6 Determination of soil pH

This was determined in water and in an electrolyte (KCl), using the pH meter at a ratio of 1:2.5 soil: water ratio according to Herdershot *et al*., (1993).

3.16.7 Determination of Soil Organic Carbon and Organic Matter

This was determined by the Walkley and Black (1934) wet-oxidation. Organic matter value will be calculated by multiplying the organic carbon values by 1.724 (Van Bermelen factor); soil organic carbon contains 58 % organic matter.

3.16.8Total Nitrogen

This was determined by Kjeldahl digestion method using concentrated H_2S0_4 and sodium copper sulphate catalyst mixture according to Bremner and Yeomans (1988).

3.16.9 C/N

This was determined by computation of organic carbon and total nitrogen values (Brady and Weil, 1999), as follows: $\frac{C}{N}$ equation 9

3.16.10 Ca/Mg

This was determined by computation of calcium and magnesium; dividing calcium values by magnesium values as follows: $\frac{Ca}{Mg}$ equation 10

3.16.11 Na/K

This was determined by computation of sodium and potassium; dividing sodium values by potassium values as follows: $\frac{Na}{K}$ equation 11

3.16.12 Exchangeable Acidity (H^+ and Al^{3+})

This was determined by the titrimetric method. Brady and Weil (2004).

3.16.13Exchangeable Bases (Ca^{2+}, Mg^{2+}, Na^+ and K^+)

Calcium and Magnesium were determined by the complex metric titration method; sodium and potassium were determined by the flame-photometric method (Thomas, 1982). The soil samples were leached with ammonium chloride and ammonium hydroxide buffer 10 solutions.

3.16.14 Effective Cation Exchange Capacity (ECEC).

This was calculated by summing up the values of the exchangeable bases and the exchangeable acidity: calcium, magnesium, sodium, potassium, hydrogen and aluminum.

ECEC = $TEB + TEA$ equation 12

3.16.15 Percentage Base saturation (% BS)

This was calculated by the summation of the total exchangeable bases and divided by effective cation exchange capacity, and multiplied by 100.

$$\mathrm{BS} = \frac{\mathrm{EB}}{\mathrm{ECEC}} \times 100. \qquad \text{equation 13}$$

3.16.16 Lead (mg/100 g).

This was determined by the Atomic Absorption Spectrophotometric method according to Balraadjsing (1974). In SMS sample, total lead content was determined while in the soil sample, available lead content was determined.

3.16.17 Cadmium (mg/100 g).

This was determined by the Atomic Absorption Spectroscopic method according to Williams, David & Lismaam (1972). Total cadmium content was determined in the SMS sample while available cadmium content was determined in the soil sample.

3.16.18 Chromium (mg/100 g)

This was determined by the Spectrophotometric method according to Ptaszynski and Jankiewicz (2005). Total chromium content was determined in the SMS sample while available chromium content was determined in the soil sample.

3.16.19 Mercury (mg/100 g)

Mercury was determined by the digestion and distillation method according to Picknard and Martin (1963). Total mercury content was determined in the SMS sample, while available mercury content was determined in the soil sample.

3.17 Experimental Design and Statistical Analysis

The experiment comprised five (5) treatments replicated three (3) times. The whole experiment was laid out in a Randomized Complete Block Design. Raw data generated from the research was subjected to Analysis of Variance. Treatment means were separated using Fishers-Least Significant Difference (F-LSD) at 5% probability level according to Gomez and Gomez (1984). All statistical analyses were conducted using the Statistical Package for Social Sciences (SPSS).

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

4.1 Soil characteristics before Application of Spent Mushroom Substrate.

Some soil physical and chemical properties before application of the treatment are presented in Table 4.1.

4.1.1 Physical Properties

Particle size analysis of the study site gave 922.8 g/kg sand, 36.2 g/kg clay and 41.0 g/kg silt content; having the soil of the study site under the textural class of Sandy soil, according to the United States Department of Agriculture (USDA) textural triangle. The result shows that soil of the study site is predominantly sandy; permitting ease in the downward movement of water in the soil; this is of benefit to shallow-rooted crops like upland rice. Lafitte, Yongsheng, Yan and Li (2007), stated that soils with good aeration favour crop growth under sprinkler irrigation system; hence, good for the cultivation of upland rice. Bulk Density of 1.25 g/cm^3 was recorded on the study site; this could be attributed to soil compaction due to consistent cultivation, particle size of 2.65 g/cm^{3}was also recorded. Hunt and Gikes (1992) and FAO (1996), postulated that it is desirable to have low bulk density (< 1.5 g/cm^3) for optimum aeration in the soil; the result shows that soil of the study site has the potency to support rice production. The study site recorded a Total Porosity of 52.80 %; this could be attributed to the low bulk density of the soil. Bulk density indicates soil quality and is inversely related to other soil properties, including total porosity (Wei, Teng-Fei, Yong, Anthony & Wan-Jun, 2014). High bulk density indicates low soil porosity and soil compaction while low bulk density indicates high soil porosity and soil compaction. Long term cultivation lowers porosity because of reduction in soil organic matter and peds (Brady & Weil, 2002).

Table 4.1: Pre-treatment Application Soil and Spent Mushroom Substrate (SMS) Properties.

Soil Properties	**Value**	**SMS Properties**	**Value**
Physical Properties			
Sand	922.8 g/kg		
Silt	41.0 g/kg		
Clay	36.2 g/kg		
Textural Class	sandy		
Moisture Content	18.32%		
Bulk Density	1.25 g/cm^3		
Particle Density	2.65 g/cm^3		
Total Porosity	52.80 %		
Chemical Properties			
pHw(1:2.5)	5.86	pHw(1:10)	7.28
pH KCl	4.92		
Organic Carbon	12.2 mg/100g		460.40 mg/100g
Organic Matter	21.0 mg/100g		793.70 mg/100g
Total Nitrogen	0.13%		1.61 %
Available Phosphorus	1.092 mg/100g		380.00 mg/100g
Aluminum	0.85 cmol/kg		
Hydrogen	0.50 cmol/kg		
Calcium	3.76”		400.00 mg/100g
Magnesium	1.81”		12.00 mg/100g
Sodium	0.05”		51.53 mg/100g
Potassium	0.03”		24.30 mg/100g
Total Exchangeable Bases	5.65”		
Total Exchangeable Acidity	1.35”		
Effective Cation Exchange Capacity	7.00”		
Percentage Base	80.72 %		

Source: Field Data- October, 2019.

Table 4.2: Heavy Metals Permissible Limits in the Soil

Heavy Metal	Soil Mg/Kg	FEPA Mg/Kg	EU Mg/Kg	FAO Mg/Kg
Cadmium	5.80	100.0	3.00	2.00
Lead	24.50	50.0	300.00	3.00
Mercury	0.90	-	0.50	2.00
Chromium	6.50	70.0	150.00	2.30

SOURCE: FEPA standard: Vern and Don (2011); EU standard: (Mohammed & Folorunsho, 2015; Mnistry of Environment [MoE], 2007); FAO standard: Shittu *et al*., (2008).

4.1.2 Chemical Properties

Results showed that soil pH in water was 5.86 while in potassium chloride (KCl) was 4.92; this shows moderate acidity and good for rice cultivation in dry conditions (Howeler, 2002). Organic carbon of 12.2 mg/100g and Organic matter of 21.0 mg/100g were recorded. This shows a relatively poor organic carbon and matter contents of the soil due to consistent anthropogenic activities that disstable soil aggregates; hence, poor in maintaining a stable structure. (Patrick *et al.*, 2013) stated that the minimum value for maintaining stable structure in tropical soils is 20.0 mg/100g organic carbon and 34.0 mg/100g organic matter. Total Nitrogen of 0.13 % was low; this low nitrogen content in the soil could hinder good crop growth because nitrogen is an essential nutrient in crop growth, especially vegetatively (Ogbodo *et al*., 2009) available phosphorus of 1.092 mg/100 g was medium in content. Calcium 3.76 cmol/kg was medium, magnesium 1.81 cmol/kg was high, sodium 0.05 cmol/kg was low and potassium 0.03 cmol/kg was equally low. All basic cations, apart from magnesium were within tolerable toxic limits for crop growth according to the Soil Science Society of Nigeria Conference (1998). Total Exchangeable Bases recorded a value of 5.65 cmol/kg and Total Exchangeable Acidity 1.35 cmol/kg. Effective Cation Exchange Capacity had value of 7.00 cmol/kg. Percentage Base Saturation was high at 80.72 %. This suggests that base cations were present in the soil solution; displacing acidic cations at the exchange site; hence, will have high fertility status and support crop growth.

4.2 Properties of Spent Mushroom Substrate.

Result showed that pH of the treatment in water was 7.28 which is neutral and in line with studies carried out by and (Wuest & Fahy, 1991) and (Ilknur & Cevdet, 2017); who gave average records of fresh SMS to be 7.36 and 7.28 respectively; hence, being a neutral to slightly alkaline pH. This pH value will favour crop growth and production. Organic carbon and Organic matter contents were 460.4 mg/100g and 793.7 mg/100g respectively. This suggests high organic carbon and matter contents which will bind soil particles together and retain soil moisture content; favouring crop productivity. (Ilknur & Cevdet, 2017) recorded organic carbon content of 388.0 mg/100g and organic matter content of 668.9 mg/100g in their study. Total Nitrogen of 1.61 % was low; this value may hamper crop growth, especially if the soil is also lacking in nitrogen. In their studies, Wuest & Fahy (1991) and Ilknur & Cevdet (2017), recorded values of 2.61 % and 1.93 % respectively. Calcium (400 mg/100g), Sodium (51.53 mg/100g), Magnesium (12 mg/100g), Potassium (24.30 mg/100g) and Phosphorus (380 mg/100g) were recorded. According to Wuest and Fahy (1991), values of calcium, sodium, potassium and phosphorus were high; higher content of basic cations makes it possible for microorganisms to thrive in the soil solution; they help in the decomposition of organic matter which binds soil particles together though magnesium recorded a low value of 12 mg/100g compared with the findings of Wuest and Fahy (1991) who recorded a value of 36 mg/100g. Heavy metals of Lead, Chromium, Mercury and Cadmium had values of 24.50 mg/kg, 6.50 mg/kg, 0.90 mg/kg and 5.80 mg/kg respectively. These values according to Zhang & Sun (2014) are low and not detrimental to crop growth.

4.3 Effect of Spent Mushroom Substrate (SMS) on selected Soil Physico-chemical Properties at the end of Vegetative Growth.

4.3.1 Soil Physical Properties

The effect of spent mushroom substrate on selected soil physical properties at 100 days after planting is presented in Table 4.3.

Table 4.3: Effect of Spent Mushroom Substrate Treatment on Selected Soil Physical Properties at the end of Vegetative Growth (100 Days After Planting).

Treatment	% Moisture content	Bulk Density (gcm^{-3})	Total porosity	Sand gkg^{-1}	Silt gkg^{-1}	Clay gkg^{-1}	Textural class
T1	7.40^{e}	1.48^{a}	44.15^{c}	919.10^{a}	40.00^{b}	40.90^{b}	Sandy soil
T2	7.49^{d}	1.40^{d}	44.53^{c}	912.40^{a}	33.30^{c}	54.30^{a}	Sandy soil
T3	7.98^{c}	1.47^{a}	47.17^{a}	912.40^{a}	46.70^{a}	40.90^{b}	Sandy soil
T4	8.33^{b}	1.43^{b}	46.19^{b}	905.70^{a}	43.30^{b}	50.90^{a}	Sandy soil
T5	9.33^{a}	1.41^{c}	46.83^{b}	902.40^{a}	53.30^{a}	44.30^{b}	Sandy soil
FLSD (p=0.05)	0.06	0.01	0.71	7.80	4.20	4.20	

Source: Field Data- January, 2020.

NOTE: NS= Not significant.

KEY: T1 = SMS 0 t/ha, T2 = NPK 300 kg/ha, T3 = SMS 5 t/ha, T4 = SMS 10 t/ha and T5 = SMS 15 t/ha.

Means with the same superscript are not statistically significant.

4.3.1.1 Moisture Content (%)

There were significant differences when the percentage moisture content of the control plots was compared with other treatments and when the NPK treatment was compared with the SMS treatment plots. Significant differences were also recorded when the percentage moisture content of the plots treated with SMS were compared with one another. There were 0.09, 0.58, 0.93 and 1.93 % higher moisture content in the plots treated with T2, T3, T4 and T5 when compared with the control. The highest mean difference of 1.93% moisture content was recorded when T5 was compared with T1. Comparison of the NPK with the SMS revealed that T3, T4 and T5 outperformed the NPK treatment by producing 0.49, 0.84 and 1.84 % higher moisture content when compared with NPK treatment. However, the comparison of the different rates of SMS showed that T3 had 0.35 and 1.35 % less moisture content than T4 and T5 treatment plots respectively. The highest moisture content was recorded from plots treated with 15 t/ha SMS. This value was 1.0 % higher than those recorded from the 10 t/ha SMS treated plots. The trend of the improvement of soil moisture content showed that T5 > T4 > T3 > T2 > T1. This showed that increasing rate of application of SMS resulted in increase in the soils ability to hold moisture. Organic material in the form of SMS performs the function of binding soil particles together. The bond soils will prevent loss through evaporation. This may explain why the highest rate (15 t/ha SMS) proved to be superior to the rest of the treatments. It could be attributed to favourable soil-water relationship which improved with the addition of SMS as stated by (Reed, 2007; Brady & Weil, 2008; Ogbodo *et al*., 2009). Organic materials in form of SMS perform the function of binding soil particles together. The bond soils will prevent ease of moisture loss through evaporation. This may explain why the highest rate (SMS 15 t/ha) proved to be superior to the rest of the treatment.

4.3.1.2Bulk Density (gcm^{-3})

There were significant differences when the bulk density of the control plots was compared with other treatments and when NPK treatment was compared with the SMS treated plots. Significant differences also existed when the bulk density of the plots treated with SMS were compared with one another. The bulk density reduced by 0.08, 0.01, 0.05 and 0.07 gcm^{-3} in the plots treated with T2, T3, T4 and T5 respectively when compared with the control. The highest mean difference was recorded when T2 was compared with T1. Again, NPK treated plots recorded 0.07, 0.03 and 0.01 gcm^{-3} less bulk density when compared with SMS 5 t/ha, 10 t/ha and 15 t/ha respectively. However, comparison of the different rates of SMS treated plots showed that T3 had 0.04 and 0.06 gcm^{-3} higher bulk density than T4 and T5 respectively. The highest bulk density was recorded in the control plots. This value was 0.01 gcm^{-3} higher than those recorded from SMS 5 t/ha; it showed that T1> T3 > T4 > T5 > T2. The result showed that increasing rate of application of SMS resulted in decrease in the bulk density of the soil. The lower values of bulk density (< 1.5) observed is desirable for optimum movement of air and water through the soil as postulated by Hunt and Gikes (1992). The reduced bulk density values in SMS applied plots compared with higher value of the control plot is one of the functions of SMS (an organic amendment) which decreases soil bulk density; enhancing soil structure (Mbagwu, 1992; Curtin & Mullen, 2007 and Ogbodo *et al*., 2009). This reduction in bulk density could be due to the binding effects of SMS on soil particles into aggregates as a result of increase in microbial population which enabled the formation of soil aggregates.

4.3.1.3 Total Porosity (%).

There were significant differences when the % total porosity of the control plots were compared with other treatments and when NPK treatment was compared with the SMS treated plots. More so, significant differences were recorded when the SMS treated plots were compared with one another. Control plots recorded 0.38 %, 3.02 %, 2.04 % and 2.68 % less % total porosity when compared with T2, T3, T4 and T5 plots respectively. Comparison of the NPK treated plots with the SMS treated plots revealed 2.64 %, 1.66 % and 2.30 % higher % total porosity contents in SMS 5 t/ha, SMS 10 t/ha and SMS 15 t/ha respectively. Furthermore, SMS 5 t/ha recorded higher % total porosity of 0.98 and 0.34 in SMS 10 t/ha and SMS 15 t/ha respectively. The highest % total porosity was recorded from SMS 5 t/ha; this value was 0.34 % higher than those recorded from the SMS 15 t/ha treated plots. The result showed that T3 > T5 > T4 > T2 > T1. The result showed an irregular flow in the plots treated with SMS in increasing rate of application; this could be attributed to nutrient migration. The improvement in total porosity in the plots treated with SMS when compared with control plots could be attributed to reduced bulk density. Mbagwu (1992) and Ogbodo *et al* (2009) stated that organic amendments reduced soil bulk density and increased total porosity; the lower the soil bulk density, the higher the total porosity; the lower the compaction as a result of promotion of aggregation of soil properties on application of organic amendments which has binding effect on soil properties in aggregates (Brady & Weil, 2017).

4.3.1.4 Particle Size Distribution (gkg^{-1})

Particle size result showed that the soils were predominantly sandy. The result showed that there were no statistically significant differences in the sand content when the treatments were compared with the control and when the SMS treatments were compared with NPK treated plots, though there were variations in values. Control plots recorded 6.70, 6.70, 13.30 and 16.70 gkg^{-1} higher sand contents when compared with T2, T3, T4 and T5 plots respectively. NPK treated plots recorded the same sand content when compared with SMS 5 t/ha treated plots, but 6.7 and 10.00 gkg^{-1} more sand content when compared with SMS 10 t/ha and SMS 15 t/ha respectively. SMS 5 t/ha recorded higher sand content when compared with SMS 10 t/ha and 15 t/ha with higher values of 6.70 and 10.00 gkg^{-1} respectively. Control plots recorded 6.70 gkg^{-1} higher silt content when compared with NPK treated plots, but 6.70%, 3.30 gkg^{-1} and 13.30 gkg^{-1} less silt content when compared with SMS 5 t/ha, SMS 10 t/ha and SMS 15 t/ha respectively. NPK treated plots recorded less silt content when compared with SMS 5 t/ha, SMS 10 t/ha and SMS 15 t/ha treated plots with values of 13.30, 10.00 and 20.00 gkg^{-1} respectively. When compared with one another, SMS treated plots recorded more silt content value of 3.30 gkg^{-1} and less silt content value of 6.70 gkg^{-1} in SMS 10 t/ha and 15 t/ha respectively when compared with SMS 5 t/ha. Control treated plots recorded less clay content values of 6.70, 10.00 and 3.30 gkg^{-1}, but the same value when compared with NPK, SMS 10 t/ha, 15 t/ha and 5 t/ha respectively. NPK treated plots recorded higher clay content values of 6.70 and 3.30 gkg^{-1}, but less clay content value of 3.30 gkg^{-1} when compared with SMS 5 t/ha, 15 t/ha and 10 t/ha respectively. When the SMS treated plots were compared with each other, SMS 5 t/ha recorded less clay content of 10.00 and 3.30 gkg^{-1} in 10 t/ha and 15 t/ha respectively. The significant differences in the silt and clay contents could be attributed to the addition of amendments which did not change the predominant sandy nature of the soils of the area because they originated from the same parent material.

4.3.2 Chemical Properties at the end of Vegetative Growth.

The effect of spent mushroom substrate (SMS) on soil chemical properties at 100 days after planting is presented in Table 4.4.

4.3.2.1 pH in water (pHw) and pH in Potassium Chloride(pKCl)

The result showed that there were significant differences when control plots were compared with other treatments and also when NPK treated plots were compared with SMS treated plots. Significant differences were also recorded when SMS treated plots were compared with each other. Control plots recorded the same value when compared with NPK treated plots, but recorded lesser values of 0.51, 0.60 and 0.72 when compared with SMS 5 t/ha, 10 t/ha and 15 t/ha respectively. NPK treated plots also recorded lesser pH values of 0.51. 0.61 and 0.72 when compared with SMS 5 t/ha, 10 t/ha and 15 t/ha respectively.SMS 5 t/ha recorded less values of 0.09 and 0.21 when compared with SMS 10 t/ha and 15 t/ha respectively. The highest pH value was recorded from plots treated with SMS 15 t/ha with value of 0.12 higher than 10 t/ha SMS treated plots. The trend of the improvement of soil pH value showed that T5 > T4 > T3 > T2 = T1.This showed an increase in pH value with increase in the application rate of SMS. The lower pHw value recorded in NPK fertilizer explains it's acidifying effect while the higher values in SMS treated plots shows it's buffering capacity on the soil which is in line with the findings of Ogbodo *et al.*, (2009) and Medina *et al.*, (2009). Gunes et al., (2004) stated that high pH values from 6.0 affects root development which encourages suitable growth for growing seedlings and also for the availability of various macro and micro nutrients. Significant differences were also observed when control plots were compared with other treatment plots. NPK treated plots also recorded significant differences when compared with SMS treated plots. When SMS treated plots were compared among each other, significant differences were also recorded. The result showed that control plots had less values of 0.01, 0.61, 0.77 and 0.90 pHKCl when compared with NPK, SMS 5 t/ha, 10 t/ha and 15 t/ha plots respectively. NPK treated plots also recorded lesser values of 0.60, 0.76 and 0.89 pHKCl when compared with SMS 5 t/ha, 10 t/ha and 15 t/ha treated plots respectively. When the SMS treated plots were compared with one another, SMS 5 t/ha had lesser values of 0.16 and 0.29 when compared with 10 t/ha and 15 t/ha respectively. The highest pH value was recorded in SMS 15 t/ha treated plots; having 0.13 value more than SMS 10 t/ha treated plots. The trend of the improvement of soil pH in KCl showed that T5 > T4 > T3 > T2 = T1. The low value of control plots, which is strongly acidic, could be attributed to the acidic nature of the control plot which are leached of the basic cations due to heavy rainfall associated with the rainforest zone (Ojimgba & Mbagwu, 2007). According to the ratings of Babalola *et al.*, (1998), control plots and NPK 300 kg/ha plots were moderately acidic, SMS 5 t/ha and SMS 10 t/ha were slightly acidic while SMS 15 t/ha was neutral. This indicated good pHw conditions for rice cultivation (Howeler, 2002).

Table 4.4: Effect of Spent Mushroom Substrate Treatment on Soil Chemical Properties at the end of Vegetative Growth (100 Days after Planting).

Treatment	pH in water	pH in Kcl	OC mg/ 100g	OM mg/ 100g	% N	AP mg/100g	EAl^{3+} Cmol/kg	H^{+} Cmol/kg	Ca^{2+}	Mg^{2+}	K^{+}	Na^{+}	TEA Cmol/kg	TEB Mg/ 100g	ECEC	% BS	C/N	Ca/Mg	Na/K
									$\longrightarrow$ **Mg/100g** $\longleftarrow$										
T1	5.97^{d}	5.18^{d}	16.1^{d}	27.8^{d}	0.10^{d}	0.831^{e}	0.79^{c}	0.46^{a}	2.61^{d}	1.06^{e}	2.11^{e}	3.94^{d}	1.25^{b}	9.72^{e}	10.97^{e}	88.63^{e}	16.10^{b}	2.47^{a}	1.87^{a}
T2	5.96^{d}	5.20^{d}	16.0^{d}	27.7^{d}	0.16^{a}	1.841^{a}	0.88^{a}	0.40^{b}	2.52^{d}	1.12^{d}	5.78^{b}	3.96^{d}	1.28^{a}	13.38^{c}	14.66^{c}	91.23^{d}	10.00^{d}	2.25^{b}	0.69^{e}
T3	6.48^{c}	5.80^{c}	19.1^{c}	33.0^{c}	0.13^{c}	1.359^{d}	0.82^{b}	0.30^{d}	3.60^{c}	1.45^{c}	3.55^{d}	4.32^{c}	1.12^{c}	12.92^{d}	14.04^{d}	92.03^{c}	14.69^{c}	2.48^{a}	1.22^{b}
T4	6.57^{b}	5.96^{b}	23.6^{b}	40.6^{b}	0.15^{b}	1.496^{c}	0.77^{c}	0.27^{e}	4.12^{b}	1.74^{b}	4.73^{c}	5.14^{b}	1.04^{d}	15.74^{b}	16.78^{b}	93.79^{b}	15.73^{b}	2.37^{a}	1.09^{c}
T5	6.69^{a}	6.09^{a}	27.8^{a}	47.9^{a}	0.16^{a}	1.577^{b}	0.66^{d}	0.34^{c}	4.28^{a}	2.00^{a}	6.18^{a}	6.28^{a}	1.00^{e}	18.74^{a}	19.74^{a}	94.94^{a}	17.38^{a}	2.14^{b}	1.01^{d}
FLSD (p=0.05)	0.03	0.03	0.02	0.03	0.00	0.031	0.02	0.02	0.22	0.05	0.16	0.16	0.00	0.28	0.28	0.15	0.37	0.11	0.04

Source: Field Data- January, 2020.

Legend: OC = Organic Carbon, OM = Organic Matter, N = Nitrogen, AP = Available Phosphorus, EA = Exchangeable Acidity, H= Hydrogen, Ca = Calcium, K = Potassium, Na = Sodium, Mg = Magnesium, TEA = Total Exchangeable Acidity, TEB = Total Exchangeable Bases, ECEC = Effective Cation Exchange Capacity, BS = Base Saturation, C/N = Carbon-Nitrogen ratio, Ca/Mg = Calcium-Magnesium ratio, Na/K = Sodium-Potassium ratio.

NOTE: Means with the same superscript indicate not significant.

4.3.2.2 Organic Carbon (mg/100 g)

There were significant differences when the control treated plots were compared with other treatment plots. Significant differences were also recorded when NPK treated plots were compared with SMS treated plots; among SMS treated plots, significant differences were also recorded. Control treated plots recorded the same value with NPK treated plots, but recorded lesser organic carbon contents of 3.00, 7.50 and 11.70mg/100g when compared with SMS 5 t/ha, 10 t/ha and 15 t/ha treated plots respectively. NPK treated plots also recorded lesser organic carbon contents of 3.10, 07.60 and 11.80mg/100g when compared with SMS 5 t/ha, 10 t/ha and 15 t/ha respectively. When the SMS treated plots were compared among each other, SMS 5 t/ha recorded lesser contents of 4.50, and 8.70 when compared with 10 t/ha and 15 t/ha respectively. The highest organic carbon content was recorded in SMS 15 t/ha with 4.20value higher than 10 t/ha. The trend of the improvement of soil organic carbon content showed that T5 > T4 > T3 > T2 = T1. Increased rate of application of SMS resulted to increased soil organic carbon in the soil. The increased values of organic carbon in plots treated with SMS is in line with the findings of Adeli *et al*., (2009); Ogbodo *et al*.,(2009) and Hairu *et al*., (2016); as an organic amendment, SMS increases soil organic carbon; hence, enhancing soil productivity.

4.3.2.3 Total Nitrogen (%)

Higher rates of SMS treated plots recorded higher Nitrogen values than control plots, but less than NPK treated plots. There were significant differences when control plots were compared with other treatment plots. Significant differences were also observed when NPK treated plots were compared with SMS treated plots; when SMS treated plots were compared with one another, significant differences were also observed. Control treated plots recorded lesser nitrogen values of 0.06, 0.03, 0.05 and 0.06 % when compared with NPK, SMS 5 t/ha, 10 t/ha and 15 t/ha respectively. NPK treated plots recorded higher nitrogen values of 0.03 and 0.01when compared with SMS 5 t/ha and 10 t/ha, but was the same value with SMS 15 t/ha. When the SMS treated plots were compared with each other, SMS 15 t/ha recorded higher nitrogen values of 0.01 and 0.03 when compared with 10 t/ha and 5 t/ha respectively. The highest nitrogen was recorded in SMS 15 t/ha and NPK treated plots. This value was

0.01 higher than SMS 10 t/ha treated plots. The trend of the improvement of soil total nitrogen content showed that T5 = T2 > T4 > T3 > T1. Total nitrogen increased with increased rate of application of SMS; this is in line with the findings of Medina *et al*., (2009) and Unal (2015) who stated that SMS was found to be nutritionally rich in nitrogen and has a considerable agronomic value when used as soil improver. Ekpe *et al*., (2017) also noted that mineralization of organic wastes resulted in the release of organic bound nutrients in the soil; significantly nitrogen, phosphorus, potassium and organic matter.

4.3.2.4 Available Phosphorus (mg/100 g)

The result showed that NPK treated plots released more phosphorus into the soil than the SMS treated plots, while the control treated plot recorded the lowest value. There were significant differences in available phosphorus content when the control treated plots were compared with other treatment plots. Significant differences also existed when NPK treated plots were compared with the SMS treated plots. There were also significant differences when a comparison was made among the SMS treated plots. Control treated plots recorded 1.011, 0.528, 0.666 and 0.746 mg/100g less available phosphorus when compared with NPK, SMS 5 t/ha, 10 t/ha and 15 t/ha treated plots respectively. NPK treated plots had higher available phosphorus values of 0.483, 0.345 and 0.264 mg/100g when compared with SMS 5 t/ha, 10 t/ha and 15 t/ha treated plots respectively. When the SMS treated plots were compared among each other, 15 t/ha recorded higher values of 0.218 and 0.080 mg/100g when compared with 5 t/ha and 10 t/ha respectively. The trend in improvement of soil available phosphorus content showed that T2 > T5 > T4 > T3 > T1. There was increase in phosphorus values as the rate of application of SMS increased; this is in line with the findings of Unal (2015); Hairu *et al*., (2016) and Ekpe *et al*., (2017). Lower values recorded in SMS 5 t/ha and SMS 10 t/ha could be attributed to the fact that the presence of some nutrients in high quantity can limit the availability of others.

4.3.2.5 Exchangeable Aluminum- Al^{3+}(Cmol/kg)

There were significant differences in exchangeable aluminum content when the control treated plots were compared with other treatment plots. Significant differences were also recorded when NPK treated plots were compared with SMS treated plots. When the SMS treated plots were compared with one another, significant differences were also recorded. Control treated plots had lesser exchangeable aluminum values of 0.09 and 0.03 Cmol/kg when compared with NPK and SMS 5 t/ha treated plots respectively, but higher values of 0.02 and 0.13 when compared with SMS 10 t/ha and 15 t/ha respectively. NPK treated plots had higher contents of 0.06, 0.22 and 0.23 Cmol/kg when compared with SMS 5 t/ha, 10 t/ha and 15 t/ha respectively. When the SMS treated plots were compared with each other, SMS 5 t/ha had higher values of 0.04 and 0.16 Cmol/kg exchangeable aluminum than 10 t/ha and 15 t/ha respectively. The highest value was recorded in NPK treated plots with 0.06 Cmol/kg higher content than SMS 5 t/ha. The trend in improvement of soil exchangeable aluminum showed that NPK > SMS 5 t/ha > SMS 0 t/ha > SMS 10 t/ha > SMS 15 t/ha. It was observed that aluminum values reduced in increasing order of application of SMS; this could be attributed to the increase in soil pH which buffered the soil solution; increase in organic matter content that helped in reducing acidity: aluminum and hydrogen being the acidic cations (Ojimgba & Mbagwu, 2007).

4.3.2.6 Hydrogen – H^+ (Cmol/kg)

There were significant differences in hydrogen ion content when the control treated plots were compared with other treatment plots. Significant differences also existed when NPK treated plots were compared with SMS treated plots. Even among the SMS treated plots, significant differences were recorded. Control treated plots recorded higher hydrogen values of 0.06, 0.16, 0.19 and 0.12 Cmol/kg when compared with NPK, SMS 5 t/ha, 10 t/ha and 15 t/ha treated plots respectively. NPK treated plots had higher hydrogen values of 0.10, 0.13 and 0.06 Cmol/kg when compared with SMS 5 t/ha, 10 t/ha and 15 t/ha respectively. Among the SMS treated plots, 15 t/ha had higher hydrogen values of 0.04 and 0.07 Cmol/kg when compared with SMS 5 t/ha and 10 t/ha treated plots respectively. Control treated plots recorded the highest hydrogen content with higher value of 0.06 when compared with NPK treated plots. The trend in the improvement of soil hydrogen showed that T1 > T2 > T5 > T3 T4. Hydrogen concentration values decreased with increased application rate of SMS, except in SMS 15 t/ha where it increased. The reduction in concentration could be attributed to the acidic nature of hydrogen as a result of increase in organic matter and soil pH. The increase in SMS 15 t/ha could be attributed to nutrient migration.

4.3.2.7 Calcium – Ca^{2+} (mg/100 g)

There were significant differences when control treated plots were compared with other treatment plots. Significant differences were also observed when NPK treated plots were compared with SMS treated plots. When SMS treated plots were compared wih one another, significant differences were also recorded. Control treated plots had higher calcium value of 0.09 mg/100g when compared with NPK treated plots, but lesser calcium values of 0.99, 1.51 and 1.67 mg/100g when compared with SMS 5 t/ha, 10 t/ha and 15 t/ha respectively. NPK treated plots recorded lesser calcium values of 1.08, 1.60 and 1.76 mg/100g when compared with SMS 5 t/ha, 10 t/ha and 15 t/ha respectively. SMS 15 t/ha recorded more calcium content values of 0.68 and 0.16 mg/100g when compared with 5 t/ha and 10 t/ha respectively. The highest calcium content value was recorded in SMS 15 t/ha; this value was 0.16 mg/100g higher than those of the 10 t/ha treated plots. The trend in the improvement of the soil calcium content showed that T5 > T4 > T3 > T1 > T2. Increased calcium content was observed with increased application rate of SMS; this is in line with the findings of Unal (2015).

4.3.2.8 Magnesium - Mg^{2+} (mg/100 g)

The result showed that SMS 15 t/ha released more magnesium content into the soil than other treatment plots. There were significant differences in magnesium content when control treated plots were compared with other treatment plots. Significant differences were also observed when NPK treated plots were compared with SMS treated plots. Among SMS treated plots, significant differences also existed. Control treated plots recorded lower magnesium values of 0.06, 0.39. 0.68 and 0.94 mg/100g when compared with NPK, SMS 5 t/ha, 10 t/ha and 15 t/ha treated plots respectively. NPK treated plots also had lower magnesium values of 0.33, 0.62 and 0.88 mg/100g when compared with SMS 5 t/ha, 10 t/ha and 15 t/ha treated plots respectively. Spent Mushroom Substrate 15 t/ha had higher magnesium values of 0.55 and 0.26 mg/100 g when compared with SM 5 t/ha and 10 t/ha treated plots respectively. The highest value was recorded in SMS 15 t/ha; this value was 0.26 mg/100g more than the value recorded from the plots treated with 10 t/ha SMS. The trend in the improvement of soil magnesium content showed that T5 > T4 > T3 > T2 > T1. Increased magnesium content was observed with increased application rate of SMS; this is in agreement with the findings of Wisniewska and Pankiewirz (1989); Unal (2015) and Ekpe *et al*. (2020).

4.3.2.9 Potassium- K^+ (mg/100 g)

There were significant differences in soil potassium content when the control treated plots were compared with other treatment plots. Significant differences were also observed when NPK treated plots were compared with SMS treated plots. When SMS treated plots were compared with one another, significant differences were also recorded. Control plots recorded less potassium values of 3.67, 1.44, 2.63 and 4.08 mg/100g when compared with NPK, SMS 5 t/ha, 10 t/ha and 15 t/ha treated plots respectively. NPK treated plots had less potassium value of 0.40 mg/100g when compared with SMS 15 t/ha but higher values of 2.23 and 1.05 mg/100g when compared with SMS 5 t/ha and 10 t/ha treated plots respectively. Spent Mushroom Substrate 15 t/ha recorded higher potassium values of 2.63 and 1.45 mg/100g when compared with SMS 5 t/ha and 10 t/ha treated plots respectively. The highest value of potassium content was recorded in SMS 15 t/ha; this value was 0.40 mg/100g higher than the NPK treated plots value. The trend in the improvement of soil potassium content showed that T5 > T2 > T4 > T3 > T1. Increase in potassium content was recorded with increase in the application rate of SMS; this is in line with the results of Unal (2015) and Ekpe *et al*., (2017) who reported that organic materials like SMS increased soil potassium content.

4.3.2.10 Sodium - Na^+ (mg/100 g).

There were significant differences in soil sodium content when the control treated plots were compared with other treatment plots. Significant differences were also recorded when NPK treated plots were compared with SMS treated plots; even among SMS treated plots, significant differences were also observed. The control treated plots had less sodium content of 0.02, 0.38, 1.20 and 2.34 mg/100g when compared with NPK, SMS 5 t/ha, 10 t/ha and 15 t/ha treated plots respectively. NPK treated plots also recorded less sodium content values of 0.03, 1.18 and 2.32 mg/100g when compared with SMS 5 t/ha, 10 t/ha and 15 t/ha treated plots respectively. The highest value of sodium was recorded in SMS 15 t/ha; this value was 1.14 mg/100g more than those of the 10 t/ha treated plots. The trend in the improvement of soil sodium content showed that T5 > T4 > T3 > T2 > T1.An increase in sodium content was recorded with increase in the application rate of SMS. This increase in sodium content could be toxic in the long-term usage because it could lead to soil salinization; this is in agreement with the findings of Moral *et al.*, (2008), who observed accumulation of sodium in the soil as a result of high sodium content in organic amendments.

4.3.2.11 Total Exchangeable Acidity (TEA- Al^{3+} and H^{+}) (Cmol/kg).

There were significant differences in Total Exchangeable Acidity (TEA) when the control plots were compared with other treatment plots. Significant differences also existed when NPK treated plots were compared with SMS treated plots. Among SMS treated plots, significant differences were also recorded. Control plots had less TEA value of 0.03 Cmol/kg when compared with NPK treated plots, but recorded higher TEA values of 0.13, 0.21 and 0.25 Cmol/kg when compared with SMS 5 t/ha, 10 t/ha and 15 t/ha treated plots respectively. NPK treated plots recorded higher TEA values of 0.17, 0.24 and 0.29 Cmol/kg than SMS 5 t/ha, 10 t/ha and 15 t/ha treated plots respectively. When the SMS treated plots were compared among each other, SMS 5 t/ha had higher TEA values of 0.07 and 0.12 Cmol/kg than 10 t/ha and 15 t/ha treated plots respectively. The highest TEA value was recorded in NPK treated plots; they had value of 0.03 Cmol/kg more than control treated plots. The trend in the improvement of soil TEA content showed that T2 > T1 > T3 > T4 > T5. Total Exchangeable Acidity values reduced with increase in application rate of SMS; this could be attributed to increase in soil pH on addition of SMS in increasing rate, which neutralized/ buffered the soil solution; reducing acidity. This is in line with the findings of Sanchez (1976), who stated that on sites that have a tendency to iron, aluminum or hydrogen toxicity, humifying organic matter works to combat toxic metal concentrations by forming complexes with a high molecular weight; where there is absence or little presence of organic matter, aluminum or hydrogen toxicity cannot be combated; this confirms the increase in aluminum and hydrogen saturation in the control plots than in those applied with SMS.

4.3.2.12Total Exchangeable Bases (TEB) (mg/100 g).

There were significant differences in TEB when the control treated plots were compared with other treatment plots. Significant differences also existed when NPK treated plots were compared with SMS treated plots. Among SMS treated plots, significant differences also existed. Control treated plots had TEB values of 3.66, 3.21, 6.02 and 9.03 mg/100g less than NPK, SMS 5 t/ha, 10 t/ha and 15 t/ha treated plots respectively. NPK treated plots recorded higher value of 0.45 mg/100g than SMS 5 t/ha, but recorded values of 2.36 and 5.37mg/100g less than 10 t/ha and 15 t/ha treated plots respectively. Spent Mushroom Substrate 15 t/ha recorded TEB values of 5.82 and 3.00 mg/100g more than 5 t/ha and 10 t/ha treated plots respectively. The highest TEB value of 18.74 mg/100g was recorded in the SMS 15 t/ha treated plots. This value was 3.00 mg/100g more than those of 10 t/ha treated plots. The trend in improvement of soil TEB showed that T5 > T4 > T2 > T3 > T1. Total Exchangeable Bases increased with increased application rate of SMS; this is attributed to the increase in soil pH and organic matter content which displaced acidic cations at the exchange site and increased basic cations. This result is in line with the findings of Unal (2015), Ekpe *et al*., (2017) and Ekpe *et al*., (2021) and who stated that SMS increased exchangeable bases with increased rate of application. Mbagwu (1992) also stated that increase in exchangeable bases was due to increase in application of organic residues.

4.3.2.13 Effective Cation Exchange Capacity (ECEC).

There were significant differences observed in ECEC when control treated plots were compared with other treatment plots. Significant differences were also observed in ECEC when NPK treated plots were compared with SMS treated plots. Among the SMS treated plots, significant differences also existed. Control plots recorded ECEC values of 3.99, 3.08, 5.82 and 8.79 less than NPK, SMS 5 t/ha, 10 t/ha and 15 t/ha treated plots respectively. NPK treated plots recorded ECEC value of 0.62 more than SMS 5 t/ha treated plots, but ECEC values of 2.12 and 5.09 less than SMS 10 t/ha and 15 t/ha treated plots respectively. Spent Mushroom Substrate 15 t/ha recorded ECEC values of 5.71 and 2.96 more than SMS 5 t/ha and 10 t/ha treated plots respectively. SMS 15 t/ha recorded the highest value of 19.74; this value was 2.96 more than SMS 10 t/ha treated plots. The trend in the improvement of soil ECEC showed that T5 > T4 > T2 > T3 > T1. ECEC increased with increase in application rate of SMS; this could be attributed to increase in organic matter content and agrees with the findings of Ogbodo *et al*. (2009) and Ekpe *et al*. (2020), who stated that organic amendments have buffering capacities; making soil more resistant to pH and improves soil ECEC.

4.3.2.14 Base Saturation- BS (%)

Base saturation values recorded significant differences when control treated plots were compared with other treatment plots. Significant differences were also observed when NPK treated plots were compared with SMS treated plots. When SMS treated plots were compared with one another, significant differences were also recorded. Control plots recorded % base saturation values of 2.60, 3.40, 5.16 and 6.31 % less than NPK, SMS 5 t/ha, 10 t/ha and 15 t/ha treated plots respectively. NPK treated plots had % base saturation values of 0.80, 2.54 and 3.71 % less than SMS 5 t/ha, 10 t/ha and 15 t/ha treated plots respectively. Spent Mushroom Substrate 15 t/ha recorded % base saturation values of 2.91 and 1.15 % more than SMS 5 t/ha and 10 t/ha treated plots respectively. The highest % base saturation value was recorded in SMS 15 t/ha treated plots; this value was 1.15 % more than those of SMS 10 t/ha treated plots. The trend in the improvement of % soil base saturation showed that T5 > T4 > T3 > T2 > T1. Increase in base saturation was observed with increase in the application rate of SMS; this could be attributed to increase in organic matter content and basic cations (Ca^{2+}, Mg^{2+}, Na^{2+} and K^{+}) in the soil and agrees with the findings of Unal (2015) and Ogbodo *et al*. (2009).

4.3.2.15 Carbon and Nitrogen ratio (C/N).

Carbon/Nitrogen value recorded significant differences when control plots were compared with other treatment plots. Significant differences were also recorded when NPK treated plots were compared with SMS treated plots. Among SMS treated plots, significant differences were observed when they were compared with one another. Control plots recorded C/N values of 6.10 and 1.41 % more than NPK and SMS 5 t/ha treated plots respectively, but the same value with SMS 10 t/ha and value of 1.28 % less than SMS 15 t/ha. NPK treated plots recorded C/N values of 4.49, 5.74 and 7.38 % less than SMS 5 t/ha, 10 t/ha and 15 t/ha treated plots respectively. When compared with each other, SMS 15 t/ha recorded C/N values of 2.69 and 1.65 % more than 5 t/ha and 10 t/ha treated plots respectively. The highest C/N value of 17.38 was recorded in SMS 15 t/ha. This value was 1.28 % more than those of control plots. The trend in the improvement of soil C/N showed that T5 > T1 > T4 > T3 > T2. C/N increased with increased rate of application of SMS. These values fall between the slow fractions C/ N of 10-25 as stated by Brady & Weil (2002). Deng *et al*., (2013) postulated that such range of values of 15-30 indicated a good energy supply to soil microbes which increases the decomposition rate of organic matter and release of nitrogen; Swangjang (2015) stated that ratio of less than 20 is said to be poor in nutrient due to fast release of nitrogen during the decomposition process.

4.3.2.16 Calcium and Magnesium ratio (Ca/Mg) (mg/100 g)

There were significant differences in Ca/Mg when control plots were compared with other treatment plots. Significant differences were also observed in Ca/Mg when NPK treated plots were compared with SMS treated plots. Significant differences were also recorded when SMS treated plots were compared with one another. Control plots recorded Ca/Mg values of 0.22, 0.10 and 0.33 more than NPK, SMS 10 t/ha and 15 t/ha treated plots, but recorded same values with SMS 5 t/ha treated plots. Nitrogen Phosphorus Potassium treated plots had Ca/Mg values of 0.23 and 0.12 mg/100g less than SMS 5 t/ha and 10 t/ha treated plots, but value of 0.11 mg/100g more than SMS 15 t/ha treated plots. When SMS treated plots were compared with each other, SMS 5 t/ha recorded Ca/Mg values of 0.11 and 0.24 mg/100g higher than SMS 10 t/ha and 15 t/ha treated plots respectively. The highest value of 2.48 was recorded in SMS 5 t/ha. This value was 0.11 mg/100g more than those of SMS 10 t/ha treated plots. The trend in the improvement of Ca/Mg showed that T3 = T1 > T4 > T2 > T1. A decrease in Ca/ Mg was recorded with increase in application rate of SMS. The values of Ca/ Mg recorded will enhance good plant growth as stated in the findings of Shulte and Kelling (1993).

4.3.2.17 Sodium and Potassium ratio (Na/K) (mg/100 g).

There were significant differences in Na/K content when control plots were compared with other treatment plots. Significant differences were also observed in Na/K when NPK treated plots were compared with SMS treated plots. When SMS treated plots were compared with one another, significant differences were also observed. Control plots had Na/K values of 1.18, 0.65, 0.78 and 0.86 mg/100g higher than NPK, SMS 5 t/ha, 10 t/ha and 15 t/ha treated plots respectively. NPK treated plots recorded Na/K values of 0.53, 0.40 and 0.32mg/100g less than SMS 5 t/ha, 10 t/ha and 15 t/ha treated plots respectively. When the SMS treated plots were compared with each other, SMS 5 t/ha recorded values of 0.13 and 0.21mg/100g higher than 10 t/ha and 15 t/ha treated plots respectively. The highest value of 1.87 mg/100g was recorded in control plots. This value was 0.65 higher than those of SMS 5 t/ha. The trend in the improvement of soil Na/K showed that T1 > T3 > T4 > T5 > T2. An increase in the application rate of SMS led to a decrease in Na/ K. Akintunde *et al*., (2000) stated that the medium fertility range of Na/ K is 1.3, the values recorded in Na/K is below it and said to be poor; hence, will bring about a poor fertility rate in the growth of crops.

4.3.2.18 Selected Heavy Metals (Cadmium-Cd, Lead-Pb, Chromium-Cr, Mercury-Hg) (mg/kg).

The effect of spent mushroom substrate (SMS) on some selected heavy metals at the end of vegetative growth (at 100 days after planting) is presented in Table 4.5.

4.3.2.18.1 Cadmium (Cd- mg/kg)

No significant difference was recorded in Cadmium content when control plots were compared with other treatment plots, except in SMS 15 t/ha treated plots which had 0.30 mg/kg higher value than control treated plots. Nitrogen Phosphorus Potassium (NPK) treated plots were also not significantly different, except in SMS 15 t/ha treated plots which had 0.30 mg/kg higher values than NPK treated plots. Spent Mushroom Substrate 15 t/ha treated plots recorded higher value of 0.20 than 5 t/ha and 10 t/ha treated plots. The highest value of 2.40 mg/kg was recorded in SMS 15 t/ha treated plots. According to the findings of the European Union standard (Mohammed & Folorunsho, 2015) and Xu *et al*., (2012), these values were found to be low as SMS reduced cadmium content in the soil; hence, will not hamper soil productivity.

4.3.2.18.2 Lead (Pb- mg/kg)

There were significant differences recorded in lead content when the control treated plots were compared with other treatments and when the NPK treated plots were compared with the SMS treated plots. Equally, significant differences existed when the SMS treated plots were compared with one another. Control plots recorded lead values of 0.30 and 0.60 mg/kg lower values than SMS. Spent Mushroom Substrate 10 t/ha and 15 t/ha treated plots respectively, but recorded no significant difference when compared with NPK and SMS 5 t/ha treated plots. NPK treated plots recorded no significant difference when compared with SMS 5 t/ha treated plots, but it recorded lead values of 0.40 and 0.70 mg/kg lower values of lead when compared with SMS 10 t/ha and 15 t/ha treated plots respectively. SMS 15 t/ha treated plots had 0.50 and 0.30 mg/kg higher lead contents when compared with 5 t/ha and 10 t/ha treated plots. The highest lead value of 3.60 mg/kg was recorded in SMS 15 t/ha. This value was 0.30 mg/kg higher than those of SMS 10 t/ha treated plots. The trend in lead content of the soil showed that T5 > T4 > T3 = T1 = T2. The value of lead increased with increased application rate of SMS. Spent Mushroom Substrate has low concentration of heavy metals; hence, the values recorded were low and will not reduce soil productivity or crop yield neither will it pose a threat to human health as reported in the findings of FEPA (Vern & Don, 2011), FAO (Shittu *et al*., 2008) and Xu *et al*., (2012).

Table 4.5: Effect of Spent Mushroom Substrate Treatment on Some Selected Heavy Metals at the end Of Vegetative Growth (100 Days after Planting).

Treatment	Cadmium (Cd)	Lead (Pb)	Chromium (Cr)	Mercury (Hg)
		→ Mg/kg ←		
T1	2.10^{b}	3.00^{c}	0.80^{d}	0.00^{NS}
T2	2.10^{b}	2.90^{c}	0.80^{d}	0.00^{NS}
T3	2.20^{b}	3.10^{c}	0.90^{c}	0.10^{a}
T4	2.20^{b}	3.30^{b}	1.10^{b}	0.10^{a}
T5	2.40^{a}	3.60^{a}	1.20^{a}	0.10^{a}
FEPA	10.00	5.00	7.00	-
EU	0.30	30.00	15.00	0.50
FAO	0.20	0.30	0.23	2.00
FLSD (p=0.05)	0.10	0.10	0.00	NS

Source: Field Data- January, 2020.

NOTE: Lower case alphabets in superscripts indicate significance in ascending order of alphabets.

NS = Not Significant.

Legend: T1 = SMS 0 t/ha, T2 = NPK 300 kg/ha, T3 = SMS 5 t/ha, T4 = SMS 10 t/ha and T5 = SMS 15 t/ha.

Means with the same superscript are not statistically significant.

4.3.2.18.3 Chromium (Cr- mg/kg)

There were significant differences when the chromium content of the control plots were compared with the other treatments and when the NPK treatment was compared with the SMS treated plots. Significant differences were also observed when SMS treated plots were compared with one another. There were 0.10, 0.30 and 0.40 mg/kg lower values of chromium when control plots were compared with SMS 5 t/ha, 10 t/ha and 15 t/ha treated plots, but has same value with NPK treated plots. NPK treated plots followed the same trend of significant differences like control plots when compared with SMS 5 t/ha, 10 t/ha and 15 t/ha respectively. Spent Mushroom Substrate 15 t/ha recorded higher chromium values of 0.30 and 0.10 mg/kg when compared with 5 t/ha and 10 t/ha treated plots respectively. The highest chromium value of 1.20 mg/kg was recorded in SMS 15 t/ha. This value is 0.10 mg/kg higher than those of 10 t/ha treated plots. The trend in chromium content showed that T5 > T4 > T3 > T2 = T1. Chromium values of plots treated with SMS increased with increase in application rate of SMS. According to FEPA standard (Vern & Don, 2011) and Wisniewska-Kadzajan and Jankowski (2013), SMS has concentration of heavy metals within the permissible limits as recorded in the values.

4.3.2.18.4 Mercury (Hg- mg/kg)

There were no significant differences in the values of mercury recorded in all the treatments when the control plots were compared with the other treatments. No Significant difference was equally recorded when NPK treated plots were compared with SMS treated plots. In addition, no significant difference was also recorded when the SMS treated plots were compared with one another. All SMS treated plots contained very low/ negligible mercury. This is in line with the findings of Zhang & Sun (2014), EU (MoE., 2007) and FAO (Shittu *et al*., 2008), who stated that SMS has low level of heavy metals and absence of plant pathogens and weed seeds.

4.4 Effect of Spent Mushroom Substrate (SMS) on Soil Physico-chemical Properties and Heavy Metals at Harvest.

4.4.1 Soil Physical Properties at Harvest.

The effect of spent mushroom substrate (SMS) on moisture content (%), bulk density (g/cm^3), total porosity and particle size distribution at harvest are presented in Table 4.6 while the effect of spent mushroom substrates on soil chemical properties are presented in Table 4.7.

4.4.1.1 Moisture Content (%)

There were no significant differences when the percentage moisture content at the end of the research of the control plots was compared with the other treatments and when the NPK treatment was compared with the SMS treated plots in their moisture content. Significant differences were not also recorded when the percentage moisture content of the plots treated with SMS were compared with one another. However, variations existed in the values among all the treatments. There were 0.12, 0.24 and 0.38 % less moisture content in the plots treated with T2, T4 and T5 respectively when compared with the control, but was 0.02 % higher than T3.The highest mean difference of 0.38 % moisture content was recorded when T5 was compared with T1. Comparison of the NPK with the SMS revealed that T4 and T5 outperformed the NPK treatment by producing 0.12 and 0.26 % higher moisture content, but NPK treated plots outperformed T3 by producing 0.14 % higher moisture content. However, in the comparison of the different rates of SMS treatment plots respectively, the highest moisture content was recorded from plots treated with 15 t/ha SMS. This value was 0.14 % higher than those recorded from the 10 t/ha SMS treated plots. The trend in the improvement of soil moisture content showed that T5 > T4 > T3 > T2 > T1.

Table 4.6: Effect of Spent Mushroom Substrate Treatment on Some Soil Physical Properties at Harvest.

Treatment	% Moisture Content	Bulk Density (gcm^{-3})	Total porosity	Sand (gkg^{-1})	Silt (gkg^{-1})	Clay (gkg^{-1})	Textural class
T1	7.92^a	1.48^a	44.13^d	917.3^a	47.3^b	35.4^b	Sandy soil
T2	8.04^a	1.41^b	46.65^c	920.7^a	44.0^c	35.3^b	Sandy soil
T3	7.90^a	1.39^c	47.29^b	910.7^b	54.0^a	35.3^b	Sandy soil
T4	8.16^a	1.37^d	48.10^a	907.3^b	47.3^b	45.4^a	Sandy soil
T5	8.30^a	1.37^d	48.29^a	897.3^c	54.0^a	48.7^a	Sandy soil
FLSD (p=0.05)	NS	0.01	0.44	4.70	2.90	4.70	

Source: Field Data- February, 2020.

NOTE: Figures with the same superscript are not significant statistically.

NS = Not Significant. Legend: T1 = SMS 0 t/ha, T2 = NPK 300 kg/ha, T3 = SMS 5 t/ha, T4 = SMS 10 t/ha and T5 = SMS 15 t/ha.

Means with the same superscript are not statistically significant.

4.4.1.2 Bulk Density (gcm^{-3})

There were significant differences when the bulk density of the control plots was compared with other treatments and when NPK treatment was compared with the SMS treated plots at harvest. Significant differences also existed when the bulk density of the plots treated with SMS were compared with one another. There were 0.07, 0.09, 0.11and 0.11 gcm^{-3} lower bulk density in the plots treated with T2, T3, T4 and T5 respectively when compared with the control. The highest mean difference was recorded when T2 was compared with T1. More so, NPK treated plots recorded 0.02, 0.04 and 0.04 gcm^{-3} lower bulk density contents when compared with SMS 5 t/ha, 10 t/ha and 15 t/ha respectively. However, comparison of the different rates of SMS treated plots showed that T3 had 0.02 gcm^{-3} more bulk density content than T4 and T5 respectively. The highest bulk density content was recorded in the control plots. This value was 0.07 gcm^{-3} higher than those recorded from NPK treated plots. This showed that T1> T2 > T3 > T4 = T5. The result showed that increasing rate of application of SMS resulted in decrease in the bulk density of the soil. The lower values of bulk density (< 1.5) observed is desirable for optimum movement of air and water through the soil as postulated by Hunt and Gikes (1992). The reduced bulk density values in SMS applied plots compared with higher value of the control plot is one of the functions of SMS (an organic amendment) which decreases soil bulk density; enhancing soil structure (Ogbodo *et al.*, 2009).This result is in line with the findings of Mbagwu (1992) and Curtin and Mullen (2017). This reduction in bulk density could be due to the binding effects of SMS on soil particles into aggregates as a result of increase in microbial population which enabled the formation of soil aggregates.

4.4.1.3 Total Porosity (%)

There were significant differences when % total porosity of the control plots at harvest were compared with other treatments and when NPK treatment was compared with the SMS treated plots. More so, significant differences were recorded when the SMS treated plots were compared with one another. Control plots recorded 2.52 %, 3.16 %, 3.97 % and 4.16 % lower % total porosity when compared with T2, T3, T4 and T5 plots respectively. Comparison of the NPK treated plots with the SMS treated plots revealed 0.64 %, 1.45 % and 1.64 % higher % total porosity contents in SMS 5 t/ha, SMS 10 t/ha and SMS 15 t/ha respectively. Furthermore, SMS 15 t/ha recorded higher % total porosity of 1.00 and 0.19 in SMS 10 t/ha and SMS 15 t/ha respectively. The highest % total porosity was recorded from SMS 15 t/ha; this value was 0.19 % higher than those recorded from the SMS 10 t/ha treated plots. The trend in the improvement of % total porosity showed that T5 > T4 > T3 > T2 > T1. . Increase in the application rate of SMS gave rise to increase in total porosity; this could be attributed to reduction in bulk density which increased total porosity as stated by Mbagwu (1992) and Ogbodo *et al.* (2009); the lower the soil bulk density, the higher the total porosity; the lower the compaction as a result of promotion of aggregation of soil properties on application of organic amendments which has binding effect on soil properties in aggregates.

4.4.1.4 Particle Size Analysis (gkg^{-1})

Particle size result showed that the soils were predominantly sandy. The result showed that there were significant differences in the sand content in all the plots. Significant differences also existed when NPK treated plots were compared with SMS treated plots. Among the SMS treated plots, significant differences also existed. Control plots recorded 6.70, 10.00 and 20.00 gkg^{-1} higher sand contents when compared with T3, T4 and T5 plots respectively, but less value of 3.40 gkg^{-1} when compared with T2. NPK treated plots recorded 10.00, 13.30 and 23.30 gkg^{-1} more sand content when compared with SMS 5 t/ha, 10 t/ha and SMS 15 t/ha respectively. SMS 5 t/ha recorded higher sand content when compared with SMS 10 t/ha and 15 t/ha with higher values of 3.40 and 13.40 gkg^{-1} respectively. A decrease in sand content was recorded with increased rate of application of SMS. Control plots recorded 3.30 gkg^{-1} higher silt content when compared with NPK treated plots, but 6.70 gkg^{-1} less silt content when compared with SMS 5 t/ha and SMS 15 t/ha; however, control plots recorded same value with SMS 10 t/ha treated plots. NPK treated plots recorded less silt content when compared with SMS 5 t/ha, SMS 10 t/ha and SMS 15 t/ha treated plots with values of 10.00, 3.30 and 10.00 gkg^{-1} respectively. When compared with one another, SMS 5 t/ha and 15 t/ha treated plots recorded equal but more silt content value of 6.70 gkg^{-1} than SMS 10 t/ha. Control treated plots recorded less clay content values of 10.00 and 13.30 gkg^{-1} when compared with SMS 10 t/ha and 15 t/ha respectively, but the same value when compared with NPK and 5 t/ha treated plots. NPK treated plots recorded less clay content values of 10.00 and 13.40 gkg^{-1}, when compared with SMS 10 t/ha and 15 t/ha respectively, but the same clay content value with SMS 5 t/ha. When the SMS treated plots were compared with each other, SMS 5 t/ha recorded less clay content of 10.00 and 13.40 gkg^{-1} in 10 t/ha and 15 t/ha respectively. The highest clay content was recorded from SMS 15 t/ha. This value was 3.40 gkg^{-1} higher than those of SMS 10 t/ha treated plots. An increase was observed with increase in application rate of SMS. The slight significant differences could be attributed to the addition of amendments which did not change the predominant sandy nature of the soils of the area because they originated from the same parent material.

4.4.2 Chemical Properties at Harvest.

4.4.2.1 pHw and pHKCl

Soil pH regulates chemical and biological reactions in the soil. The result showed that there were significant differences when control plots were compared with other treatments and also when NPK treated plots were compared with SMS treated plots. Significant differences were also recorded when SMS treated plots were compared with each other. Control plots recorded less values of 0.25, 0.37 and 0.52 when compared with SMS 5 t/ha, 10 t/ha and 15 t/ha respectively, but higher value of 0.11 when compared with NPK treated plots. Nitrogen Phosphorus Potassium (NPK) treated plots also recorded less pH values of 0.36, 0.48 and 0.63 when compared with SMS 5 t/ha. 10 t/ha and 15 t/ha respectively. SMS 5 t/ha recorded less values of 0.12 and 0.27 when compared with SMS 10 t/ha and 15 t/ha respectively. The highest pH value was recorded from plots treated with SMS 15 t/ha with value of 0.15 higher than 10 t/ha SMS treated plots. The trend of the improvement of soil pH value showed that T5 > T4 > T3 > T1 > T2.According to the ratings of Babalola *et al* (1998), control plots and NPK 300 kg/ha plots were moderately acidic, SMS 5 t/ha, SMS 10 t/ha and 15 t/ha were slightly acidic This indicated good pHw conditions for rice cultivation (Howeler, 2002).

In pHKCl, significant differences were also observed at the end of the research when control plots were compared with other treatment plots. NPK treated plots also recorded significant differences when compared with SMS treated plots. When SMS treated plots were compared among each other, significant differences were also recorded. The result showed that control plots had less values of 0.32, 0.55 and 0.67 pHKCl when compared with SMS 5 t/ha, 10 t/ha and 15 t/ha plots respectively, but higher value of 0.08 when compared with NPK treated plots. NPK treated plots also recorded less values of 0.40, 0.63 and 0.75 pHKCl when compared with SMS 5 t/ha, 10 t/ha and 15 t/ha treated plots respectively. When the SMS treated plots were compared with one another, SMS 5 t/ha had less values of 0.23 and 0.35 when compared with 10 t/ha and 15 t/ha respectively. The highest pH value was recorded in SMS 15 t/ha treated plots; having 0.12 value more than SMS 10 t/ha treated plots. The trend of the improvement of soil pH in KCl showed that T5 > T4 > T3 > T1 > T2.This showed an increase in pH value with increase in the application rate of SMS. NPK had the highest negative impact on soil pH. This is understandable given the fact that NPK is known to low pH and increase soil acidity. The lower pHw value recorded in NPK fertilizer explains it’s acidifying effect while the higher values in SMS treated plots shows it’s buffering effect on the soil which is in line with the findings of Ogbodo *et al*. (2009) and Medina *et al*. (2009).

Table 4.7: Effect of Spent Mushroom Substrate Treatment on Soil Chemical Properties at Harvest.

Treatment	pH in water	pH in Kcl	OC mg/100g	OM mg/100g	% N	AP mg/100g	EAl^{3+}Cmol /kg	H^+Cmol /kg	Ca^{2+}	Mg^{2+}	K^+	Na^+	TEA Cmol /kg	TEB mg/ 100g	ECEC	% BS	C/N	Ca /Mg	Na/K
									$\longrightarrow$ Mg/100g $\longleftarrow$										
T1	5.68^d	4.99^d	10.50^d	18.10^d	0.06^d	0.644^d	0.80^a	0.50^b	1.34^d	0.62^d	1.07^e	1.85^d	1.30^a	4.88^d	6.18^d	78.92^e	17.50^a	2.21^b	1.73^a
T2	5.57^e	4.91^e	10.30^d	17.80^e	0.10^a	0.633^d	0.76^b	0.54^a	1.37^d	0.53^e	2.54^a	1.67^e	1.30^a	6.11^c	7.41^c	82.38^d	10.30^c	2.67^a	0.66^d
T3	5.93^c	5.31^c	12.40^c	21.30^c	0.08^c	0.718^c	0.76^b	0.45^d	1.98^c	0.73^c	1.50^d	2.05^c	1.21^b	6.26^c	7.47^c	83.73^c	15.35^b	2.73^a	1.37^b
T4	6.05^b	5.54^b	13.60^b	23.40^b	0.09^b	0.855^b	0.74^b	0.45^d	2.23^b	1.06^b	1.86^c	2.36^b	1.19^c	7.51^b	8.70^b	86.28^b	15.11^b	2.09^b	1.26^c
T5	6.20^a	5.66^a	16.00^a	27.60^a	0.10^a	0.925^a	0.67^c	0.49^c	2.56^a	1.22^a	2.36^b	2.95^a	1.10^d	9.09^a	10.19^a	89.15^a	16.00^b	2.10^b	1.25^c
FLSD(p =0.05)	0.04	0.05	0.03	0.06	0.00	0.031	0.02	0.03	0.08	0.06	0.15	0.11	0.01	0.22	0.22	0.49	0.65	0.32	0.10

Source: Field Data- February, 2020.

Key: OC = Organic Carbon, OM = Organic Matter, N = Nitrogen, EAl = Exchangeable Aluminum, H = Hydrogen, Ca = Calcium, Mg = Magnesium, K = Potassium, Na = Sodium, TEA = Total Exchangeable Acidity, TEB = Total Exchangeable Bases, ECEC = Effective Cation Exchange Capacity, BS = Base Saturation, C/N = Carbon-Nitrogen ratio, Ca/Mg = Calcium-Magnesium ratio, Na/K = Sodium-Potassium ratio. NS = Not Significant.
NOTE: Means with the same superscript are not significant statistically.

Legend: T1 = SMS 0 t/ha, T2 = NPK 300kg/ha, T3 = SMS 5t/ha, T4 = SMS 10t/ha and T5 = SMS 15t/ha

4.4.2.2 Organic Carbon (mg/100 g)

There were significant differences when the organic carbon content of the control treated plots were compared with other treatment plots. Significant differences were also recorded when NPK treated plots were compared with SMS treated plots; among SMS treated plots, significant differences were also recorded. Control treated plots recorded higher organic carbon value of 0.20 mg/100g when compared with NPK treated plots, but recorded lower organic carbon contents of 1.90, 3.10 and 5.50 mg/100g when compared with SMS 5 t/ha, 10 t/ha and 15 t/ha treated plots respectively. NPK treated plots also recorded less organic carbon contents of 2.10, 3.30 and 5.70mg/100g when compared with SMS 5 t/ha, 10 t/ha and 15 t/ha respectively. When the SMS treated plots were compared with one another, SMS 5 t/ha recorded lower contents of 1.20, and 3.60 mg/100g when compared with 10 t/ha and 15 t/ha respectively. The highest organic carbon content was recorded in SMS 15 t/ha with 2.40 mg/100g higher when compared with the values from the plots treated with 10 t/ha. The trend of the improvement of soil organic carbon content showed that T5 > T4 > T3 > T1 >T2. Increased rate of application of SMS resulted to increased soil organic carbon in the soil. The increased values of SOC on SMS treated plots were in agreement with the findings of Adeli *et al*. (2009), Hairu *et al*. (2016), and Ekpe *et al*. (2021), who stated that as an organic amendment, SMS increases soil organic carbon and organic matter; enhancing soil productivity.

4.4.2.3 Total Nitrogen (%)

Higher rates of SMS treated plots recorded higher % Nitrogen values than those from the control plots. There were significant differences when control plots were compared with other treatment plots. Significant differences were also observed when NPK treated plots were compared with SMS treated plots; when SMS treated plots were compared with one another, significant differences were also observed. Control treated plots recorded less nitrogen values of 0.04, 0.02, 0.03 and 0.04 % when compared with NPK, SMS 5 t/ha, 10 t/ha and 15 t/ha respectively. NPK treated plots recorded higher nitrogen values of 0.02 and 0.01when compared with SMS 5 t/ha and 10 t/ha, but was the same value with SMS 15 t/ha. When the SMS treated plots were compared with each other, SMS 15 t/ha recorded higher nitrogen values of 0.01 and 0.02 when compared with 10 t/ha and 5 t/ha respectively. The highest nitrogen was recorded in SMS 15 t/ha and NPK treated plots. This value was 0.01 higher than SMS 10 t/ha treated plots. The trend of the improvement of soil total nitrogen content showed that T5 = T2 > T4 > T3 > T1. Total nitrogen content increased with increase in the application rate of SMS; this is in agreement with the findings of Medina *et al*. (2009), Unal (2015) and Ekpe *et al*. (2017).They stated that as an organic amendment, SMS was found to be nutritionally rich in nitrogen and has a considerable agronomic value when used as a soil improver.

4.4.2.4 Available Phosphorus- AP (mg/100 g)

The result showed that SMS treated plots released more phosphorus into the soil than the NPK treated plots, and control plots while the NPK treated plots recorded the lowest value. There were significant differences in available phosphorus content when the control treated plots were compared with other treatment plots. Significant differences also existed when NPK treated plots were compared with the SMS treated plots. There were also significant differences when a comparison was made among the SMS treated plots. Control treated plots recorded 0.074, 0.211, and 0.281 mg/100g less available phosphorus when compared with SMS 5 t/ha, 10 t/ha and 15 t/ha treated plots respectively, but recorded higher value of 0.011 mg/100g when compared with NPK treated plots. Nitrogen Phosphorus and Potassium (NPK) treated plots had lower available phosphorus values of 0.085, 0.222 and 0.282 mg/100g when compared with SMS 5 t/ha, 10 t/ha and 15 t/ha treated plots respectively. When the SMS treated plots were compared among each other, 15 t/ha recorded higher values of 0.207 and 0.070 mg/100g when compared with 5 t/ha and 10 t/ha respectively. The highest value was recorded from SMS 15 t/ha with higher value of 0.070 mg/100g than those of 10 t/ha. The trend in improvement of soil available phosphorus content showed that T5 > T4 > T3 > T1 > T2. Increase in phosphorus values was recorded with increase in the application rate of SMS; this is in line with the findings of Unal (2015) and Hairu *et al.* (2016). Phosphorus aids in the fruiting of crops and in photosynthetic process.

4.4.2.5 Exchangeable Aluminum- Al^{3+} (cmol/kg)

There were significant differences in exchangeable aluminum content of the soil at harvest when the control treated plots were compared with other treatment plots. Significant differences were also recorded when NPK treated plots were compared with SMS treated plots. When the SMS treated plots were compared with one another, significant differences were also recorded. Control treated plots had more exchangeable aluminum values of 0.04, 0.04, 0.06 and 0.13 when compared with NPK, SMS 5 t/ha, 10 t/ha and 15 t/ha treated plots respectively. NPK treated plots had higher contents of 0.02 and 0.09 Cmol/kg when compared with SMS 10 t/ha and 15 t/ha respectively, but recorded equal value with SMS 5 t/ha treated plots. When the SMS treated plots were compared with each other, SMS 5 t/ha had higher values of 0.02 and 0.09 cmol/kg exchangeable aluminum than 10 t/ha and 15 t/ha respectively. The highest value was recorded in control plots with 0.064Cmol/kg higher content than both NPK and SMS 5 t/ha. The trend in improvement of soil exchangeable aluminum showed that T1 > T2 = T3 > T4 > T5. An increase in the application rate of SMS led to a decrease in aluminum content in SMS treated plots; this could be attributed to increased pH values with increased application rate of SMS which buffered the soil solution. Organic matter increase also led to reduction in aluminum.

4.4.2.6 Hydrogen- H^+ (Cmol/kg)

There were significant differences in hydrogen content when the control plots were compared with other treatment plots. Significant differences also existed when NPK treated plots were compared with SMS treated plots. Even among the SMS treated plots, significant differences were also recorded. Control plots recorded higher hydrogen values of 0.05, 0.05 and 0.01 cmol/kg when compared with SMS 5 t/ha, 10 t/ha and 15 t/ha treated plots respectively, but had less value of 0.04 when compared with NPK treated plots. Nitrogen Phosphorus and Potassium (NPK) treated plots had higher hydrogen values of 0.09, 0.09 and 0.05 Cmol/kg when compared with SMS 5 t/ha, 10 t/ha and 15 t/ha respectively. Among the SMS treated plots, 15 t/ha had higher hydrogen values of 0.04 Cmol/kg when compared with both SMS 5 t/ha and 10 t/ha treated plots. NPK treated plots recorded the highest hydrogen content with higher value of 0.04 when compared with control plots. The trend in the improvement of soil hydrogen showed that T2 > T1 > T5 > T4 = T3. Hydrogen concentration values increased with increased application rate of SMS. The increase in SMS treated plots could be attributed to rainfall.

4.4.2.7 Calcium- Ca^{2+} (mg/100 g)

There were significant differences when control plots were compared with other treatment plots. Significant differences were also observed when NPK treated plots were compared with SMS treated plots. When SMS treated plots were compared with one another, significant differences were also recorded. Control plots had less calcium value of 0.03, 0.64, 0.89 and 1.22 mg/100g when compared with NPK, SMS 5 t/ha, 10 t/ha and 15 t/ha respectively. NPK treated plots recorded less calcium values of 0.61, 0.86 and 1.19 mg/100g when compared with SMS 5 t/ha, 10 t/ha and 15 t/ha respectively. Spent Mushroom Substrate 15 t/ha recorded more calcium content values of 0.58 and 0.33 mg/100g when compared with 5 t/ha and 10 t/ha respectively. The highest calcium content value was recorded in SMS 15 t/ha; this value was 0.33 mg/100g higher than those of the 10 t/ha treated plots. The trend in the improvement of the soil calcium content showed that T5 > T4 > T3 > T2 > T1. Increase in calcium content was recorded with increase in application rate of SMS; this is in line with the findings of Unal (2015).

4.4.2.8 Magnesium – Mg^{2+} (mg/100g)

The result showed that SMS 15 t/ha released more magnesium content into the soil than other treatment plots. There were significant differences in magnesium content when control plots were compared with other treatment plots. Significant differences were also observed when NPK treated plots were compared with SMS treated plots. Among SMS treated plots, significant differences also existed. Control plots recorded lower magnesium values of 0.11, 0.44 and 0.60mg/100g when compared with SMS 5 t/ha, 10 t/ha and 15 t/ha treated plots respectively, but recorded higher value of 0.09 mg/100g when compared with NPK treated plots. NPK treated plots also had lower magnesium values of 0.20, 0.53 and 0.69 mg/100g when compared with SMS 5 t/ha, 10 t/ha and 15 t/ha treated plots respectively. SMS 15 t/ha had higher magnesium values of 0.49 and 0.16 mg/100 g when compared with SM 5 t/ha and 10 t/ha treated plots respectively. The highest value was recorded in SMS 15 t/ha; this value was 0.16 mg/100g more than the value recorded from 10 t/ha treated plots. The trend in the improvement of soil magnesium content showed that T5 > T4 > T3 > T1 > T2. Increase in the application rate of SMS led to an increase in magnesium content (Ogbodo *et al.*2009 and Ekpe *et al.*, 2017).

4.4.2.9 Potassium- K^+ (mg/100g).

There were significant differences in soil potassium content when the control plots were compared with other treatment plots. Significant differences were also observed when NPK treated plots were compared with SMS treated plots. When SMS treated plots were compared with one another, significant differences were also recorded. Control plots recorded less potassium values of 1.47, 0.43, 0.79 and 1.29 mg/100g when compared with NPK, SMS 5 t/ha, 10 t/ha and 15 t/ha treated plots respectively. NPK treated plots had higher potassium values of 1.04, 0.68 and 0.18 mg/100g when compared with SMS 5 t/ha, 10 t/ha and 15 t/ha treated plots respectively. SMS 15 t/ha recorded higher potassium values of 0.86 and 0.50 mg/100g when compared with SMS 5 t/ha and 10 t/ha treated plots respectively. The highest value of potassium content was recorded in NPK treated plots; this value was 0.18 mg/100g higher than the SMS 15t/ha treated plots value. The trend in the improvement of soil potassium content showed that T2 > T5 > T4 > T3 > T1. Potassium values increased with increase in application rate of SMS: this is in line with the findings of Unal (2015).

4.4.2.10 Sodium- Na^+ (mg/100g)

There were significant differences in soil sodium content when the control plots were compared with other treatment plots. Significant differences were also recorded when NPK treated plots were compared with SMS treated plots; even among SMS treated plots, significant differences were observed. The control plots had less sodium content values of 0.21, 0.51 and 1.10 mg/100g when compared with SMS 5 t/ha, 10 t/ha and 15 t/ha treated plots respectively, but recorded higher value of 0.18 mg/100g when compared with NPK treated plots. NPK treated plots also recorded less sodium content values of 0.38, 0.69 and 1.28 mg/100g when compared with SMS 5 t/ha, 10 t/ha and 15 t/ha treated plots respectively. The highest value of sodium was recorded in SMS 15 t/ha; this value was 0.59 mg/100g more than those of the 10 t/ha treated plots. The trend in the improvement of soil sodium content showed that T5 > T4 > T3 > T1 > T2.An increase in sodium content was recorded with increase in the application rate of SMS. This increase in sodium content could be toxic in the long-term usage because it could lead to soil salinization; this is in agreement with the findings of Moral *et al.*, (2008), who observed accumulation of sodium in the soil as a result of high sodium content in organic amendments.

4.4.2.11 Total Exchangeable Acidity- (TEA) (cmol/kg)

There were significant differences in TEA at harvest when the control plots were compared with other treatment plots. Significant differences also existed when NPK treated plots were compared with SMS treated plots. Among SMS treated plots, significant differences were also recorded. Control plots had higher TEA values of 0.09, 0.11 and 0.20 cmol/kg when compared with SMS 5 t/ha, 10 t/ha and 15 t/ha treated plots respectively, but same value with NPK treated plots. NPK treated plots recorded higher TEA values of 0.09, 0.11 and 0.20 Cmol/kg than SMS 5 t/ha, 10 t/ha and 15 t/ha treated plots respectively. When the SMS treated plots were compared among each other, SMS 5 t/ha had higher TEA values of 0.02 and 0.11 Cmol/kg than 10 t/ha and 15 t/ha treated plots respectively. The highest TEA value was recorded in control plots and NPK treated plots; they had value of 0.09 Cmol/kg more than SMS 5 t/ha treated plots. The trend in the improvement of soil TEA content showed that T1 = T2 > T3 > T4 > T5. Total Exchangeable Acidity values reduced with increase in application rate of SMS. This could be attributed to increase in soil pH on addition of SMS, which neutralized/ buffered the soil solution thereby reducing acidity. This is in line with the findings of Sanchez (1976), who stated that on sites that have a tendency to iron, aluminum or hydrogen toxicity, humifying organic matter works to combat toxic metal concentrations by forming complexes with a high molecular weight; where there is absence or little presence of organic matter, aluminum or hydrogen toxicity will become a problem; this confirms the increase in aluminum and hydrogen saturation in the control plots than in those treated with SMS.

4.4.2.12 Total Exchangeable Bases- TEB- Ca^{2+}, Mg^{2+}, $K^{+,}$ Na^{+} (mg/100g)

There were significant differences in TEB when the control plots were compared with other treatment plots. Significant differences also existed when NPK treated plots were compared with SMS treated plots. Among SMS treated plots, significant differences also existed. Control plots had TEB values of 1.23, 1.39, 2.63 and 4.21 mg/100g less than NPK, SMS 5 t/ha, 10 t/ha and 15 t/ha treated plots respectively. NPK treated plots recorded values of 0.15, 1.40 and 2.98mg/100g less than SMS 5 t/ha, 10 t/ha and 15 t/ha treated plots respectively. SMS 15 t/ha recorded TEB values of 5.82 and 3.00 mg/100g more than 5 t/ha and 10 t/ha treated plots respectively. The highest TEB value of 9.09 mg/100g was recorded in the SMS 15 t/ha treated plots. This value was 1.58 mg/100g more than those of 10 t/ha treated plots. The trend in improvement of soil TEB showed that T5 > T4 > T3 > T2 > T1. Increased application rate of SMS increased TEB in SMS treated plots; this is attributed to increases in soil pH and organic matter content which increases basic cations at the exchange complex and brought them into the soil solution. This result is in line with the findings of Mbagwu (1992), Ogbodo *et al*. (2009) and Unal (2015).

4.4.2.13 Effective Cation Exchange Capacity (ECEC)

There were significant differences observed in ECEC when control plots were compared with other treatment plots. Significant differences were also observed in ECEC when NPK treated plots were compared with SMS treated plots. Among the SMS treated plots, significant differences also existed. Control plots recorded ECEC values of 1.23, 1.29, 2.52 and 4.01 less than NPK, SMS 5 t/ha, 10 t/ha and 15 t/ha treated plots respectively. NPK treated plots recorded ECEC values of 0.06, 1.29 and 2.79 less than SMS 5 t/ha, 10 t/ha and 15 t/ha treated plots respectively. SMS 15 t/ha recorded ECEC values of 2.72 and 1.49 more than SMS 5 t/ha and 10 t/ha treated plots respectively. SMS 15 t/ha recorded the highest value of 10.19; this value was 1.49 more than SMS 10 t/ha treated plots. The trend in the improvement of soil ECEC showed that T5 > T4 > T3 > T2 > T1. ECEC increased with increase in application rate of SMS; this is attributed to increase in organic matter content and agrees with the findings of Ogbodo *et al*. (2009) and Hairu *et al*. (2016) who stated that organic amendments have buffering capacities; making soil more resistant to pH and improves soil ECEC.

4.4.2.14 Base Saturation (BS) (%)

Base saturation values recorded significant differences when control plots were compared with other treatment plots. Significant differences were also observed when NPK treated plots were compared with SMS treated plots. When SMS treated plots were compared with one another, significant differences were also recorded. Control plots recorded % base saturation values of 3.46, 4.81, 7.36 and 10.23 % less than NPK, SMS 5 t/ha, 10 t/ha and 15 t/ha treated plots respectively. NPK treated plots had % base saturation values of 1.35, 3.90 and 6.77 % less than SMS 5 t/ha, 10 t/ha and 15 t/ha treated plots respectively. SMS 15 t/ha recorded % base saturation values of 5.42 and 2.87 % more than SMS 5 t/ha and 10 t/ha treated plots respectively. The highest % base saturation value was recorded in SMS 15 t/ha treated plots; this value was 2.87 % more than those of SMS 10 t/ha treated plots. The trend in the improvement of % soil base saturation showed that T5 > T4 > T3 > T2 > T1. Base saturation increased with increasing rate of application of SMS; this is attributed to increase in soil organic matter content and basic cations in the soil. This is in line with the findings of Ogbodo *et al*. (2009) and Unal (2015).

4.4.2.15 Carbon and Nitrogen ratio (C/N)

C: N value recorded significant differences at harvest when control plots were compared with other treatment plots. Significant differences were also recorded when NPK treated plots were compared with SMS treated plots. Among SMS treated plots, significant differences were observed when compared with one another. Control plots C/N values of 7.20, 2.15, 2.39 and 1.50 % more than NPK , SMS 5 t/ha, 10 t/ha and 15 t/ha treated plots respectively. NPK treated plots recorded C/N values of 5.05, 4.81 and 5.70 % less than SMS 5 t/ha, 10 t/ha and 15 t/ha treated plots respectively. When compared among each other, SMS 15 t/ha recorded C/N values of 0.65 and 0.89 % more than 5 t/ha and 10 t/ha treated plots respectively. The highest C/N value of 17.50 was recorded in control plot

.This value was 1.50 % more than those of SMS 15 t/ha treated plots. The trend in the content of soil C/N showed that T1 > T5 > T3 > T4 > T2. Irregular flow of values of C/ N was recorded with increase in the application rate of SMS. The values recorded fall between the slow fractions C/ N of 10-25 as stated by Brady and Weil (2002). Values of range 15-30 (Deng *et al.*, 2013) indicate food energy supply of soil microbes which increases the decomposition rate of organic matter and nitrogen (Deng *et al*, 2013).

4.4.2.16 Calcium and Magnesium ratio (Ca/ Mg)

There were significant differences in Ca/Mg when control plots were compared with other treatment plots. Significant differences were also observed in Ca/Mg when NPK treated plots were compared with SMS treated plots. Significant differences were also recorded when SMS treated plots were compared with one another. Control plots recorded Ca/Mg values of 0.46 and 0.52 less than NPK and SMS 5 t/ha treated plots, but recorded higher values of 0.12 and 0.11than SMS10 t/ha and 15 t/ha treated plots respectively. Nitrogen Phosphorus and Potassium (NPK) treated plots had Ca/Mg value of 0.06 less than SMS 5 t/ha treated plots, but values of 0.58 and 0.57 more than SMS 10 t/ha and 15 t/ha treated plots respectively. When SMS treated plots were compared with each other, SMS 5 t/ha recorded Ca/Mg values of 0.64 and 0.63 higher than SMS 10 t/ha and 15 t/ha treated plots respectively. The highest value of 2.73 was recorded in SMS 5 t/ha. This value was 0.06 more than those of NPK treated plots. The trend in the improvement of Ca/Mg showed that T3 > T2 > T1 > T5 > T4. The values of Ca/ Mg recorded will enhance good plant growth as stated in the findings of Schulte and Kelling (1993).

4.4.2.17 Sodium and Potassium ratio (Na/K)

There were significant differences in Na/K content when control plots were compared with other treatment plots at the end of the research. Significant differences were also observed in Na/K when NPK treated plots were compared with SMS treated plots. When SMS treated plots were compared with one another, significant differences were also observed. Control plots had Na/K values of 1.07, 0.36, 0.47 and 0.48 % higher than Na:K values than NPK, SMS 5 t/ha, 10 t/ha and 15 t/ha treated plots respectively. NPK treated plots recorded Na/K values of 0.70, 0.60 and 0.59 less than SMS 5 t/ha, 10 t/ha and 15 t/ha treated plots respectively. When the SMS treated plots were compared with each other, SMS 5 t/ha recorded values of 0.11 and 0.12higher than 10 t/ha and 15 t/ha treated plots respectively. The highest value of 1.73 was recorded in control plots. This value was 0.36 higher than those of SMS 5 t/ha. The trend in the content of soil Na/K showed that T1 > T3 > T4 > T5 > T2. An increase in the application rate of SMS led to a decrease in Na/ K. Akintunde *et al*. (2000) stated that the medium fertility range of Na/K is 1:3; the values recorded in the Na/ K is below the medium fertility range and are said to be low; hence, will lead to poor fertility rate in the growth of crops.

4.4.2.18 Selected Heavy Metals (Cadmium- Cd, Lead- Pb, Chromium- Cr and Mercury- Hg) (mg/kg).

The effect of spent mushroom substrate (SMS) on some selected heavy metals at harvest is presented on Table 4.8.

4.4.2.18.1 Cadmium (Cd- mg/kg)

No significant difference was recorded at harvest in Cadmium content when control plots were compared with other treatment plots, except in SMS 5 t/hand 10 t/ha treated plots which had less values of 0.20 and 0.10 mg/kg respectively. Nitrogen Phosphorus and Potassium (NPK) treated plots were also not significantly different, except in SMS 5 t/ha and 10 t/ha treated plots which had 0.20 and 0.10 mg/kg less values than NPK treated plots respectively. Spent Mushroom Substrate 15 t/ha treated plots recorded higher value of 0.20 and 0.10 mg/kg than 5 t/ha and 10 t/ha treated plots respectively. The highest value of 1.70 mg/kg was recorded in control, NPK and SMS 15 t/ha treated plots. According to Xu *et al*. (2012), these values were found to be low as SMS reduced cadmium content in the soil; hence, will not reduce soil productivity and crop yield. These values of cadmium are below the permissible limit of 2.00 mg/kg according to the Food and Agricultural Organization standard as sited by Shittu *et al*. (2008).

4.4.2.18.2 Lead (Pb- mg/kg)

No significant difference was recorded in lead content when control plots were compared with other treatments. There was also no significant difference when NPK treated plots were compared with SMS treated plots. Among the SMS treated plots, no significant difference was also recorded. SMS has low concentration of heavy metals; hence, the values recorded will not reduce soil productivity or crop yield as reported by Xu *et al*. (2012). The values recorded were very low and in line with the permissible limits of 50.0 and 3.00 mg/kg standards by FAO (Shittu *et al*., 2008) and FEPA (Vern & Don, 2011) respectively.

4.4.2.18.3 Chromium (Cr) (mg/kg)

There were significant differences when the chromium content of the control plots were compared with other treatments and when the NPK treatment was compared with the SMS treated plots. Significant differences were also observed when SMS treated plots were compared with one another. There were 0.10, 0.10 and 0.30 mg/kg higher values of chromium when control plots were compared with SMS 5 t/ha, 10 t/ha and 15 t/ha treated plots, but has same value with NPK treated plots. Nitrogen Phosphorus Potassium (NPK) treated plots followed the same trend of significant differences like control plots when compared with SMS 5 t/ha, 10 t/ha and 15 t/ha respectively. SMS 15 t/ha recorded higher chromium values of 0.20 mg/kg when compared with 5 t/ha and 10 t/ha treated plots. The highest chromium value of 0.70 mg/kg was recorded in SMS 15 t/ha. This value was 0.20 mg/kg higher than those of 5 t/ha and 10 t/ha treated plots. The trend in chromium content showed that T5 > T4 = T3 > T2 = T1.

TABLE 4.8: Effect of Spent Mushroom Substrate Treatment on Some Selected Heavy Metals at Harvest

Treatment	Cadmium (Cd)	Lead (Pb)	Chromium (Cr)	Mercury (Hg)
		→ mg/kg	←	
T1	1.70^{a}	2.70^{a}	0.40^{c}	0.00^{NS}
T2	1.70^{a}	2.40^{a}	0.40^{c}	0.00^{NS}
T3	1.50^{s}	2.50^{a}	0.50^{b}	0.00^{NS}
T4	1.60^{b}	2.70^{a}	0.50^{b}	0.00^{NS}
T5	1.70^{a}	2.60^{a}	0.70^{a}	0.10^{a}
FEPA	10.00	5.00	7.00	-
EU	0.30	30.00	15.00	0.50
FAO	0.20	0.30	0.23	2.00
FLSD (p=0.05)	0.00	0.30	0.00	0.00

Source: Field Data- February, 2020.

Means with the same superscript are not statistically significant.

NS = Not Significant

Legend: T1 = SMS 0 t/ha, T2 = NPK 300 kg/ha, T3 = SMS 5 t/ha, T4 = SMS 10 t/ha and T5 = SMS 15 t/ha.

Chromium values of plots treated with SMS increased with increase in application rate of SMS. Wisniewska-Kadzajan and Jankowski (2013) stated that SMS has low concentration of chromium as recorded. The values recorded were also below the permissible limits of 2.30, 150.0 and 70.0 for soil productivity according to FAO standard (Shittu *et al.*, 2008), FEPA standard (Vern & Don, 2011) and EU standard (Mohammed & Folorunsho, 2015) respectively.

4.4.2.18.4 Mercury (Hg- mg/kg)

There was no significant difference of mercury recorded in all the treatments when control plots were compared with other treatments. No Significant difference was also recorded when NPK treated plots were compared with SMS treated plots. In addition, no significant difference was also recorded when the SMS treated plots were compared with one another. All treatment recorded no mercury content in the soil; this is in agreement with the European Union (EU) standard (Ministry of Environment [MoE], 2007) and also the findings of Zhang and Sun (2014) who stated that SMS contained low level of heavy metals and absence of plant pathogens and weeds.

4.4.3 Comparison of results after 100 days of Planting and at Harvest.

A reduction in moisture content in plots treated with SMS was observed compared with results at the end of vegetative growth while at harvest, there was an increase in moisture content in NPK treated plots and control plots compared with values at the end of vegetative growth. Results of bulk density at harvest on SMS treated plots were found to have reduced compared with result at the end of vegetative growth; control plots remained the same while there was an increase in NPK treated plots. This could be attributed to the effect of SMS in improving soil structure. Result of total porosity at harvest in SMS treated plots were found to have increased compared with result at the end of vegetative growth. This is attributed to reduced bulk density which increased total porosity. Nitrogen Phosphorus and Potassium (NPK) treated plots increased at harvest while control plots reduced at harvest. Compared with results obtained at the end of vegetative growth, there was slight reduction in % sand and % clay contents while % silt content recorded a slight increase in results obtained at harvest. This did not affect the textural class of each of the plots; which remained sandy (sandy soil); this could be attributed to their origination from the sane parent material.

pH results at harvest ranged from 4.99 to 6.20, which is rated to be very strongly acidic to slightly acidic (Babalola *et al.*,1998) while pH at the end of vegetative growth ranged from 5.18 to 6.69, which is rated to be strongly acidic to neutral (Babalola *et al.*, 1998). Hence, there was reduction in soil pH at harvest compared with results at the end of vegetative growth, The reduction in pH (acidic nature) at harvest could be attributed to the exposure of the subsoil due to anthropogenic activities and heavy leaching of basic cations as a result of rainfall associated with the rainforest zone or irrigation (Ojimgba & Mbagwu, 2007). This will in turn affect other soil physic-chemical properties because soil pH is an indicator; regulating chemical and biological reactions in the soil. Soil organic carbon result at harvest on SMS treated plots were found to have reduced compared with result at the end of vegetative growth. This could be attributed to reduced pH values as a result of leaching of basic cations. Total nitrogen result at harvest on SMS treated plots were found to have reduced compared with result at the end of vegetative growth. This could be attributed to the intake of nitrogen (nitrification) in the soil in forms usable by plants which have been mainly used in the growth of vegetative parts of the plant at the end of vegetative growth; reduced soil pH also affected total nitrogen. Available phosphorus values in the plots at harvest were found to reduce compared with results at the end of vegetative growth; this is attributed to reduction in soil pH which affects soil physic-chemical properties. Phosphorus must have been used up by the rice plant for fruiting. Result at harvest recorded similar result at the end of vegetative growth, except that control plots recorded an increase at harvest compared with at the end of vegetative growth. Hydrogen content at harvest increased compared with values at the end of vegetative growth; this is as a result of reduced soil pH due to leaching of basic cations which increases acidic cations (H^+ and Al^{3+}).

Results of calcium content at harvest reduced compared with result at the end of vegetative growth; this is as a result of reduction in soil pH and organic matter due to leaching of basic cations .e.g Ca^{2+} from the exchange site. Result of magnesium at harvest reduced, compared with result at the end of vegetative growth. This is attributed to reduction in soil pH and organic matter as a result of leaching of basic cations e.g Mg^{2+} from the exchange complex. There was reduction in potassium values at harvest compared with values at the end of vegetative growth; this is attributed to reduction in pH and organic matter as a result of leaching of basic cations e.g K^+ from the soil exchange complex. A reduction in sodium content at harvest was recorded compared with sodium content at the end of vegetative growth; this is attributed to reduction in pH and organic matter as a result of leaching basic cations e.g Na^+ from the soil exchange complex. Total Exchangeable Acidity (TEA) result at harvest showed an increase compared with TEA result at the end of vegetative growth; this is attributed to the reduced pH values at harvest, which increased soil acidity. Total Exchangeable Bases (TEB) result at harvest showed a decrease compared with TEB values at the end of vegetative growth; this is attributed to reduced pH values and organic matter content as a result of leaching of basic cations. ECEC result at harvest recorded a decrease compared with ECEC result at the end of vegetative growth; this is attributed to reduced pH values and organic matter content as a result of leaching of basic cations. A decrease in base saturation at harvest was recorded compared with result at the end of vegetative growth; this is attributed to reduction in soil pH and organic matter contents which led to leaching of basic cations.

C/N values at harvest increased compared with values at the end of vegetative growth, except in SMS 15 t/ha and SMS 10 t/ha where there was reduction at harvest compared with values at the end of vegetative growth.At harvest, values of Ca/ Mg in SMS 0 t/ha, SMS 10 t/ha and SMS 15 t/ha reduced compared with their respective values at the end of vegetative growth while values of Ca/

Mg in NPK 300 kg/ha and SMS 5 t/ha increased at harvest compared with their respective values at the end of vegetative growth. Na/ K values at harvest increased compared with values at the end of vegetative growth.

Cadmium values at harvest recorded a decrease compared with values at the end of vegetative growth; this shows that SMS reduced heavy metal content in the soil with time; the longer the time, the less heavy metal content in the soil on application of SMS. Lead values at harvest recorded a reduction compared with lead values at the end of vegetative growth. Chromium values at harvest recorded a reduction compared with values at the end of vegetative growth; this could be attributed to reduced concentration of heavy metals in the soil when decomposition of organic matter is completed with time. Mercury content at harvest recorded almost the same result with mercury content at the end of vegetative growth.

4.5 Effect of Spent Mushroom Substrate (SMS) on selected Agronomic and Grain Yield Parameters of Rice.

The effect of spent mushroom substrate (SMS) on selected agronomic parameters of rice is presented in Table 4.9 while the effect of spent mushroom substrate on selected grain yield parameters of rice is presented in Table 4.10.

4.5.1 Plant Height (cm)

No significant difference was recorded in plant height when control plots were compared with other treatments; though there were variations in values, except in SMS 10 t/ha where significant difference existed in plant height. Nitrogen Phosphorus and Potassium (NPK) treated plots were not also significantly different from SMS treated plots; though variations existed in values, except in SMS 10 t/ha where significant difference was recorded. Significant difference was recorded when SMS treated plots were compared with one another. Control plots had less values of 1.63, 2.47 and 5.03 cm less plant height than NPK, SMS 5 t/ha and 10 t/ha treated plots respectively, but recorded plant height value of 0.03 more than SMS 15 t/ha. NPK treated plots had values of 0.84 and 3.40 cm shorter plants than SMS 5 t/ha and 10 t/ha respectively, but value of 1.67 cm taller plant than SMS 15 t/ha.

Spent Mushroom Substrate 10 t/ha recorded taller plants of 2.56 and 5.06 cm more than 5 t/ha and 15 t/ha treated plots respectively. The highest plant height of 49.93 cm was recorded from SMS 10 t/ha; this value was 2.56 cm more than those of SMS 5 t/ha. The trend in plant height improvement showed that T4 > T3 > T2 > T1 > T5. Spent Mushroom Substrate 15 t/ha recorded the shortest plant while SMS 10 t/ha recorded the tallest plant. The irregular flow in values of SMS treated plots was observed. SMS treated plots recorded higher values than NPK treated plots except in SMS 15 t/ha where it was lower. Increase in plant height on addition of SMS is in line with the findings of Ogbodo *et al*. (2009) who reported that there was increase in plant height when organic amendment was added to the soil. The higher content of salt (sodium) recorded in SMS 15 t/ha may have negatively affected plant height of the plots.

4.5.2 Root Weight (t/ha)

There were significant differences in root weight when control plots were compared with other treatments and when NPK treated plots were compared with SMS treated plots at harvest. SMS treated plots also recorded significant difference when compared with one another. Control plots had root weight values of 0.48, 0.82, 1.17 and 0.18 t/ha less than NPK, SMS 5 t/ha, 10 t/ha and 15 t/ha treated plots respectively. Nitrogen Phosphorus and Potassium (NPK) treated plots recorded value of 0.30 more than SMS 15 t/ha treated plots, but less values of 0.36 and 0.69 t/ha when compared with 5 t/ha and 10 t/ha treated plots respectively. Spent Mushroom Substrate 10 t/ha recorded higher values of 0.33 and 0.99 t/ha when compared with 5 t/ha and 15 t/ha treated plots respectively. The highest root weight of 2.65 t/ha was recorded from SMS 10 t/ha; this value was 0.33 t/ha more than those of SMS 5 t/ha. The trend in the improvement of root weight showed that T4 > T3 > T2 > T5 > T1.The increase in root weight on application of SMS is in line with the findings of Ogbodo *et al*., (2009) who stated that decrease in soil bulk density led to improvement in soil physico-chemical properties of the crop environment for improved root growth, improved aeration and soil porosity which brought about increase in grain yield of rice on application of organic amendment like SMS.

Table 4.9: Effect of Spent Mushroom Substrate on Agronomic Parameters

Treatment	Plant height (cm)	Root weight (t/ha)	Leaf area (cm^2)	Number of Tillers
T1	44.90^b	1.48^b	3261.27^a	14.33^d
T2	46.53^b	1.96^a	3612.82^a	15.00^d
T3	47.37^b	2.32^a	3632.66^a	22.00^c
T4	49.93^a	2.65^a	4817.44^a	24.00^b
T5	44.87^b	1.66^b	5048.24^a	26.33^a
FLSD (p=0.05)	2.39	0.40	1204.48	1.45

Source: Field Data- February, 2020.

Means with the same superscript are not significant statistically.

Legend: T1 = SMS 0 t/ha, T2 = NPK 300 kg/ha, T3 = SMS 5 t/ha, T4 = SMS 10 t/ha, T5 = SMS 15 t/ha

NS = Not Significant

Lower value from SMS 15 t/ha treatment could be attributed to higher sodium content which may have negative effect on root growth and weight as stated by Moral *et al*. (2008).

4.5.3 Leaf Area (LA- cm^2)

No significant difference in leaf area was recorded when control plots were compared with other plots and also when NPK treated plots were compared with SMS treated plots at harvest. Again, no significant difference was recorded among the SMS treated plots. However, variations existed in leaf area across the treatments. Control plots had leaf area values of 351.55, 371.39, 1556.17 and 1786.97 cm^2 less than NPK, SMS 5 t/ha, 10 t/ha and 15 t/ha treated plots. Nitrogen Phosphorus and Potassium (NPK) treated plots had values of 19.84, 1204.62 and 1435.42 cm^2 less than SMS 5 t/ha, 10 t/ha and 15 t/ha treated plots. Spent Mushroom Substrate 15 t/ha recorded values of 1415.58 and 230.81 cm^2 more than 5 t/ha and 10 t/ha. The highest value was recorded from SMS 15 t/ha and had value of 230.81cm^2 more than those of 10 t/ha. The trend in the improvement of leaf area showed that T5 > T4 > T3 > T2 > T1. Increase in leaf area value was observed with increase in the application rate of SMS as stated by Mustapha and Kadiri (2010). Zhao *et al*. (2003) also stated that increase in nutrients like nitrogen increased leaf area index of crops with increase in the application rate of SMS.

4.5.4 Number of Tillers

There were significant differences in tiller number when control plots were compared with other treatments and when NPK treated plots were compared with SMS treated plots. Significant differences also existed when SMS treated plots were compared with one another. Control plots had lower values of 0.67, 7.67, 9.67 and 12.00 when compared with NPK, SMS 5 t/ha, 10 t/ha and 15 t/ha treated plots respectively. NPK treated plots recorded less values of 7.00, 9.00 and 11.33 when compared with SMS 5 t/ha, 10 t/ha and 15 t/ha treated plots respectively. SMS 15 t/ha recorded higher number of tiller values 4.33 and 2.33 when compared with 5 t/ha and 10 t/ha respectively. The highest tiller number of 26.33 was recorded from SMS 15 t/ha. This value is 2.33 more than those of 10 t/ha. The trend in the improvement of tiller numbers showed that T5 > T4 > T3 > T2 > T1. Increase in the application rate of SMS increased the number of tillers in SMS treated plots; this agrees with the findings of Ahlawat *et al*. (2007) who stated that SMS is nutritionally rich in nitrogen, phosphorus and potassium; increase in their contents will increase tiller number in cereal crops; Fairhurst *et al*. (2007) reported the same findings.

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Table 4.10: Effect of Spent Mushroom Substrate on Rice Grain Yield

Treatment	Filled Grain (t/ha)	Unfilled Grain (t/ha)	Total Grain Yield (t/ha)	% Unfilled Grain	% Filled Grain
T1	6.77^b	6.87^b	13.64^b	50.37^a	49.63^b
T2	13.67^b	2.27^b	15.94^b	14.24^a	85.76^a
T3	7.50^b	9.17^b	16.67^b	55.00^a	45.00^b
T4	24.90^a	20.33^a	45.23^a	55.05^a	44.95^b
T5	8.57^b	9.17^b	17.74^b	51.69^a	48.31^b
FLSD (p=0.05)	10.85	7.68	17.01	14.28	14.28

Source: Field Data- February, 2020.

Means with the same superscript are not significant statistically.

Legend: T1 = SMS 0 t/ha, T2 = NPK 300 kg/ha, T3 = SMS 5 t/ha, T4 = SMS 10 t/ha, T5 = SMS 15 t/ha.

NS = Not Significant

4.5.5 Total Grain Yield (t/ha)

There was no significant difference recorded in Total grain yield when control plots were compared with other treatments, except in SMS 10 t/ha and 15 t/ha treated plots. Significant difference was recorded in total grain yield when NPK treated plots were compared with SMS treated plots, except in 5 t/ha where there was no significant difference. When SMS treated plots were compared with one another, significant difference were recorded. Control plots had less total grain yield values of 2.30. 3.03, 31.59 and 4.10 t/ha when compared with NPK, SMS 5 t/ha, 10 t/ha and 15 t/ha treated plots respectively. Nitrogen Phosphorus and Potassium (NPK) treated plots recorded less yields of 0.73, 29.29 and 1.80 t/ha when compared with SMS 5 t/ha, 10 t/ha and 15 t/ha treated plots respectively. SMS 10 t/ha recorded higher total grain yield values of 28.56 and 27.49 t/ha when compared with SMS 5 t/ha and 15 t/ha respectively. The highest yield of 45.23 t/ha was recorded from SMS 10 t/ha. This value was 27.49 t/ha more than those of 15 t/ha of SMS treatment. Total grain yield content showed that T4 > T5 > T3 > T2 > T1. An increase in total grain yield was recorded with increase in the application rate of SMS, except in SMS 15 t/ha where it reduced; this is in agreement with the findings of Ogbodo *et al*. (2009) who reported that at rates of SMS 15 t/ha and above, low level of rice grain yield was observed, higher grain yield was recorded in SMS 10 t/ha than in SMS 15 t/ha; the low level of grain yield in plot treated with 15 t/ha compared with the 10 t/ha high yield could be attributed to excess supply of nutrients (especially nitrogen) to the soil which favours more vegetative growth increase and is detrimental to grain yield. Agba *et al*., (2012) had similar finding in maize where there was reduction in yield beyond optimal level of SMS 20 t/ha.

4.5.6 Filled Grain (t/ha)

No significant difference was recorded in filled grain when the control plots were compared with other treatments, except in the NPK and SMS 10 t/ha treated plots where significant difference existed. NPK treated plots also recorded no significant difference when compared with SMS treated plots, except in the SMS 10 t/ha treated plots where significant difference was recorded. No significant difference was also recorded when SMS treated plots were compared with one another, except in the SMS 10 t/ha treated plots where significant difference was recorded. However, variations in values were recorded across all treatments. Control plots had less filled grain values of 6.90, 0.73, 18.13 and 1.80 t/ha when compared with NPK, SMS 5 t/ha, 10 t/ha and 15 t/ha treated plots respectively. Nitrogen Phosphorus and Potassium (NPK) treated plots recorded less value of 11.23 t/ha when compared with SMS 10 t/ha, but higher value s of 6.17 and 5.10 t/ha when compared with SMS 5 t/ha and 15 t/ha respectively. Spent Mushroom Substrate 10 t/ha recorded higher filled grain values of 17.40 and 16.33 t/ha when compared with SMS 5 t/ha and 10 t/ha respectively. The highest filled grain value of 24.90 t/ha was recorded from SMS 10 t/ha; this value was more than 11.23 t/ha those of NPK treated plots. The filled grain content showed that T4 > T2 > T5 > T3 > T1. Increase in the application rate of SMS led to an increase in filled grain weight, except in SMS 15 t/ha where it reduced; this could be attributed to increased vegetative growth and lower filled grain weight as confirmed by Ogbodo *et al*. (2009).

4.5.7 Unfilled Grain (t/ha)

There were significant differences recorded in unfilled grain when control plots were compared with other treatments, except in NPK treated plots where no significant difference existed. There were also significant differences when SMS treated plots were compared with one another. Control plots had higher unfilled grain value of 4.60 t/ha when compared with NPK treated plots, but less unfilled grain values of 2.30, 13.46 and 2.30 t/ha when compared with SMS 5 t/ha , 10 t/ha and 15 t/ha respectively. Nitrogen Phosphorus and Potassium (NPK) treated plots had less unfilled grain values of 6.90, 18.06 and 6.90 t/ha when compared with SMS 5 t/ha, 10 t/ha and 15 t/ha respectively. Spent Mushroom Substrate 10 t/ha recorded higher unfilled grain values of 11.16 t/ha when compared with 5 t/ha and 15 t/ha treated plots NPK treated plots recorded significant difference when compared with SMS treated plots .The highest unfiled grain value was recorded from SMS 10 t/ha. This value was 11.16 t/ha more than those of 15 t/ha and 5 t/ha. Result of the unfilled grain showed that T4 > T5 >= T3 > T1 > T2.

4.5.8 Percentage Unfilled Grain

There was no significant difference recorded in % unfilled grain when control plots were compared with other treatments and no significant difference also when NPK treated plots were compared with SMS treated plots. Among the SMS treated plots, no significant difference was also observed. However, variations in values were observed across all treatments. Control plots had more % unfilled grain value of 36.13 % when compared with NPK treated plots, but recorded less values of 4.63, 4.68, 1.32 % when compared with SMS 5 t/ha, 10 t/ha and 15 t/ha treated plots respectively. Spent Mushroom Substrate 10 t/ha recorded higher values of 0.05 and 3.36 % when compared with 5 t/ha and 10 t/ha respectively. The highest value of 55.05 % was recorded from SMS 10 t/ha. The values recorded stemmed from the unfilled grain values.

4.5.9 Percentage Filled Grain

There were significant differences in percentage filled grain when control plots were compared with other treatments and also significant differences when NPK treated plots were compared with SMS treated plots. Again, significant difference existed when SMS treated plot were compared with one another. Control plots hadhigher % filled grain values of 4.63, 4.68 and 1.32 % when compared with SMS 5 t/ha, 10 t/ha and 15 t/ha respectively, but less value of 36.13 % when compared with NPK treated plots. Nitrogen Phosphorus and Potassium (NPK) treated plots recorded more % filled grain values of 40.76, 40.81 and 37.45 % when compared with SMS 5 t/ha, 10 t/ha and 15 t/ha respectively. SMS 15 t/ha recorded higher values of 3.31 and 3.36 % when compared with 5 t/ha and 10t/ha respectively. The highest value was recorded from NPK treated plots. This value was 36.13 % higher than those of control plots. Result of % filled grain showed that T2 > T1 > T5 > T4 > T3. Values recorded stemmed from the weight of filled grains. The treatment likely led to excessive vegetative growth and empty grains.

CHAPTER FIVE

5.0 CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

Research findings on the effect of spent mushroom substrate (SMS) on selected soil properties and performance of upland rice in Owerri, Imo State, Nigeria was carried out in the field of the Centre for Agricultural Research and Extension, Federal University of Technology, Owerri (FUTO). Five treatments of SMS 0 t/ha, NPK 300 kg/ha, SMS 5 t/ha, SMS 10 t/ha and SMS 15 t/ha were replicated three times and applied to the soil.

Generally, spent mushroom substrate treated plots were found to increase soil physico-chemical properties with increase in application rate compared to control plots and NPK treated plots, except in exchangeable acidity (aluminum and hydrogen contents) where a decline was recorded in SMS values as a result of increase in pH and organic matter, which buffered the soil solution; basic cations displacing acidic cations at the exchange site and enters into the soil solution. SMS increased growth and grain yield of upland rice. It was also found to contain low concentration of heavy metals in the soil; hence, making them less available in the soil. All treatment rates of SMS application can be used to improve the growth and grain yield of upland rice in an ultisol; SMS 10 t/ha rate being highly recommended because it recorded the best yield and beyond this rate, it was observed that upland rice grew more vegetatively; having less grain yield.

Spent Mushroom Substrate has little or no adverse effect on human health. It is non-hygroscopic and odourless. Therefore, SMS with adequate treatment could be adopted in an ultisol for upland rice production without compromising the health of both farmers and consumers. It is available where there are mushroom farms and has little or no cost; hence, farmers can adopt its use compared to using chemical fertilizers such as NPK fertilizers because of its availability, economical value and poses no threat to human health.

5.2 Recommendations

Based on the result of this study, I recommend the use of spent mushroom substrate in an ultisol at the rate of 10 t/ha for optimum yield of FARO 56/ NERICA 2 upland rice production since it gave the best grain yield. Further research should be carried out on:

- effect of spent mushroom substrate on soil microbial count.
- effect of spent mushroom substrate on soil degradation

5.3 Contribution to Knowledge

This study will contribute in equipping farmers with adequate knowledge on the effect of spent mushroom substrate on the soil and in the performance of upland rice in Owerri, Imo State, Nigeria. Knowledge acquired through this study will guide rice farmers in Owerri, Imo State, Nigeria and beyond to reposition themselves towards having increased yield in their rice enterprise, using spent mushroom substrate void of fear of capital for the purchase of NPK fertilizers, its threat to health nor loss of soil productivity due to heavy metal contamination. Hence, there will be equal and even increased yield in the production of upland rice without using NPK fertilizers.

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Appendix 1: Spent Mushroom Substrate

Appendix 2: Field layout after land and bed preparation, reinstallation of irrigation system and treatment application

Appendix 3: Field layout of rice plant at two weeks after planting.

Appendix 4: Field layout of rice plant at four weeks after planting and after first weeding.

Appendix 5: Field layout of rice plant some days after panicle initiation while being irrigated.

Appendix 6: Panicling stage of upland rice; some rice grains ready for harvest.