**EFFECTS OF ORGANIC AMENDMENTS ON DISEASE SUPPRESSION AND SOIL PROPERTIES USING TOMATO AS A TEST CROP**

**BY**

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MAY, 2022

**DECLARATION**

I, (**Faridat, Temilomo, OLANIYAN**), an M.Sc. student in the Department of **Crop and Soil Science**, Landmark University, Omu-Aran, hereby declare that this thesis entitled ***“Effects of organic amendments on disease suppression and soil properties using tomato as a test crop”***, submitted by me is based on my original work. Any material(s) obtained from other sources or work done by any other persons or institutions have been duly acknowledged.

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**CERTIFICATION**

This is to certify that this thesis has been read and approved as meeting the requirements of the Department of Crop and Soil Sciences, College of Agricultural Sciences, Landmark University, Omu-Aran, Nigeria, for the Award of Master of Science (M.Sc.) in soil science.

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ABSTRACT

Two field trials (site A and site B) were conducted to evaluate the potential of three organic amendments and inorganic fertilizer on disease suppression, response of soil microorganisms, physical and chemical properties of soil as well as growth and yield of tomato. The experiments were laid out in randomize complete block design (RCBD). The treatments applied were compost (3.4t/ha), poultry manure (4.2t/ha), *Tithonia diversifolia* (4.8t/ha)*,* NPK (15:15:15) (0.8t/ha) at 120kg N/ ha and the control. Treatments were replicated three times at the two sites. Tomato seeds were raised in the nursery and each seedling was transplanted to the field after 3weeks with a spacing of 50 × 50 cm at the two sites. Soil physical, chemical and biological analyses were carried out using standard laboratory methods. Data collected were subjected to analysis of a variance using statistical package for social sciences (SPSS) and means were separated using Duncan Multiple range test at 5% level of probability. The results showed that disease incidence and severity in site B were significantly lower than site A. The plant height, number of leaflets, leaf area and yield in site B were significantly higher than site A. Compost and poultry manure reduced the disease incidence of tomato significantly than other amendments. Compost had the least disease severity followed by poultry manure, *Tithonia diversifolia* and NPK. Compost improved both the total number and diversity of fungi than other amendments while diversity of bacteria was increased more by poultry manure and *Tithonia diversifolia* than the other amendments studied. Compost significantly increased the growth and yield of tomato than other treatments as well as control. Compost significantly increased soil organic carbon, potassium and phosphorus contents than other treatments while *Tithonia diversifolia* significantly increased magnesium content in soil than other treatments. All the treatments significantly increased the moisture content of soil than un-amended soil. Base on the results of this study, application of poultry manure and compost are recommended for reduction of disease incidence of tomato while for the reduction of disease severity in tomato, compost, poultry manure and *Tithonia diversifolia* are recommended. Compost is recommended for improvement of soil moisture and chemical properties. Compost, poultry manure and *Tithonia diversifolia* are recommended for the improvement of soil microbial properties.

**Keywords:** *Tomato, disease suppression, physical and chemical properties, microbial properties, treatments*

**DEDICATION**

This study is dedicated to the Almighty, my late father Dr Bello-Olaniyan W. N and my loving mother, Mrs Olaniyan A. W.

**ACKNOWLEDGEMENTS**

My gratitutde goes to the Almighty Allah the most Beneficent, the most Merciful for giving me grace to accomplish this work. He is indeed the Supreme Creator. My sincere appreciation goes to my jewel, Mrs Olaniyan A.W., for her total support throughout the course of this study. May Almighty Allah bless you ma, Amen.

I sincerely appreciate the effort and support of my supervisors, DR. E.T. Alori and DR. A.O. Adekiya, may the Almighty bless you and your families. I also appreciate all the amiable lecturers in the department of Crop and Soil Science for their support. I extend my greetings to Mr Peter and Mrs Awotunde for their kindness, support and readiness to offer assistance.

My profound appreciation goes to my loving and caring siblings, Pharm. Seleem, Hamidat, Abdulmueez and Hisbat for their support. May Almighty Allah bless you abundantly and bestow you His endless mercy. You are really appreciated.

I will also like to appreciate my family friends, Ustadh Abdulfatah Aribidesi , uncle Toyin and Mr Oni T. for their kindness and support. I say a very big thank you, may Almighty Allah bless you with His infinite mercy.

To my entire friends (Wuthem, Bisola, Mrs Ajayi, Bukola, John, Adeolu, Mr Razak, Faith, Tayo), I am privileged to meet you all, thank you all for your support. May the Almighty reward you all.

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**CHAPTER ONE**

**INTRODUCTION**

**1.1 Background of study**

Over the years, the idea of practicing intensive agriculture is to achieve high productivity however; this practice had adversely affected soil health and biodiversity despite the remarkable increases in overall food production (Tuğrul, 2019). Long-term usage of inorganic fertilizers causes soil, water and environmental pollution, food insecurity, development of pathogen/pest resistance, residual toxicity towards micro and macro organisms and loss of biodiversity (Ruano-Rosa and Mercado-Blanco, 2015). This therefore necessitated the need for eco and human health friendly, sustainable and alternative farming practice.

Organic farming is a sustainable and affordable system which strictly prohibits the use of synthetic fertilizers thereby reducing the negative effect of chemical fertilization. (Chaney and Ramsubhag, 2017; Ye et al, 2020). It’s one of the oldest ways of practicing sustainability in agriculture (Faissal et al., 2017). Application of organic amendments such as compost, plant debris, animal manure, peat moss and organic mulch increase the organic matter content of the soil. It’s also a major substrate in management of soil and plant health as well as suppression of diseases resulted from soil borne pathogens. The organic matter content of soil is use to determine soil health as it governs the physical, chemical and biological properties of soil (Gómez-Sagasti et al., 2018). It has been reported that presence of soil organic matter can reduce bulk density and increase water holding capacity and soil aggregate stability (Murphy, 2014; Gómez-Sagasti et al., 2018). Organic matter supply microorganisms with essential nutrients (Reeve et al. 2016) therefore increase the microbial population, catalyze their activity (Larkin, 2015), allows high biodiversity (Turmel et al., 2015). As stated by Chandrashekara and Bhatt (2014) and Scotti et al. (2015) organic matter aids natural disease suppression and soil fertility thereby improving soil health. Organic matter reduces the effect of soil-borne pathogens and pollutant ecotoxicity (Scotti et al., 2015).

Compost as a type of organic amendment has been known to improve the growth and yield of plant by improving the physio-chemical properties of soil hence enhance nutrient availability (Chaney and Ramsubhag, 2017).Compost serves as antagonist for plant diseases through its physical, chemical and biological contribution (Chaney and Ramsubhag, 2017; Zaccardelli et al., 2020).

Soil can be enriched through the incorporation of green manures (Larkin, 2013) which is an important alternative source of organic fertilizers (Hafifah et al., 2016). Green manure has lot of benefit in the soil, which ranges from soil organic carbon enhancement, soil health improvement, high agronomic productivity (Hafifah et al. 2016), soil microbial biomass and activity enhancement as well as improved antagonistic effect against plant diseases (Larkin, 2013). Green manure has high antagonistic influence on soil borne pathogen and this is as a result of toxic substance released during the decomposition of incorporated plants (Larkin, 2013; Michel et al., 2014). However, its efficacy to suppress disease varies in crops and cultivar (Larkin, 2013).

*Tithonia* (*Tithonia diversifolia*) from Asteraceae family used as green manure due to its high nutritional composition, has proved effective in improving soil fertility (Mwangi & Mathenge, 2014; Hafifah et al., 2016), physical properties of soil (Hafifah et al., 2016; Dayo-Olagbende et al., 2020) and crop yield (Babajide et al., 2012).

The role of microorganisms is vital in the ecosystem; however, the method of intensive agricultural does not support their healthy population which could result in low productivity (Christopher Johns, 2017). Soil microorganisms are involved in many biogeochemical processes of the soil. Soil microbes are important to life as they play a pivotal role in nutrient cycling and responsible for the biological fertility of the soil (Christopher Johns, 2017). They are great determinant for soil performance through decomposition of plant materials and residues to increase the organic matter content of soil, thereby improving the soil quality (Faissal et al., 2017). Tomato is an important widely grown vegetable. It’s an edible fruit crop with a good source of vitamins and minerals (Olaniyi andAjibola, 2008). One of the factors that limit the production of tomato is disease which could be caused by pathogens such as Viruses, Bacteria, Fungi and Nematodes (Sachdev and Singh, 2017). According to studies, tomato is considered as an important plant for research and studying plant-pathogen interaction due to its susceptibility to different pest and pathogens (Sachdev and Singh, 2017). Tomato disease can rapidly spread from plant to plant in a field where condition is favourable (Damicone and Brandenberger, 2016; Testen and Miller, 2017). It can also be spread from soil to plant (Verticillium wilt, Fusarium wilt, Corky root rot, Black dot root rot and Root rot nematodes) (Damicone and Brandenberger, 2016).

**1.2 Statement of the problem**

The use of inorganic pesticide to control crop disease results in soil degradation, environmental pollution and jeopardizes plants, farm animals, and human health. Hence there is need to seek for an alternative that is eco-friendly and causes no harm to human.

**1.3 Justification**

There has been well documented information on how organic amendments improve soil fertility and productivity. However, research results shows that modern plant protection (via inorganic pesticides) results in toxic residues in food; enhance environmental pollution and elimination of non-target organisms from the ecosystem. There is need to study the potential of some soil organic amendments on disease suppression as well as the response of soil microorganisms to these amendments since soil microorganisms are important energy transformers and nutrient regulator in agro-ecosystems.

**1.4 Objectives**

The main objective of this study was to determine the effects of organic amendments on disease suppression, soil properties and tomato performance.

The specific objectives of this study are to compare inorganic and organic amendments:

1. potential to suppress soil borne diseases in tomato,
2. effects on microbial community in two soil types,
3. effects on some soil physical and chemical properties,
4. effects on growth and yield of tomato.

**CHAPTER TWO**

**Review of Literature**

**2.1 General overview**

The soil is the basis for food production. Soil degradation is a global problem that is especially severe in the tropics and subtropics (Lal, 2015). Intensive management can lead to soil degradation (Scotti et al. 2015) which can be reversed by employing good soil management practices (Faissal et al., 2017). Amending the soil organically is an old strategy to reduce the effect of chemical fertilization which in turn restore the fertility of soil and provide nutrients for crops (Pugliese et al., 2015; Faissal et al., 2017). It was observed by Pugliese et al. (2015), that there is positive correlation between amendment application and control of soil borne diseases. It was also stated that the full potential utilization of organic amendment has not been achieved due to factors like type of amendments use and its application rate, inconsistent efficacy and complexity in their use. Compost is a type of organic amendment produced from the decomposition of organic material in the presence of aerobic microorganisms (Pugliese et al., 2015). It amends the soil, improve crop yield, suppress soil-borne pathogens, reduce effect of green house gases and serve as biological control for plant disease (Das et al., 2017; Ayilara et al., 2020).

**2.2 Effect of Compost on physical and chemical properties of soil**

The study conducted by Das et al. (2017) compared the response of composted cattle and swine manure on microbial activity and soil fertility in rice and reported that the two amendments performed better than control and composted cattle manure improved the chemical properties of the soil. Result of Lee et al. (2019) showed that soil chemical properties of saturated and unsaturated soils were improved in the application of all rates of food waste compost. The result of Kranz et al. (2020) showed that compost incorporation generally improved the physical properties of soil. Bulk density, saturated hydraulic conductivity and soil aeration were improved in the soil treated with tillage and municipal green waste compost (Somverville et al., 2018).

**2.2.1 Effect of Compost on disease suppression and microbial activity in the soil**

Research conducted by Das et al. (2017) reported that composted cattle manure increased microbial biomass carbon than composted swine manure due to enhancement of autochthonous microorganisms of the soil. The study also showed that enzyme activities were significantly increased in the amended soils. Phylum *Proteobacteria* and other dominant phyla like *Firmicutes* spp were highest in soil treated with composted cattle manure. Olabiyi and Oladeji (2014), carried out research using four composts to suppress nematode disease of okra. The results showed that the population of plant parasitic nematode in okra was significantly reduced by compost than the control. Zhao et al. (2018) experiment showed that soil treated with manure and bio organic fertilizer had higher numbers of bacterial and fungal communities. *Proteobacteria* had the highest abundance in addition with other dominant phyla while *Firmicutes* decreased significantly. Moreover, the Fusarium wilt disease incidence was effectively reduced. The result of Enebe and Babalola (2020) on effects of organic and inorganic fertilizer on the microbial community using a shotgun metagenomics method on maize rhizosphere showed that lower dose of organic compost had the same effect as higher dose of inorganic fertilizer which enhanced the abundance, and diversity of the bacteria, fungi, and archaea, which in turn enhance the stability of community at the rhizosphere.

**2.2.2 Effect of compost on crop yield**

Composted cattle manure increased grain yield of submerged rice compared to other treatment and control (Das et al., 2017). Yield and quality of watermelon was improved by composted bio fertilizer compared to other treatments used (Zhao et al., 2018).

**2.3 Poultry manure**

Enujeke (2013) reported that poultry manure is a cheap, effective and richest known animal manure. It improves soil moisture availability which results in nutrient availability to plants for increased growth and yield and maintains the soil physical conditions for efficient plant use.

**2.3.1 Effect of Poultry manure on physical and chemical properties of soil**

Influence of poultry manure was studied by Adeyemo et al. (2019) on infiltration rate, soil organic matter content and maize performance. The results showed that the highest rate of poultry manure applied significantly increased the infiltration rate and organic matter content of soil. In a study carried out by Iren et al. (2015), the results showed that poultry manure and other organic amendments used significantly increased most of the soil chemical properties. Adekiya and Agbede (2017) compared the effect of broadcast and incorporation method of poultry manure on soil and leaf nutrient concentrations of tomato and reported that incorporation of poultry manure significantly increased the chemical properties of soil. It was reported by Hafifah et al. (2016) that poultry manure and grain cotton compost affected the properties of saline soil and reduced bulk density.

**2.3.2 Effect of Poultry manure on Disease suppression and microbial activities in the soil**

An in vitro experiment was carried out on two different concentrations of poultry manure and plant hormones against tobacco mosaic virus (Basit et al., 2021). The results showed that disease severity of tobacco was reduced at the optimum concentration of treatment. Result of Pan et al. (2019) showed that poultry manure restricted fungal colonization on shoots of fresh Zoysia grass by 75%, compared to the control and inhibited the growth of Rhizoctonia solani mycelial on potato dextrose agar after treatment. The study concluded that the fungi inhibition was due to increased bacterial group hence recommending poultry based manure as an alternative for conventional fungicides.

**2.3.3 Effect of Poultry manure on crop yield**

As reported in Iren et al. (2015) soil treated with poultry manure significantly increased growth and yield of waterleaf. In a study carried out by Biratu et al. (2018), the result showed that poultry manure significantly increased root yields of cassava and yield components and concluded that poultry manure is economically efficient. Incorporation method of poultry manure increased the growth and yield of tomato better than broadcast method as reported by Adekiya and Agbede (2017).

**2.4 *Tithonia diversifolia***

*Tithonia diversifolia* is commonly referred to the Mexican sunflower. It’s commonly found along roads in the humid .*Tithonia diversifolia* has potential for maintaining soil fertility (Dayo-Olagbende et al., 2020).

**2.4.1 Effect of *Tithonia diversifolia* on physical and chemical properties of soil**

*Tithonia diversifolia* is a green manure which decomposes rapidly in the soil and increases the organic matter content of soil thereby ameliorates the water holding capacity, acidity and leaching (Mwangi & Mathenge, 2014). Tithonia mulch significantly improved soil quality by reducing soil bulk density, stabilizing the soil structure, lowers soil temperature and increased soil moisture in the soil (Dayo-Olagbende et al., 2020). Application of *Tithonia diversifolia* green manure improved the soil organic matter , decreased soil bulk density, increased soil total pore space, had highest stable aggregate compared to other amendments used and improved the structure of the soil (Hafifah et al., 2016).

**2.4.2 Effect of *Tithonia diversifolia* on disease suppression and microbial activities in the soil**

As reported by Mapa et al. (2016), leaf extracts of invasive *Tithonia diversifolia* potentially reduced the fungal effect in plants at the same time conserving soil biodiversity. Study conducted by Chege and Kimaru (2021) showed that the highest dose of Tithonia extacts has antifungal activity against anthracnose on mycelial growth and sporulation in avocado.

**2.4.3 Effect of *Tithonia diversifolia* on crop yield**

Mwangi and Mathenge (2014) applied *Tithonia diversifolia* as nutrient source of rice and maize. *Tithonia diversifolia* positively improved soil fertility, crop productivity. *Tithonia diversifolia* application improved the growth parameters and yield of Sesame than other treatment studied (Babajide et al., 2012).

**CHAPTER THREE**

**Materials and Methods**

**3.1 Experimental Site:**

The experiment was conducted in the Teaching and Research farm and staff quarters of Landmark University, Omu-Aran, Kwara State, Nigeria. The farm is located behind Old college building of the university in the derived savanna ecological zone of Nigeria (Latitude 08o 9' N and Longitude 5o 61' E) while the coordinates for staff quarters is (Latitude 05o 08915' E and Longitude 08o 12107' N; Elevation 555m). The area’s annual rainfall ranges from 600 - 1,500mm.

**3.2 Experimental layout and design**

The study adopted a two-by-five factorial design. Two sites (site A - sandy loam and site B - sandy soil) and five soil amendments (compost, animal manure, *Tithonia diversifolia*, inorganic fertilizer (NPK: 15:15:15) and control). Each experimental site consists of 15 plots with each measuring 1 × 1m and 0.5 m alley separating each of the plots. The layout of the experiment was randomized complete block design (RCBD) with three replications.

**3.2.1- Experimental layout**

|  |  |  |
| --- | --- | --- |
| Compost | Control | NPK |
| poultry manure | *Tithonia diversifolia* | Control |
| *Tithonia diversifolia* | NPK | poultry manure |
| NPK | poultry manure | Compost |
| Control | Compost | *Tithonia diversifolia* |

**3.3 Sources of organic amendments**

The compost used was purchased from Institute of Agricultural Research and Training (IART) in Ibadan, poultry manure was collected from the poultry section of Landmark University Teaching and Research Farm, *Tithonia diversifolia* was collected from Landmark University Teaching and Research Farm and inorganic fertilizer (NPK: 15:15:15) was purchased from agro-allied store Omu-Aran, Kwara state.

**3.4 Land preparation, manure incorporation, seed sowing and fertilizer application**

Ploughing and harrowing of the two sites was done mechanically using the tractor drawn disc plough and harrow; thereafter the experimental sites were laid out in 1 × 1 m plot sizes. Organic amendments were incorporated at rate of 120kg N/ha using a hoe to a depth of 20 cm approximately. The weight of each amendment applied were compost (3.4t/ha), poultry manure (4.2t/ha), *Tithonia diversifolia* (4.8t/ha) and NPK (0.8t/ha). Before land preparation the tomato seeds were raised in the nursery at a temperature of about 23 0C and watered daily. The plots were permitted for mineralization of amendments before seedlings were transplanted. Transplanting was carried out at cool hours of the day and each seedling was transplanted with some soil beneath to reduce damage on the seedling roots (Adekiya, 2019). Each seedling were transplanted with a spacing of 50 × 50 cm. NPK fertilizer was applied 10cm away from the seedlings a week after transplanting employing the side placement method. Manual weeding was done at interval of 3 weeks after transplanting and the tomato plants were staked at fifth week after transplanting.

**3.4.1 Seed Variety**

The variety used for the experiment was Roman

**3.5 Soil sampling and laboratory analysis**

Prior to the experiment soil samples were taken to determine the initial properties of soil. Samples of soil were taken with a soil auger at a depth of 0-15 cm, for analyses. Collected samples were bulked, air-dried, crushed and sieved through 2mm mesh. Prepared samples were subjected to chemical and physical analysis in the laboratory.

**3.5.1 Determination of Soil acidity**

Acidity of soil was measured with a pH meter in both water and a 1M CaCl2 solution. Two (10g) of prepared sample were weighed inside a specimen bottle and each were mix with 20ml CaCl2 and 20ml of distilled water then shook in a mechanical shaker for 30minutes thereafter; pH readings for each soil sample were recorded.

**3.5.2 Determination of soil organic carbon**

Walkley and Black wet oxidation method was used to determine the soil organic carbon. One (1g) of sediment was taken into 500ml flask then 10ml of 1N K2Cr2O7 and 20ml of concentrated H2SO4 were added and permitted to stand for 30minutes. Thereafter, 100ml of distilled water was totted up with 3 drops of diphenylamine indicator then tititrated against 0.5N ferrous ammonium sulphate till maroon colour was observed.

Organic carbon = (Blank-Titre) x NF x 0.003 x Correction factor x 100

Weight of sample

The organic matter value was estimated by multiplying the organic carbon value with 1.724 **3.5.3 Determination of available phosphorus**

Determination of available phosphorus was done using the modified No. 1 method of Bray (1970). Bray-P solution was measured into a specimen bottle with 5g of prepared soil sample and was left on stand for 30minutes thereafter; chromatography paper was used to filter the suspension then 5ml of extract, 4ml of developed solution (reagent B) were added into a 25ml flask and then filled to mark with distilled water and set aside for 15 minutes to develop light blue color. Using a spectrophotometer, the absorbance was measured at 660nm wavelength. The absorbance values were used to estimate the value of available phosphorus.

**3.5.4 Determination of Exchangeable bases**

Ammonium acetate method of Chapman (1965) was used to determine the exchangeable bases (potassium (K), calcium (Ca), sodium (Na) and magnesium (Mg)). 1N NH4OAC at neutral was used to extract the bases. K and Na were determined using a flame photometer however; titration method was used to determine Ca and Mg using 0.02N EDTA. Ten grams of prepared soil samples was weighed in a 250ml beaker and 100 mL of NH4AC was totted up. Mixtures were placed on the mechanical shaker for 1 hour after which the samples were filtered using filter paper with the aid of a volumetric flask to obtain the extracts.

**3.5.4.1 Ca and Mg determination**

5mL of the extract was measuered with a measuring cylinder into a conical flask, and then 5mL of concentrated NH4OH, 5 drops 2% sodium cyanide and 3 drops of erychrome black T indicator were added and finally titrated with 0.02N EDTA. Color change was observed from colorless to blue at the end point.

For determination of Calcium, 5mL of the extract was measured into a conical flask with 5mL of KOH. 5 drops of 10% hydroxylamine hydrochloride, 5 drops of 2% sodium cyanide and 3 drops of calon as indicators. 0.02N EDTA solution was used for the titration. Color change was observed at the point. The values of calcium and magnesium were estimated as follows:

**3.5.4.2 Determination of Na and K**

The standard of sodium and potassium were prepared with concentration in part per million (ppm). A blank of ammonium acetate extract was also prepared which has no soil sample. This was used to neutralize the flame photometer electrode.

The percentage of flame emission for each of the soil extract was recorded. Sodium and potassium standard were plotted against their various concentration and the extracts were determined using their percentage emission.

**3.5.5 Determination Exchangeable Acidity**

Exchange acidity was determined by weighing 5 g of dried soil into a sample bottle with 50 mL of 1M Kcl. The mixture was shook for an hour then suspension was filtered with a filter paper to obtain filtrate. Inside a 100 mL conical flask, 25 mL of the extract was measured with 5 drops of phenolphthalein indicator and then titrated with 0.02N EDTA until color change was observed. The value of Exchangeable acidity was estimated as follows:

Exchangeable acidity = (T – B) × CNaOH × V1 × 100

Weight of soil × V2

Where, T = titre (mL),

B = blank titre (mL),

W = soil weight (g),

V1 = volume of extracting solution (mL),

V2 = volume of soil extract (mL),

CNaOH = standardized concentration of NaOH (0.002 M NaOH).4

**3.5.6 Total nitrogen**

FOSS KjeltecTM 8200 Auto Distillation Machine was used for the determination of soil total nitrogen. The kjeldhal digestion method was employed. A tablet of Kjeldhal was totted into each digesting tubes where a gram of soil was weighed then 12ml of H2SO4 was totted and mixed thoroughly. Samples were preheated to 4200C on a digester for 1hr to digest the samples. Samples on cooling down were then taken to the automatic distillatory which dispense other reagents and distilled for 5mins. The distillate is then titrated against 0.01M HCL with an automatic titrator.

Total Nitrogen was evaluated by:

Where:

T = Control titer.

M = Molarity of acid.

V2 = Volume of digest used in the digest.

V1 = Final volume of digest.

W = Weight of soil used for digestion.

**3.5.7 Determination of physical analysis**

Initial bulk density was determined by collecting one undisturbed sample from the centre at 0–0.15 m depth of each site at random using a core steel sampler. Moisture content of sample was determined after oven-drying at 100 °C for 24 hours. Particle density of 2.65 g cm-3 was used to evaluate porosity from the bulk density. Five undisturbed samples were taken after harvesting from each plot at 0.15 m away from each tomato plant for the determination of physical properties.

**3.5.8 Textural analysis**

Textural analysis was done by employing hydrometer method (Anderson and Ingram, 1993). 50g of prepared sample was weighed into a conical flask then sodium hexametaphosphate (dispersing agent) was totted and then leave on stand for 16hours. Samples were then transferred into a 1000ml cylinder and distill water was added to mark. After 40 seconds and 2 hours, hydrometer was used to measure the density of the suspension of soil and water. Prior to each reading, a thermometer was used to measure the temperature.

Textural analysis evaluation:

% Silt + % Clay = (R1-B40s) + (T1 – 20) x 0.36 X 100

Weight of soil sample

|  |  |  |
| --- | --- | --- |
| % Clay = | (R2-B2hr) + (T2 – 20) x 0.36 | X 100 |

Weight of soil sample

% Silt = (% Silt + % Clay) – (% Clay)

% Sand = 100 - (% Silt + % Clay)

Where R1 is the first hydrometer reading,

R2 is the second hydrometer reading,

T1 is temperature of suspension at first hydrometer reading,

T2 is temperature of suspension at second hydrometer reading.

**3.5.9 Determination of bulk density**

Determination of bulk density was done by employing the gravimetric method with undisturbed soil samples (Blake and Hartge, 1986).

Calculations:

Bulk density = Mass of oven dry soil (g)

Bulk volume of soil (cm3**)**

**3.5.10 Organic amendment analysis**

Samples of organic amendments (compost manure, poultry manure and green manure) were taken for laboratory analysis. Chemical properties determined were: organic carbon, nitrogen, phosphorus, potassium, calcium and magnesium.

**3.5.11 Microbial analysis**

Samples were collected into polythene bag at random using soil auger and transported for the laboratory for microbial count. The standard plate count agar method was employed. Isolation of bacteria and fungi were done using Potato Dextrose Agar (PDA) and Nutrient Agar (NA) respectively. Fungi and bacteria population were estimated using the 6-fold serial dilution method. The pour plate technique was used to culture fungi and bacteria from 10-3 and 10-5soil dilutions respectively. Incubation of PDA and NA were done at 370c for 3-5 days and 24 hours at 280c respectively. Thereafter; colony-forming units were counted. The frequencies of occurrence of isolates were then calculated.

**3.6 Disease symptom observation**

The tomato plants were observed periodically for disease symptoms. Disease rating was carried out 2 weeks after transplanting base on visible macroscopic symptoms characteristics of the disease observed. The incidence was calculated as follows:

Disease severity was assessed based on scale modified by Lebeda and Buczkowskias described by Popoola et al., (2015).

**3.6.1- Disease severity scale description**

|  |  |  |  |
| --- | --- | --- | --- |
| Severity grade | Features of manifestation | Range of Disease Severity grade | Interpretation |
| 1 | Plants with 21-50% yellow leaves | 0.00-1.44 | Immune |
| 2 | Plants with 5 % yellow leaves- very minute wilting | 1.45–2.44 | Resistant |
| 3 | Plants with 6-10% yellow leaves - less wilting | 2.45–3.44 | Moderately resistant |
| 4 | Plants with 11-20% yellow leaves - moderate wilting | 3.45 – 4.44 | Moderately susceptible |
| 5 | Plants with 21-50% yellow leaves - severe wilting | 4.45 – 5.44 | Susceptible |
| 6 | Plants with above 50% yellow leaves- very severe wilting | Above 5.45 | Highly susceptible |

**3.7 Growth and yield data collection**

Parameters measured for growth were: height of plant, number of leaflet and leaf area. Data was collected from two tagged plants. The average of the two (2) tagged plantsmeasured per plot was used for data analysis.

**3.7.1 Height of plant (cm)**

Plant height was measured from the base of the plant to the peak point of the main stem.

**3.7.2 Number of leaflets:**

The number of leaflets was counted manually.

**3.7.3 Leaf area (cm2)**

Leaf length (cm) and width (cm) was measured using a measuring tape. The leaf area was then calculated as follows: Length x Width x 0.5 (Carmassi et al., 2007).

**3.7.4** Y**ield parameters**

Tomato fruit were harvested and weighed from up to 100 days after transplanting (Adekiya, 2019).

**3.8 Statistical analysis**

Data collected were subjected to analysis of variance (ANOVA) using statistical package for social sciences (SPSS Institute Inc. 2009). Significant means difference were by Duncan multiple range test at 0.05 level of probability.

**CHAPTER FOUR**

**RESULTS AND DISCUSSION**

**4.1 Results**

**4.1.1 Initial properties of study sites prior to planting**

The textural class of soils in site A and site B indicates sandy loam and sandy soil respectively. Site A contains (81.12% sand, 7% silt and 11.88% clay) and site B contains (90.6% sand, 4% silt and 5.4% clay). The pH of site A (5.3 in H20 and 5.2 in CaCl2) shows strong acidity while, site B (7.3 in H20 and 6.5 in CaCl2) is characterized by slight acidity (FFD, 2011). Exchangeable acidity of site A is higher (2.9 cmol kg-1) than site B (1.6 cmol kg-1) which shows that site A is highly acidic than site B. The organic carbon of site B is higher (1.6%) than site A (1.1%). Hence, the organic matter content of site B is higher (2.8%) than site A (1.8%). The exchangeable calcium (Ca2+) for site A and site B contains 3 and 2.7 cmol kg-1sequentially. Magnesium (Mg2+) contents of the two sites were 1.3 cmol kg-1 and 2.7 cmol kg-1accordingly. The exchangeable sodium (Na+) content of the soils were 0.1 cmol kg-1 and 0.01 cmol kg-1sequentially. Potassium (K2+) contents of the two sites were 0.12 cmol kg-1 and 0.18 cmol kg-1accordingly. Phosphorus level in site A is extremely low (7.6 mg kg-1) compare to site B (24.5 mg kg-1). The moisture content and porosity of site B is higher (14.0%, 36.2%) than site A (12.0%, 35.5) while the bulk density of site B (1.69 g/cm3) is lower than site A (1.71 g/cm3) which show that soil in site B is porous than site A.

**Table 1: Initial properties of study sites prior to planting**

|  |  |  |
| --- | --- | --- |
| SOIL PARAMETERS | SITE A | SITE B |
| pH in H20 | 5.3b | 7.3a |
| pH in CaCl2 | 5.2b | 6.5a |
| Exchangeable acidity(cmol/ kg) | 2.9a | 1.6b |
| Organic carbon (%) | 1.1b | 1.6a |
| Organic matter (%) | 1.8b | 2.8a |
| Phosphorus (mg/kg) | 7.6b | 24.5a |
| Calcium (cmol/kg) | 3.0a | 2.7b |
| Magnesium (cmol/kg) | 1.3b | 2.7a |
| Sodium (cmol/kg) | 0.1a | 0.01b |
| Potassium (cmol/kg) | 0.12b | 0.18a |
| Bulk density (g/cm3) | 1.53a | 1.51b |
| Moisture content (%) | 12.0b | 14.0a |
| Porosity (%) | 35.5b | 36.2a |
| **Particle size distribution** |  |  |
| Sand (%) | 81.12 | 90.6 |
| Silt (%) | 7.0 | 4.0 |
| Clay (%) | 11.88 | 5.4 |
| Textural class | Sandy loam | Sandy |

**4.1.2 Nutrient component of the organic amendments used**

The organic carbon content of compost is higher (52.0%) than poultry manure (26.4%) and *Tithonia diversifolia* (17.4%). The nitrogen content of compost is higher (3.5%) than poultry manure (2.85%) and *Tithonia diversifolia* (2.5%). The calcium content of compost is 2.65 cmol/kg, poultry manure is 1.5 cmol/kg and *Tithonia diversifolia*is 1.73 cmol/kg. *Tithonia diversifolia* has the highest (11.27 cmol/kg) magnesium content follow by poultry manure (5.7 cmol/kg) while compost has the lowest (4.85 cmol/kg). However, compost has the highest (0.42 cmol/kg) potassium content follow by poultry manure (0.34 cmol/kg) and *Tithonia diversifolia* (0.3 cmol/kg) has the lowest level of potassium. All the amendments have the same sodium content 0.01 cmol/kg.

**Table 2: Chemical component of the organic amendments used for the study**

|  |  |  |  |
| --- | --- | --- | --- |
| PARAMETERS | COMPOST | POULTRY MANURE | *TITHONIA DIVERSIFOLIA* |
| Organic carbon (%) 52.0a | | 26.4b | 17.4c |
| Nitrogen (%) | 3.5a | 2.9b | 2.5c |
| Calcium (cmol/kg) | 2.7a | 1.5c | 1.7b |
| Magnesium (cmol/kg) | 4.9c | 5.7b | 11.3a |
| Sodium (cmol/kg) | 0.01a | 0.01a | 0.01a |
| Potassium (cmol/kg) | 0.4a | 0.3b | 0.3b |

**4.1.3 Effect of sites and amendments (organic and inorganic) on disease incidence of tomato**

Table 3 shows that at 2 weeks after transplanting (WAT) the disease incidence was not significantly different between the 2 sites. The results show that site B had less disease incidence (66.67) than site A (86.67). At 3WAT and across other weeks of sampling, significance differences were observed between the two study sites with site B having less disease incidence. The mean effect of the amendments on disease incidence is significant at 3 and 4 weeks after transplanting. There was no significant interaction between the study sites and amendments applied.

Among the amendments, *Tithonia diversifolia* had the highest value of disease incidence at 2 WAT and 3 WAT. It had the same value with NPK from week 5 to week 7. Control had the second to highest from week 2 to 8 except week 4 where it had the highest. NPK had similar disease incidence as *Tithonia diversifolia* from 5 WAT to 7 WAT and had the highest value of disease incidence at week 8. However, compost and poultry manure had lowest disease incidence from week 3 to 7 and similar value at weeks 5 to 8.

**Table 3: Effect of sites and amendments (organic and inorganic) on disease incidence of tomato**

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Treatments | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| Sites (S) | Weeks after transplanting | | | | | | |
| Site A | 86.67a | 70.00a | 53.33a | 100.00a | 100.00a | 100.00a | 100.00a |
| Site B | 66.67b | 23.33b | 20.00b | 50.00b | 50.00b | 50.00b | 50.00b |
| Amendments (A) |  |  |  |  |  |  |  |
| Compost | 77.78ab | 22.22b | 11.11b | 55.56a | 55.56a | 55.56ab | 66.67ab |
| Poultry manure | 55.86b | 22.22b | 16.67b | 55.56a | 55.56a | 55.56ab | 66.67ab |
| *Tithonia diversifolia* | 88.89a | 66.67a | 44.44a | 77.78a | 77.78a | 77.78b | 55.56b |
| NPK | 61.11ab | 22.22b | 33.33ab | 77.78a | 77.78a | 77.78a | 77.78a |
| Control | 83.33ab | 61.11a | 55.55a | 66.67a | 66.67a | 66.67ab | 66.67ab |
| ANOVA response |  |  |  |  |  |  |  |
| S | .11 | .00 | .00 | .00 | .00 | .00 | .00 |
| A | .09 | .00 | .00 | .06 | .06 | .06 | .06 |
| S\*A | .98 | .32 | .06 | .75 | .75 | .75 | .75 |

**4.1.4 Effect of sites and amendments (organic and inorganic) on disease severity of tomato**

Disease severity in site A was significantly higher (3.27-5) than site B (1.67-2.33) across all weeks of study. There was no significant interaction of disease severity at the sites and amendments across the weeks of observation. The mean effect of amendment shows that disease severity was significantly reduced by the amendments applied at 2, 3, 4 and 5 weeks after transplanting. Across the 8 weeks of study, the amendments significantly reduced disease severity compare to the control. At 2 WAT Compost and poultry manure significantly reduced disease severity than other amendments with compost having the least severity. At 3 and 4 WAT compost, poultry manure, and *Tithonia diversifolia* significantly reduced disease severity than NPK and control. At 5, 6 and 7 WAT compost and poultry manure significantly reduced disease severity than NPK and control but not than *Tithonia diversifolia*with compost and poultry manure having the least severity. At 8WAT the disease severity in all the treatments are not significantly different from the control with compost, poultry manure and *Tithonia diversifolia* having the least severity.

**Table 4: Effect of sites and amendments (organic and inorganic) on disease severity of tomato**

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Treatments | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| Sites (S) | Weeks after transplanting | | | | | | |
| Site A | 3.33a | 3.27a | 3.60a | 5.00a | 5.00a | 5.00a | 5.00a |
| Site B | 2.00b | 1.67b | 1.80b | 1.80b | 2.07b | 2.07b | 2.33b |
| Amendments (A) |  |  |  |  |  |  |  |
| Compost | 1.67b | 1.56c | 1.78b | 2.33c | 2.78b | 2.78b | 3.00a |
| Poultry manure | 2.44ab | 1.56c | 1.56b | 2.33c | 2.78b | 2.78b | 3.00a |
| *Tithonia diversifoliar* | 2.56a | 2.11bc | 2.11b | 2.78bc | 3.00ab | 3.00ab | 3.00a |
| NPK | 2.67a | 2.44b | 3.00a | 3.22ab | 3.40a | 3.44a | 3.44a |
| Control | 2.89a | 3.33a | 3.56a | 3.67a | 3.22ab | 3.22ab | 3.67a |
| ANOVA response |  |  |  |  |  |  |  |
| S | .00 | .00 | .00 | .00 | .00 | .00 | .00 |
| A | .05 | .00 | .00 | .00 | .07 | .07 | .40 |
| S\*A | .12 | .53 | .99 | .18 | .77 | .77 | .97 |

**4.1.5 Effect of sites and amendments (organic and inorganic) on number of leaflets, plant height, leaf area and yield of tomato**

The results show that numbers of leaflets were not significantly different from each other at the two study sites at 2 WAT. However, site A was significantly lower (45-0) than site B (264-1068.33) across the weeks of sampling. The ANOVA response of amendments shows that the treatments did not significantly influence the number of leaflets across the weeks of sampling. However there was no significant interaction between the study sites and the amendment used across the weeks. At 2 WAT after transplanting, control was significantly higher than other treatments. However, from week 4 to 8, compost had the highest significant number of leaves follow by poultry manure, NPK, control then *Tithonia diversifolia*.

The table also shows the effects of amendment on height of tomato planted in two sites. The result shows that there was significant difference at week 2 and 4 between the sites with site B having taller plants (2.93 - 8.76 cm) than A (2.24 – 0.00 cm) across weeks of sampling. The overall mean effect of amendments shows that there was significant difference across the weeks of sampling. Significant difference was also noticed in the sites and treatments interaction at 2 and 4 WAT.

Among the amendments, *Tithonia diversifolia* was significantly different from all other treatment at 2 WAT, compost was significantly higher than poultry manure and poultry manure was significantly higher than NPK and control however, there was no significant difference between NPK and control. As observed from the table *Tithonia diversifolia* had the highest value in weeks 2 and 4, followed by compost, poultry manure, NPK then control. At 4 WAT, plant height was significantly influenced by *Tithonia diversifolia* than other treatments. Compost does not significantly differ from poultry manure but from NPK and control. At 6 WAT compost and *Tithonia diversifolia* significantly differ from control but not different from poultry manure and NPK with *Tithonia diversifolia* had the highest value while control had the lowest. At 8 WAT poultry manure was significantly higher than other treatments while compost, *Tithonia diversifolia*, NPK and control do not significantly differ from each other.

The response of tomato leaf area to amendments is also presented in table 5. No significant difference was observed at 2WAT in the two sites, while significant difference was observed from week 4-8. At week 6 and 8, significant difference was observed among the amendments used. However, between sites and treatments there was no significant interaction. The results also indicated that at 2 WAT all treatments were not significantly different with compost having the highest leaf area. At week 4 all the treatments significantly differ from the control with compost and poultry manure having highest. At 6 WAT compost is significantly influence than other treatments except from poultry manure which was not significantly different from all other treatments. At week 8, NPK had the highest value and it was significantly different from all other treatments. All other treatments do not significantly differ from each other with control having the lowest.

The mean value of yield also shows that site B is significantly higher in yield than A. Among the treatments, compost has maximum fruit yield while control had the lowest.

**Table 5: Effect of sites and amendments (organic and inorganic) on number of leaflets, plant height, leaf area and yield of tomato**

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Treatments | Number of leaflets | | | | Plant height (cm) | | | | Leaf area(cm2) | | | | Yield |
| Sites (S) | 2 WAT | 4WAT | 6 WAT | 8 WAT | 2WAT | 4WAT | 6WAT | 8WAT | 2WAT | 4 WAT | 6WAT | 8 WAT |  |
| Site A | 30.77a | 45.00b | 9.60b | 0.00b | 2.24b | 3.00b | 5.13a | 0.00b | 4.24b | 4.61b | 7.20b | 0.00b | 10.67b |
| Site B | 47.77a | 264.00a | 829.77a | 1068.33a | 2.93a | 3.70a | 5.05b | 8.76a | 4.76a | 13.84a | 19.49a | 22.77a | 456.28a |
| Amendment(A) |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Compost | 53.61ab | 317.83a | 1062.78a | 1187.78a | 2.36b | 2.80ab | 6.11a | 8.30b | 5.53a | 12.48a | 20.61a | 11.66bc | 556.87a |
| Poultry manure | 31.44bc | 251.61ab | 639.67b | 775.33b | 1.78c | 2.36bc | 4.98ab | 10.91a | 5.37a | 12.48a | 14.19ab | 16.54ab | 472.87ab |
| *Tithonia*  *diversifoliar* | 27.11c | 87.00c | 280.56c | 364.89c | 3.22a | 4.11a | 6.68a | 6.21b | 3.60a | 7.40a | 9.29b | 18.97ab | 226.35abc |
| NPK | 30.78bc | 162.78b | 407.33bc | 640.78bc | 1.11d | 1.62c | 4.27ab | 8.62ab | 3.66a | 9.80a | 12.79b | 21.68a | 117.39bc |
| Control | 67.56a | 135.78bc | 391.56bc | 592.33bc | 1.30cd | 1.34d | 3.34b | 8.32b | 4.79a | 7.05c | 8.12b | 11.65bc | 105.23c |
| ANOVA response |  |  |  |  |  |  |  |  |  |  |  |  |  |
| S | .09 | .00 | .00 | .00 | .00 | .00 | .99 | .00 | .83 | .00 | .00 | .00 | .00 |
| A | .00 | .00 | .00 | .00 | .00 | .00 | .04 | .01 | .39 | .37 | .015 | .00 | .04 |
| S\*A | .11 | .49 | .06 | .23 | .00 | .01 | .12 | .71 | .66 | .81 | .51 | .30 | .73 |

**4.1.6 Response of soil microbial diversity and total number (bacteria and fungi) to organic and inorganic amendments in the two study sites**

Table 6 shows that at site A, poultry manure had 21 diversity of bacteria followed by *Tithonia diversifolia* (21), NPK (18), control (17) and compost had the lowest (12). The decreasing order of total number of bacteria is compost (2945) >*Tithonia diversifolia* (1290) > NPK (964) > poultry manure (740) > control (159). However, at site B, *Tithonia diversifolia* had the highest bacteria diversity (20), followed by control (19), followed by poultry manure (18) and followed by compost which had the lowest diversity (11). The decreasing order of total number of organisms is as follows poultry manure > control > NPK > compost >*Tithonia diversifolia.* For fungi, at site A, compost had the highest fungi diversity (37) followed by NPK (29), followed by poultry manure (24), followed by *Tithonia diversifolia* (20) and control (20). Compost had the highest number of fungi (350), *Tithonia diversifolia* had (171), poultry manure and NPK had the same number of fungi (127) and control had the lowest (75). However at site B, NPK had the highest diversity of fungi (21), followed by compost (19), followed by poultry manure (18), followed by *Tithonia diversifolia* (17) and control had the lowest (16) while the order of total number of fungi at site B is compost (215) > NPK (165) > poultry manure (146) >*Tithonia diversifolia* (125) > control (101).

**Table 6: Response of soil microbial diversity and total number (bacteria and fungi) to organic and inorganic amendments in the two study sites**

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| TREATMENTS | DIVERSITY OF BACTERIA (SITE A) | DIVERSITY OF BACTERIA (SITE B) | TOTAL NUMBER OF BACTERIA (SITE A) | TOTAL NUMBER OF BACTERIA (SITE B) | DIVERSITY OF FUNGI  (SITE A) | DIVERSITY OF FUNGI  (SITE B) | TOTAL NUMBER OF FUNGI (SITE A) | TOTAL NUMBER OF FUNGI  (SITE B) |
| Compost | 12 | 11 | 2945 | 368 | 37 | 19 | 350 | 215 |
| Poultry manure | 21 | 18 | 740 | 1406 | 24 | 18 | 127 | 146 |
| *Tithonia diversifolia* | 21 | 20 | 1290 | 228 | 20 | 17 | 171 | 125 |
| NPK | 18 | 18 | 964 | 868 | 29 | 21 | 127 | 165 |
| Control | 17 | 19 | 159 | 991 | 20 | 16 | 75 | 101 |
| Initial | 8 | 14 | 78 | 319 | 8 | 16 | 16 | 76 |

**4.1.7 Frequency of occurrence of organism (bacteria and fungi) at the two study sites**

**4.1.7.1 Frequency of occurrence (%) of bacteria in site A**

Organism (ORG) 1 was suppressed in all treatment including control. ORG 2 is present only in *Tithonia diversifolia*. ORG 3 was enhanced in compost, poultry manure and control. ORG 4 was present in all treatment and control except compost. ORG 5 and 6 were enhanced in all treatments and control however ORG 7 was suppressed in compost and control. Organisms 9-48 were absent in the initial. ORG 9, 10 and 14 were observed in compost amended plots only. ORG 11 was observed in all treatments and absent in control. ORG 12 occurred only in compost and poultry manure only. ORG 13 occurred in compost and *Tithonia diversifolia* only. ORG 15 is observed in compost, NPK and *Tithonia diversifolia.* ORG 16-21, 22 and 25 growths were enhanced in *Tithonia diversifolia* treated plot. ORG 18 and 27 were observed in all plots except compost amended plot. ORG 24 was observed in *Tithonia diversifolia*, NPK and control plots. ORG 26 growth was enhanced in poultry manure, NPK and *Tithonia diversifolia* plot however was suppressed in compost and control. ORG 28-29, 31, 33 and 34 occurred in NPK plots only. ORG 30 growth was enhanced in NPK and control only. ORG 32 occurred in poultry manure, *Tithonia diversifolia* and control. Percentage of occurrence of ORG 35-42 were observed in poultry manure plots and suppressed in other plots including control. ORG 43-48 occurred in control plots only.

**Table 7a: Frequency of occurrence (%) of bacteria in site A**

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| ORGANISMS | INTIAL | COMPOST | POULTRY MANURE | TITHONIA | NPK | CONTROL | ORGANISMS | POULTRY MANURE | TITHONIA | NPK | CONTROL |
| ORG 1 | 41 | 24.8 | 14.1 | 13.5 | 12.3 | 27.04 | ORG 25 |  | 0.07 |  |  |
| ORG 2 | 6.4 |  |  | 0.16 |  |  | ORG 26 | 0.13 | 0.16 | 0.2 |  |
| ORG 3 | 1.3 | 1.6 | 0.3 |  |  | 4.4 | ORG 27 | 0.54 | 0.07 | 0.7 | 1.3 |
| ORG 4 | 10.2 |  | 6.1 | 6.7 | 13 | 5.03 | ORG 28 |  |  | 0.1 |  |
| ORG 5 | 1.3 | 3.8 | 2.4 | 7.6 | 4.9 | 4.4 | ORG 29 |  |  | 0.1 |  |
| ORG 6 | 14.1 | 45 | 22.3 | 28.5 | 24.1 | 30.2 | ORG 30 |  |  | 0.62 | 0.62 |
| ORG 7 | 24.4 | 19.63 | 51.1 | 42.6 | 42.4 |  | ORG 31 |  |  | 0.1 |  |
| ORG 8 | 1.3 |  | 0.4 | 0.07 |  | 0.62 | ORG 32 | 0.13 |  | 0.1 | 0.62 |
| ORG 9 |  | 0.03 |  |  |  |  | ORG 33 |  |  | 0.52 |  |
| ORG 10 |  | 0.06 |  |  |  |  | ORG 34 |  |  | 0.1 |  |
| ORG 11 |  | 2.1 | 0.3 | 0.07 | 0.2 |  | ORG 35 | 0.13 |  |  |  |
| ORG 12 |  | 0.1 | 0.13 |  |  |  | ORG 36 | 0.4 |  |  |  |
| ORG 13 |  | 0.06 |  | 0.07 |  |  | ORG 37 | 0.4 |  |  |  |
| ORG 14 |  | 2.8 |  |  |  |  | ORG 38 | 0.3 |  |  |  |
| ORG 15 |  | 0.03 |  | 0.07 | 0.2 |  | ORG 39 | 0.3 |  |  |  |
| ORG 16 |  |  |  | 0.31 |  |  | ORG 40 | 0.13 |  |  |  |
| ORG 17 |  |  |  | 0.31 |  |  | ORG 41 | 0.13 |  |  |  |
| ORG 18 |  |  | 0.13 | 0.16 | 0.1 | 0.62 | ORG 42 | 0.3 |  |  |  |
| ORG 19 |  |  |  | 0.07 |  |  | ORG 43 |  |  |  | 4.4 |
| ORG 20 |  |  |  | 0.07 |  |  | ORG 44 |  |  |  | 8.8 |
| ORG 21 |  |  |  | 0.07 |  |  | ORG 45 |  |  |  | 5 |
| ORG 22 |  |  |  | 0.07 |  |  | ORG 46 |  |  |  | 0.62 |
| ORG 23 |  |  |  |  |  |  | ORG 47 |  |  |  | 4.4 |
| ORG 24 |  |  |  | 0.07 | 0.2 | 1.3 | ORG 48 |  |  |  | 0.62 |

ORG-organism

**4.1.7.2 Frequency of occurrence (%) of fungi in site A**

ORG 1 and 5 were suppressed in all the treated plots and control. ORG 2 was absent in all treatments including control plot. ORG 3 was enhanced in NPK and suppressed by other treatments and control. ORG 4 was enhanced by compost, *Tithonia divesifolia,* and control however suppressed by poultry manure and NPK. ORG 6 occurred only in NPK. ORG 7 and ORG 8 were suppressed by the treatments. Organisms 9 - 81 were absent in the initial. ORG 9-10, 12-14, 17-18, 20-23, 25, 29-30, 33-39 were enhanced in compost treated plots only. ORG 11 occurred in compost, *Tithonia divesifolia,* and control. ORG 15, 19 and 31 were absent in NPK and occurred in other plots. ORG 16 occurred only in compost and *Tithonia divesifolia.* ORG 24, 26-28 occurred only in compost and poultry manure plots. ORG 32 occurred in the organic amended plots. ORG 40-48, 50-51, 53-55 were observed in NPK plot. ORG 56-58, 61-63,66-67 were observed only in poultry manure plots. ORG 59 occurred in poultry manure and *Tithonia diversifolia*. ORG 60, 64 and 65 were observed in poultry manure and control plots. *Tithonia diversifolia* treated plots enhanced the growth of ORG 68-73. ORG 74 was observed in *Tithonia diversifolia* and control. ORG 75-81 were observed in control plot.

**Table 7b: Frequency of occurrence (%) of fungi in site A**

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| ORGANISMS | INTIAL | COMPOST | POULTRY MANURE | TITHONIA | NPK | CONTROL | ORGANISMS | POULTRY MANURE | TITHONIA | CONTROL |
| ORG 1 | 12.5 | 2.3 | 7.7 | 1.75 | 6.3 | 1.3 | ORG 41 |  |  |  |
| ORG 2 | 25 |  |  |  |  |  | ORG 42 |  |  |  |
| ORG 3 | 12.5 | 1.1 | 5.5 | 7.6 | 44.1 |  | ORG 43 |  |  |  |
| ORG 4 | 6.25 | 6.3 |  | 20.47 |  | 9.3 | ORG 44 |  |  |  |
| ORG 5 | 25 | 0.6 | 2.36 | 1.75 | 4.7 | 5.3 | ORG 45 |  |  |  |
| ORG 6 | 6.25 |  |  |  | 1.6 |  | ORG 46 |  |  |  |
| ORG 7 | 6.25 | 0.9 |  | 0.58 | 1.6 |  | ORG 47 |  |  |  |
| ORG 8 | 6.25 | 1.14 |  | 1.2 |  |  | ORG 48 |  |  |  |
| ORG 9 |  | 0.3 |  |  |  |  | ORG 49 | 2.4 |  |  |
| ORG 10 |  | 0.6 |  |  |  |  | ORG 50 |  |  |  |
| ORG 11 |  | 2.6 |  | 4.7 |  | 1.3 | ORG 51 |  |  |  |
| ORG 12 |  | 1.1 |  |  |  |  | ORG 52 |  |  | 1.3 |
| ORG 13 |  | 0.6 |  |  |  |  | ORG 53 |  |  |  |
| ORG 14 |  | 1.4 |  |  |  |  | ORG 54 |  |  |  |
| ORG 15 |  | 8 | 1.6 | 1.8 |  | 1.3 | ORG 55 |  |  |  |
| ORG 16 |  | 35.7 |  | 0.6 |  |  | ORG 56 | 0.8 |  |  |
| ORG 17 |  | 9.4 |  |  |  |  | ORG 57 | 0.8 |  |  |
| ORG 18 |  | 2.3 |  |  |  |  | ORG 58 | 0.8 |  |  |
| ORG 19 |  | 4.6 | 5.5 | 7.6 |  | 4 | ORG 59 | 2.4 | 1.8 |  |
| ORG 20 |  | 0.3 |  |  |  |  | ORG 60 | 10.2 |  | 26.7 |
| ORG 21 |  | 0.6 |  |  |  |  | ORG 61 | 0.8 |  |  |
| ORG 22 |  | 0.3 |  |  |  |  | ORG 62 | 8.7 |  |  |
| ORG 23 |  | 0.3 |  |  |  |  | ORG 63 | 0.8 |  |  |
| ORG 24 |  | 5.7 | 6.3 |  |  | 1.3 | ORG 64 | 0.8 |  | 8 |
| ORG 25 |  | 0.9 |  |  |  |  | ORG 65 | 1.6 |  | 2.7 |
| ORG 26 |  | 0.3 | 0.8 |  |  |  | ORG 66 | 0.8 |  |  |
| ORG 27 |  | 0.3 | 7.9 |  |  |  | ORG 67 | 0.8 |  |  |
| ORG 28 |  | 0.9 | 2.4 |  |  |  | ORG 68 |  | 1.2 |  |
| ORG 29 |  | 0.6 |  |  |  |  | ORG 69 |  | 40.4 |  |
| ORG 30 |  | 0.9 |  |  |  |  | ORG 70 |  | 0.6 |  |
| ORG 31 |  | 2.6 | 10.2 | 2.3 |  | 1.3 | ORG 71 |  | 0.6 |  |
| ORG 32 |  | 0.3 | 1.6 | 1.8 |  |  | ORG 72 |  | 0.6 |  |
| ORG 33 |  | 5.1 |  |  |  |  | ORG 73 |  | 0.6 | 4 |
| ORG 34 |  | 0.6 |  |  |  |  | ORG 74 |  | 0.6 |  |
| ORG 35 |  | 0.3 |  |  |  |  | ORG 75 |  |  | 8 |
| ORG 36 |  | 0.3 |  |  |  |  | ORG 76 |  |  | 5.3 |
| ORG 37 |  | 0.3 |  |  |  |  | ORG 77 |  |  | 1.3 |
| ORG 38 |  | 0.6 |  |  |  |  | ORG 78 |  |  | 12 |
| ORG 39 |  | 0.3 |  |  |  |  | ORG 79 |  |  | 2.7 |
| ORG 40 |  |  |  |  |  |  | ORG 80 |  |  | 2.7 |
|  |  |  |  |  |  |  | ORG 81 |  |  | 1.3 |

ORG-organism

**4.1.7.3 Frequency of occurrence (%) of bacteria in site B**

ORG 1 and 4 were present only in the initial soil. ORG 2 and 3 were suppressed by all the treatments and enhanced by control. ORG 5 was enhanced only in poultry manure treated plot however suppressed in other treatments including control. ORG 6 was enhanced in all treatments and control except NPK. ORG 7 was suppressed in all treatments except NPK. ORG 8 was suppressed in all treatment and was enhanced in *Tithonia diversifolia*. ORG 9 was enhanced in all treatment and suppressed by control. ORG 10 was enhanced in compost and poultry manure plots and suppressed in all other plots*.* ORG 11 was enhanced in *Tithonia diversifolia*, NPK and control and suppressed in compost and poultry manure. ORG 12 was enhanced by all treatments and control except *Tithonia diversifolia*. However, ORG 13 was only enhanced in *Tithonia diversifolia* and suppressed in all other treatments including control. ORG 14 was suppressed in all treatments. Organisms 15-46 were absent in the initial. ORG 15 occurred only in poultry manure and *Tithonia diversifolia*. ORG 16 occurred only in *Tithonia diversifolia*. ORG 17 occurred in all treatments except control. ORG 18 was enhanced by poultry manure, *Tithonia diversifolia*, and NPK. ORG 19 was enhanced by poultry manure, *Tithonia diversifolia*, and control. ORG 20 was enhanced only in *Tithonia diversifolia*. ORG 21 occurred only in *Tithonia diversifolia* and NPK. ORG 22 was enhanced in all treatments and control except NPK. ORG 23 occurred in compost, poultry manure and *Tithonia diversifolia*, however, absent in NPK and control. ORG 24 and 25 occurred only in compost and poultry manure treated plot. ORG 26 occurred only in poultry manure and *Tithonia diversifolia*. ORG 27 occurred only in *Tithonia diversifolia*. ORG 28 and 29 were enhanced by poultry manure only. ORG 30-35 were enhanced by NPK only. ORG 34 was enhanced by NPK and control. ORG 36-46 occurred only in control.

**Table 7c: Frequency of occurrence (%) of bacteria in site B**

|  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| ORGANISMS | INTIAL | COMPOST | POULTRY MANURE | TITHONIA | NPK | CONTROL | ORGANISMS | COMPOST | POULTRY MANURE | TITHONIA | NPK | CONTROL |
| ORG 1 | 0.6 |  |  |  |  |  | ORG 24 | 0.3 |  | 0.4 |  |  |
| ORG 2 | 0.6 |  | 0.5 |  | 0.3 | 1.6 | ORG 25 | 0.3 |  | 0.4 |  |  |
| ORG 3 | 1.3 |  |  |  |  | 0.2 | ORG 26 |  | 0.5 | 3.5 |  |  |
| ORG 4 | 0.3 |  |  |  |  |  | ORG 27 |  |  | 0.4 |  |  |
| ORG 5 | 1.3 |  | 0.07 |  |  |  | ORG 28 |  | 0.1 |  |  |  |
| ORG 6 | 0.3 | 1.9 | 0.9 | 2.2 |  | 3.1 | ORG 29 |  | 0.2 |  |  |  |
| ORG 7 | 9.1 |  |  |  | 0.8 |  | ORG 30 |  |  |  | 0.1 |  |
| ORG 8 | 16.9 | 6.25 | 8.7 | 18.4 | 6.5 | 7.9 | ORG 31 |  |  |  | 0.1 |  |
| ORG 9 | 27.6 | 40.8 | 41.3 | 29.4 | 51.4 | 21.1 | ORG 32 |  |  |  | 0.1 |  |
| ORG 10 | 36.3 | 38.6 | 43.1 | 20.6 | 34.9 | 16.4 | ORG 33 |  |  |  | 0.1 |  |
| ORG 11 | 0.6 | 0.5 | 0.4 | 3.1 | 1 | 40.1 | ORG 34 |  |  |  | 0.1 | 0.2 |
| ORG 12 | 1.3 | 2.1 | 2 | 0.9 | 2.1 | 3.3 | ORG 35 |  |  |  | 0.1 |  |
| ORG 13 | 1.3 |  | 0.1 | 2.6 | 0.3 |  | ORG 36 |  |  |  |  |  |
| ORG 14 | 2.5 |  |  |  | 0.3 |  | ORG 37 |  |  |  |  | 1.4 |
| ORG 15 |  |  | 0.14 | 1.3 |  |  | ORG 38 |  |  |  |  |  |
| ORG 16 |  |  |  | 4.4 |  |  | ORG 39 |  |  |  |  | 0.9 |
| ORG 17 |  | 0.3 | 0.2 | 1.8 | 0.1 |  | ORG 40 |  |  |  |  | 0.2 |
| ORG 18 |  |  | 0.14 | 1.3 | 0.1 |  | ORG 41 |  |  |  |  |  |
| ORG 19 |  |  | 0.14 | 0.9 |  | 0.3 | ORG 42 |  |  |  |  | 0.3 |
| ORG 20 |  |  |  | 0.9 |  |  | ORG 43 |  |  |  |  | 0.1 |
| ORG 21 |  |  |  | 1.3 | 1.3 |  | ORG 44 |  |  |  |  | 1 |
| ORG 22 |  | 3.5 | 1 | 5.3 |  | 0.2 | ORG 45 |  |  |  |  | 0.1 |
| ORG 23 |  | 0.8 | 0.4 | 1.3 |  |  | ORG 46 |  |  |  |  | 0.8 |

ORG-organism

**4.1.7.4 Frequency of occurrence (%) of fungi in site B**

All treatments increased the percentage of occurrence of organism (ORG) 1 except the control compared to the initial. Poultry manure having the highest while control had the least. ORG 2 and 8 were encountered only in the initial soil sample. ORG 3 and 4 were enhanced by compost, *Tithonia diversifolia*, and NPK, while control and poultry manure suppressed its growth. ORG 5, 7, 9, and 13 were suppressed in all the treatments and control. ORG 10 and 12 were enhanced by compost and NPK while it was suppressed by poultry manure, *Tithonia diversifolia*, and control. ORG 11 was enhanced by NPK and control while it was suppressed in compost, poultry manure, and *Tithonia diversifolia.* Control increased the percentage of occurrence of ORG 15. ORG 16 was enhanced by compost and *Tithonia diversifolia* only. Organisms 17-39 were absent in the initial. ORG 17 is common to all amended soils including control in order of Compost > *Tithonia diversifolia* > control >NPK > PM. ORG 18 occurred most in poultry manure and had it least percentage occurrence in compost. ORG 19 occurred most in control and least in compost. ORG 20 was enhanced all treatments and control except poultry manure. ORG 21 and 24 occurred only in compost. ORG 22 and 23 were enhanced by all the treatment except control. ORG 25 and 26 occurred only in NPK and control. ORG 27 and 29 occurred only in control. ORG 30 and 32 were enhanced in *Tithonia diversifolia* and NPK treated plot and suppressed in other plots. ORG 31 was enhanced in NPK treated soil however suppressed in other plots. ORG 33 and 34 were enhanced by poultry manure, however suppressed in other plots. ORG 35 and 36 occurred only in PM and *Tithonia diversifolia*. ORG 38 and ORG 39 occurred only in poultry manure.

**Table 7d: Frequency of occurrence (%) of fungi in site B**

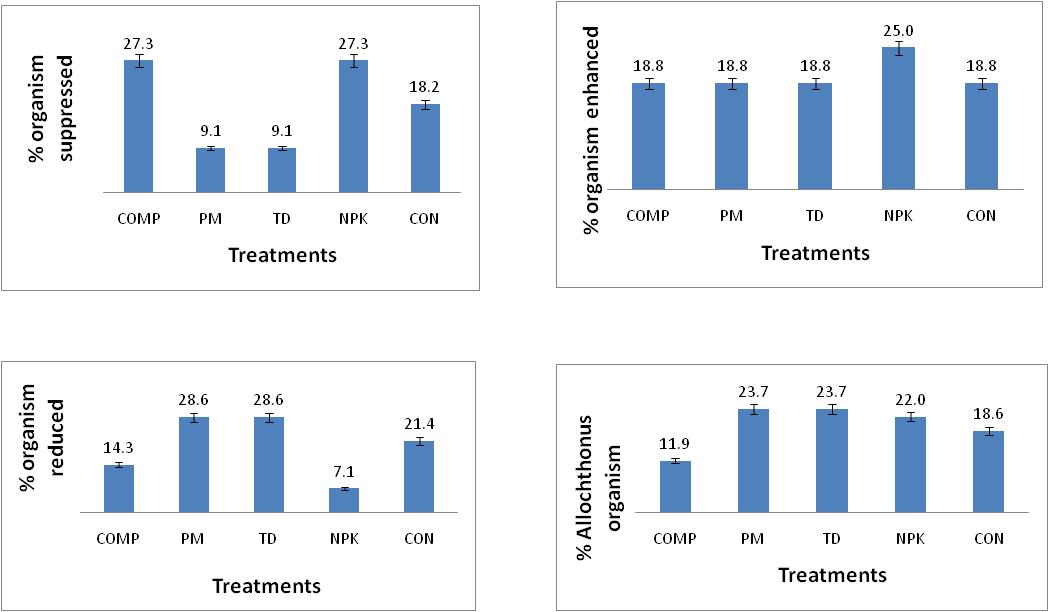
|  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| ORGANISMS | INTIAL | COMPOST | POULTRY MANURE | TITHONIA | NPK | CONTROL | ORGANISMS | COMPOST | POULTRY MANURE | TITHONIA | NPK | CONTROL |
| ORG 1 | 5.3 | 8.8 | 23.3 | 8.8 | 13.9 | 0.9 | ORG 21 | 0.5 |  |  |  |  |
| ORG 2 | 1.3 |  |  |  |  |  | ORG 22 | 0.5 | 0.7 | 1.6 | 0.6 |  |
| ORG 3 | 17.1 | 2.3 |  | 19.2 | 3.6 | 5.9 | ORG 23 | 0.5 | 1.4 | 0.8 |  |  |
| ORG 4 | 3.9 | 1.9 | 1.4 | 3.2 | 6.7 |  | ORG 24 | 0.93 |  |  |  |  |
| ORG 5 | 1.3 | 0.5 |  |  |  |  | ORG 25 |  |  |  |  |  |
| ORG 6 | 13.2 | 15.8 | 5.5 |  | 6.1 |  | ORG 26 |  |  |  | 2.4 | 9 |
| ORG 7 | 22.4 | 9.8 |  | 9.6 | 13.9 | 8.9 | ORG 27 |  |  |  | 0.6 | 1 |
| ORG 8 | 1.3 |  |  |  |  |  | ORG 28 |  |  |  |  | 2 |
| ORG 9 | 3.9 |  |  |  |  | 2 | ORG 29 |  | 13 | 3.2 | 6 | 9 |
| ORG 10 | 1.3 | 2.8 | 0.7 |  | 3.01 |  | ORG 30 |  |  |  |  | 4 |
| ORG 11 | 5.3 | 2.8 | 2.1 |  | 6.7 | 7.9 | ORG 31 |  |  | 4 | 7.3 |  |
| ORG 12 | 2.6 | 16.3 |  |  | 7.3 |  | ORG 32 |  |  |  | 4.8 |  |
| ORG 13 | 3.9 |  | 0.7 |  |  |  | ORG 33 |  |  | 9.6 | 0.6 |  |
| ORG 14 | 5.3 | 8.8 |  |  | 0.6 |  | ORG 34 |  | 8.9 |  |  |  |
| ORG 15 | 10.5 |  | 2.7 |  | 3.6 | 11.9 | ORG 35 |  | 14.4 |  |  |  |
| ORG 16 | 1.3 | 3.3 |  | 1.6 | 0.6 | 1 | ORG 36 |  | 2.7 | 1.6 |  |  |
| ORG 17 |  | 18.1 | 2.1 | 12 | 4.2 | 11.9 | ORG 37 |  | 0.7 | 1.6 |  |  |
| ORG 18 |  | 3.3 | 13 | 12 |  | 6.9 | ORG 38 |  | 0.7 |  |  |  |
| ORG 19 |  | 0.93 | 6.2 |  | 2.4 | 10 | ORG 39 |  |  | 0.8 |  |  |
| ORG 20 |  | 2.3 |  | 1.6 | 4.8 | 1 | ORG 40 |  |  | 0.8 |  |  |

ORG-organism

**4.1.8 Effects of soil treatment on organism (bacteria and fungi) at the two study sites**

**4.1.8.1 Effects of soil treatment on bacteria (site A)**

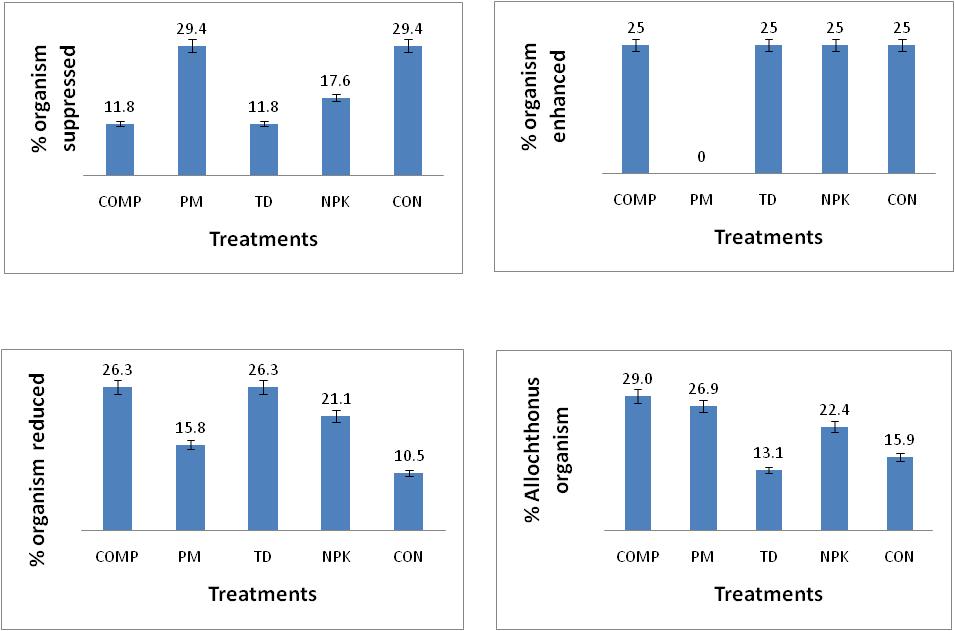
Fig 1 shows that compost and NPK suppressed the initial bacteria in the soil by 27.3% in site A. The percentage of suppression by poultry manure and *Tithonia diversifolia* is 9.1% while control is 18.2%. 18.8% of bacteria were enhanced by compost, poultry manure, *Tithonia diversifolia* and control while NPK enhanced 25% bacteria. The increasing order of reduced bacteria is NPK (7.1%) > compost (14.3%) > control 21.4% > poultry manure and *Tithonia diversifolia* (28.6%). The percentage of bacterial that were not indigenous (Allochthonus) to the soil are compost (11.9%), poultry manure and *Tithonia diversifolia* (23.7%), NPK (22%) and control (18.6%).

**** COMP- compost, PM- poultry manure, TD- *Tithonia divesifolia,* CON- control

**Fig 1: Effects of soil treatment on bacteria (site A)**

**4.1.8.2 Effects of soil treatment on fungi (site A)**

The percentage of fungi suppressed by compost and *Tithonia diversifolia* were 11.8%, poultry manure and control suppressed 29.4% fungi while NPK suppressed 17.6% fungi in site A. Compost, *Tithonia diversifolia*, NPK and control enhanced equal percentage of fungi (25%) while poultry manure did not support the proliferation of fungi in site A. The decreasing orders of fungi reduced by amendments are compost and *Tithonia diversifolia* (26.3%), NPK (21.1%), poultry manure (15.8%) and control (10.5%). The increasing orders of Allochthonus fungi are compost (29%), poultry manure (26.9%), NPK (22.4%), control (15.9%) and *Tithonia diversifolia* (13.1%).

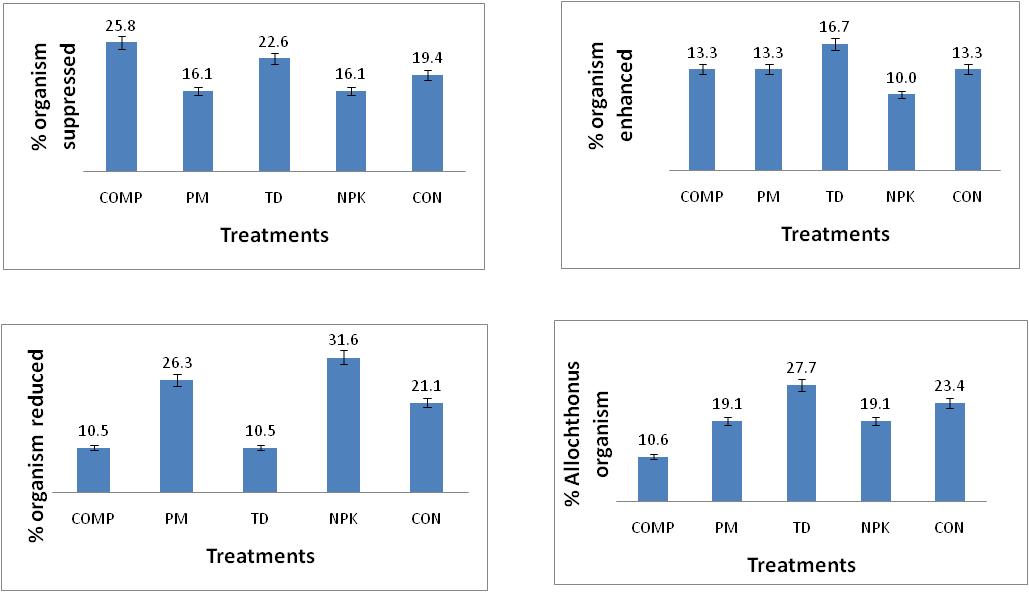
****

COMP- compost, PM- poultry manure, TD- *Tithonia divesifolia,* CON- control

**Fig 2: Effects of soil treatment on fungi (site A)**

**4.1.8.3 Effects of soil treatment on bacteria (site B)**

Compost (25.8%) had the highest suppression of bacteria site B followed by *Tithonia diversifolia* (22.6%), followed by control (19.4%) and followed by poultry manure and NPK (16.1%). Compost, poultry manure and control enhanced the percentage of bacteria by 13.3% while *Tithonia diversifolia* and control enhanced the percentage of bacteria by 16.7% and 10%. Compost and *Tithonia diversifolia* reduced the percentage of bacteria present initially in the soil by 10.5%, control by 21.1%, poultry manure by 26.3% and NPK by 31.6%. *Tithonia diversifolia* (27.7%) had the highest percentage of bacteria Allochthonus to the soil followed by control (23.4%), followed by poultry manure and NPK (19.1%) and compost (10.6%).

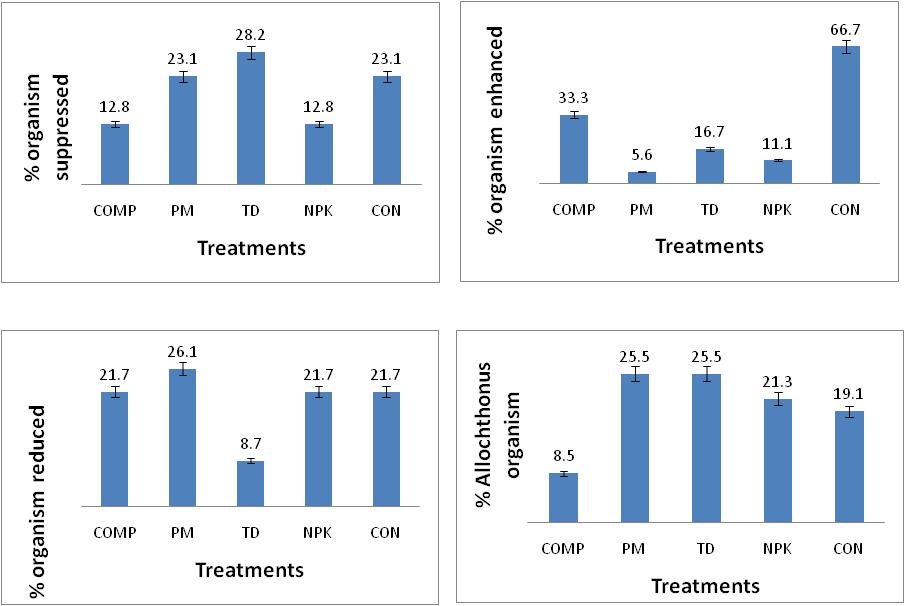
****

COMP- compost, PM- poultry manure, TD- *Tithonia divesifolia,* CON- control

**Fig 3: Effects of soil treatment on bacteria (site B)**

**4.1.8.4 Effects of soil treatment on fungi (site B)**

The increasing order of fungi suppressed in site B is compost and NPK (12.8%), poultry manure and control (23.1%), and *Tithonia diversifolia* (28.2%). The decreasing order of fungi enhanced is poultry manure (5.6%), NPK (11.7%), *Tithonia diversifolia* (16.7%), compost (33.3%) and control (66.7%). The percentage of fungi reduced by poultry manure was 26.1% while, compost, NPK and control were 21.7% and *Tithonia diversifolia* had the lowest reduction 8.7%. The increasing orders of Allochthonus fungi are compost (8.5%), control (19.1%), NPK (21.3%), poultry manure (25.5%) and *Tithonia diversifolia* (25.5%).



COMP- compost, PM- poultry manure, TD- *Tithonia divesifolia,* CON- control

**Fig 4: Effects of soil treatment on fungi (site B)**

**4.1.9 Response of soil chemical properties to organic and inorganic amendment at the two study sites**

The chemical components of the soils of the study sites are significantly different from each other as well as the interaction between the site and amendment at P < (0.05) except for Calcium (Ca), Magnesium (Mg) and Phosphorus (P) in table 8.

Site B has higher Organic carbon (OC), Ca, Mg, K and P than site A showing that site B is more fertile than site A. However, site A is higher than site B for Na and exchangeable acidity. The table further shows significant difference between amendments used. The amendments increased the values of OC in the soil, compost, poultry manure and NPK are significantly different from *Tithonia diversifolia* and initial with plot amended with compost having the highest value (1.83%). The table also shows that calcium content in the soil after amendments application was increased. The Ca content of all amended plots was significantly different from initial with plot amended with compost having the highest value. The mean values for Mg shows that *Tithonia diversifolia* is significantly different from all other amendments except from compost. Sodium content of soil was significantly increased by the treatments compare to the initial. Potassium content of the soil was generally increased. Compost and poultry manure significantly increased the available phosphorus content of the soil with compost having the highest available phosphorus. The exchangeable acidity of the soil was reduced significantly. Site A is acidic in CaCl2 (4.74) to slightly acidic in water (5.68) while site B is slightly acidic in CaCl2 (6.49) to alkaline in water (7.44). The mean values of compost, poultry manure and *Tithonia diversifolia* moderately increased the acidity of the soil while NPK and control reduced the acidity of the soil.

**Table 8: Response of soil chemical properties to organic and inorganic amendment at the two study sites**

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Treatments  Sites (S) | | OC  (%) | Ca  (cmol/kg) | Mg  (cmol/kg) | Na  (cmol/kg) | K  (cmol/kg) | EXC. ACD.  (cmol/kg) | P  (mg/kg) | pH  (CaCl2) | pH  (Water) |
| Site A |  | 1.32b | 2.10b | 1.24b | 0.04a | 0.14b | 1.22a | 9.42b | 4.74b | 5.68b |
| Site B |  | 1.76a | 4.88a | 2.23a | 0.03b | 0.17a | 0.99b | 23.83a | 6.49a | 7.44a |
| Treatments (A) |  |  |  |  |  |  |  |  |  |  |
| COMPOST | | 1.83a | 3.67ab | 1.91ab | 0.06a | 0.19a | 0.92b | 30.62a | 5.85b | 6.95a |
| POULTRY MANURE | | 1.73a | 3.78ab | 1.21b | 0.031bcd | 0.17b | 0.89b | 22.02b | 5.89ab | 6.98a |
| TITHONIA | | 1.40b | 4.43a | 3.08a | 0.038b | 0.15c | 0.81b | 14.66bc | 5.93ab | 6.88a |
| NPK |  | 1.69a | 4.48a | 1.63b | 0.036bc | 0.15c | 0.76b | 5.88b | 6.83a | 6.83a |
| CONTROL |  | 1.61ab | 4.54a | 1.32b | 0.025d | 0.12d | 0.97b | 5.78b | 6.85a | 6.85a |
| INTIAL |  | 1.43b | 2.80b | 2.23ab | 0.027cd | 0.16bc | 2.05a | 6.07a | 6.61b | 6.61b |
| ANOVA response |  |  |  |  |  |  |  |  |  |  |
| S |  | 0.00 | 0.00 | 0.05 | 0.00 | 0.00 | 0.01 | 0.00 | 0.00 | 0.00 |
| A |  | 0.00 | 0.04 | 0.05 | 0.00 | 0.00 | 0.00 | 0.00 | 0.04 | 0.02 |
| S\*A |  | 0.41 | 0.13 | 0.98 | 0.00 | 0.03 | 0.00 | 0.98 | 0.05 | 0.04 |

OC- Organic carbon Ca-Calcium, Mg-Magnesium, Na-Sodium, K-Potassium, EXC.ACD-Exchangeable acidity, P-Phosphorus

**4.1.10 Influence of amendment on soil physical properties**

Moisture content of Site B is significantly higher (27.56) than site A (13.75). All the treatments significantly increased the moisture content of site compare to the control. Bulk densities of the two study sites do not significantly differ from each other. However, all the treatments reduced the bulk density of soil compare to initial value in the following order. Poultry manure > compost >*Tithonia diversifolia* > NPK > control. The mean value of porosity shows that site B is more porous than site A. All the treatments increased porosity of the two sites compare to the initial in the following order compost > NPK > poultry manure >*Tithonia diversifolia* > control.

**Table 9: Influence of amendment on soil physical properties**

|  |  |  |  |
| --- | --- | --- | --- |
| Treatments |  |  |  |
| Sites (S) | % MC | Bulk density (g/cm3) | Porosity |
| Site A | 13.75b | 1.51a | 40.86a |
| Site B | 27.56a | 1.51a | 41.76a |
| Amendments (A) |  |  |  |
| Compost | 27.67a | 1.49a | 43.69a |
| Poultry manure | 27.11a | 1.48a | 42.88ab |
| *Tithonia diversifolia* | 27.89a | 1.49a | 42.44ab |
| NPK | 24.61a | 1.49a | 43.77a |
| Control | 17.11b | 1.51a | 40.00b |
| Initial | 13.33b | 1.52a | 35.97c |
| ANOVA response |  |  |  |
| S | 0 | 0.9 | 0.58 |
| A | 0 | 0 | 0 |
| S\*A | 0.36 | 0.4 | 0.96 |

% MC- % Moisture content

**4.2 Discussion**

The result of the initial soil analysis indicated Site A as sandy loam soil while site B sandy. The pH of site A is characterized as strongly acidic while site B is characterized as slightly acidic (FFD, 2011). Acidity or alkalinity of soil is important in determining its health as acidity affects nutrient availability, microbial activity, crop suitability and yield (Oshunsanya, 2019; USDA-NCRS). The result of the amendments showed that compost had the highest organic carbon, nitrogen, calcium and potassium (Table 2) which upon application would enhance nutrient status of soil. According to Jangir et al. (2019), soil organic matter enhances growth of plant through its positive influence on soil properties. Studies had showed that compost makes nutrient available for plant use through soil properties improvement (Masmoudi et al., 2020). High nutrient content of compost gives it an added advantage to suppress soil born plant pathogens and potential to serve as synthetic agro-chemicals alternative (Antoniou et al., 2017).

The result in table 3 shows that soil that received compost and poultry manure treatments significantly reduced disease incidence which is in line with Moahmed et al. (2013). However, *Tithonia diversifolia* had the least disease incidence reduction. Jangir et al. (2019), affirmed that soil organic matter enhances growth of plant through its positive influence on soil properties. Therefore, this may explain the low disease suppressing ability of *Tithonia diversifolia* compare to compost and poultry manure. Melero-Vara et al. (2011) experimented soil solarization with poultry manure and soil solarization alone on carnation Fusarium wilt. The results showed that poultry manure reduced the infection viability and disease incidence. Compost having the least disease incidence from 3 -7 WAT in this experiment, could be due to its high nutrient composition (Table 2). It was reported by Dordas, (2008) that nutrients can affect plants tolerance or resistance to pathogens and further stressed that nitrogen (N) reduces disease severity while potassium (K) reduces plants susceptibility to disease by enhancing resistance. This further explains why compost and poultry manure had the lowest disease incidence and severity.

The properties of the study sites shows that site B had higher nutritional element than A hence, more fertile than soil A. This may be why severity of disease is reduced in soil B than A. According to Peddi et al. (2012), improvement of soil properties enhance microbial activity which helps the suppression of plant disease through antibiosis, competition, parasitism and predation. Organic amendments serve as antagonist to plant disease by providing suppressive activity through the supply of organic matter which positively influences soil properties and plant vigor to withstand and suppress the effect of disease (Jangir et al., 2019). Disease severity reduction was reported in a research carried out by Antoniou et al., (2017) on evaluation of compost suppressiveness against Fusarium and Verticillium. Compost reduced the severity of diseases in tomato and increased the biological activities in tomato rhizosphere (Antoniou et al., 2017). Orji et al. (2015) reported the significant influence of poultry manure on *Telfairia occidentalis* (Ugu) leaf spot disease at 12 weeks after emergence. Poultry manure is one of the best organic amendments for soil fertility and improvement of root thereby making plant less susceptible to disease and pest attacks (Shaji et al., 2021). At 2 and 3 WAT the level of severity was at its lowest for all the treatments which shows the maximum utilization of amendments applied and establishment of plants.

*Tithonia diversifolia* performed least in number of leaves of tomato. This low performance of *Tithonia diversifoliar* can be due to its allelopathy attributes which might have imposed inhibitory effects on tomato. Effect of allelochemicals can be through root exudation,residue decomposition among others (Ferguson et al., 2003).As reported by Kato-Noguchi, (2020), leaf residues of *Tithonia diversifoliar* causes inhibition of plant growth, however the allelopathic substances released into the soil by the decomposition of *Tithonia diversifoliar* leaf residues are not known. More so, it could also be due to its low organic matter content compare to compost and poultry manure (Table 2).

Among the amendments applied, compost significantly influenced the growth and yield of tomato followed by poultry manure which can be due to their high nutrient composition. Impact of organic and inorganic amendments on the growth of tomato has been reported by several researchers (Olowoake et al. 2017; Acharya and Kumar, 2018; Julius et al., 2018). Compost supplemented with jatropha cake significantly increases the number of leaves of maize than NPK and control in a degraded soil (Olowoake et al., 2017). Julius et al., (2018) showed that, optimum number of leaves of soybean was attained in the highest rate of compost applied. Acharya and Kumar (2018) evaluated the effect of four organic manures (poultry manure, cow dung, goat manure and vermicompost) on growth of garlic. The results acknowledged that growth of garlic increased with application rate of manure, while poultry manure had significant effect on number of leaves. Fawole et al., (2016) evaluated of two composts for the improvement of crop yield and reported that the composts improved the heights of tomato. This result is in line with the findings of Julius et al. (2018) who reported that compost increased the height of soybean plant. Adekiya and Agbede (2016) stated that poultry manure increased leaf area of tomato when incorporation method was employed. In an experiment conducted by Musyimi and Kahihu (2012), their result revealed that aqueous shoot of *Tithonia diversifolia* increased the leaf area of spider plant. Fawole et al., (2016) findings stated that compost improved the yield of tomato significantly. Yagoub et al. (2012) found from their study that compost and other inorganic fertilizer used improved yield significantly. Adekiya and Agbede, (2016) studies showed that incorporated poultry manure increased the yield of tomato.

All treatments increased both diversity of organisms and total numbers of organisms compare to initial, as well as control. Organic amendments enhance organic matter of soil thereby providing nutrients and energy to soil which make the soil a favorable environment for crops growth and microorganism proliferation (Ansari et al., 2019). Poultry litters are important for functional and structural diversity of microbial populations (Mierzwa‑Hersztek et al., 2018). Application of poultry manure increased the microbial biomass and significantly influences the activity of nitrifying bacterial in the soil (Mierzwa‑Hersztek et al., 2018). Control despite not amended the number of bacteria and its diversity increased which shows that the crop planted had beneficial effect on the bacterial community through root exudates. Nazir et al., (2016) further stressed that root exudates is an important factor which serves as food source for soil microbes and play pivotal role in the interaction of plant and soil microbe.

The amendments affected the diversity and number of fungi presents in each site. The biotic and abiotic characteristic of compost in soil is an indicator for high soil quality (Luo et al., 2021). According to Luo et al., (2021) study, most bacteria and fungi were detected after the incorporation of compost. High fungi diversity in poultry manure and *Tithonia diversifolia* treated plot is as a result of organic matter richness*.* In addition, changes in fungi was noticed when soil was amended with poultry manure (Abdullahi et al., 2013). The difference between the diversity of fungi in each sampled plots and initial in site A is higher than site B which can be as a result in difference in their pH. In addition, considering the pH of the two soils (Table 1), the initial soil analysis shows that site A has lower pH. Rousk et al., (2009) result revealed that fungal growth increased while bacteria growth decreased in lower soil pH. It was further stressed in Rousk et al., (2009) that below pH of 4.5, there would be inhibition of all microbial variables. Fungi diversity in NPK treated plots are higher and this shows that fungi are sensitive to mineral fertilizer because it has highest diversity in site B and 2nd highest in site A. This result correlates with Zhong et al., (2010) who found higher amounts of fungal PLFA in NPK treated soil. According to Li et al., (2018), there is correlation between soil pH and soil microbial composition.

The percentage frequency of occurrence of fungi and bacteria in the study sites differed. Some treatments increased the percentage of occurrence of organisms which could be due to improved soil organic matter. Soil microbes are involved in many biogeochemical processes of the soil (Christopher Johns, 2017). Soil microbial biomass and different community structures in soil will increase with organic fertilization (Francioli et al., 2016). Higher nutritional component of compost has been reported by various researches which can be supporting the growth of the encountered organisms (Antoniou et al., 2017). Some treatments suppressed the growth of some organisms which could be associated to antagonistic effect of the treatment or the treatments and tomato plant do not support the growth and proliferation of these organisms. . Graham et al., (2010) stated that applying amendment rich in nitrogen can reduce soil borne disease through the release of allelochemicals generated during decomposition. Antoniou et al. (2017) indicated that microorganisms that grow from compost are either characterized with disease suppressing organisms or beneficial organisms. Growth of some pathogenic fungi can be reduced in the soil during mineralization of fresh poultry manure in the soil which results in high heat production through ammonia (Shaji et al., 2021). Some organisms were enhanced in the treated and control plots which were not present in the initial sample. This could be due to microbial and plant exudates or they were either slow growing organisms whose growths were only enhanced by treatment and root exudates or they were foreign organisms introduced by the treatments. According to Bahramisharif and Rose, (2019), organic amendments release organic matter into the soil thereby increasing the microbial biomass, microbial activity and production of polysaccharides in the soil. Plant root exudates are crucial for plant growth by releasing nutrients, changing of soil pH and enhancement of some microbial diversity and activities (Antoniou et al., 2017). Some organism occurred only in the initial samples. This could be as a result of nutrient consumption by the plant in control and/or as a result of microbial and plant exudates. This could also imply that all the treatments and tomato plant do not support the growth and proliferation of these organisms. Some organisms occurred only in a treatment. The occurrence of different organism in these treatments could be as a result of chemical composition difference of the treatments. For instance, it was stated in Zhong et al., (2010) that fungi are sensitive to mineral fertilizers. Some organism occurred only in control and this shows that root exudates supports the growth of microorganisms in the soil. According to Antoniou et al., (2017) plant root exudates are important for plant growth and improving soil quality by releasing nutrients, changing of soil pH and enhancement of some microbial diversity and activities. Moreover, correlating this observation to disease incidence and severity, this shows why compost as well as poultry manure has the lowest disease incidence and severity.

From table 8, it can be deduced that soil A has higher exchangeable acidity than site B making it more acidic than soil B. According to Wade, (2019), sodium concentration in a healthy and productive soil should be less than 1.0meq/100g. The two soils are of moderate sodium concentration although; soil A is a bit higher than soil B which implies more salt concentration in soil A than soil B. Compost significantly increased the organic carbon of soil and this could high organic matter value of compost as recorded in table 2. Soil organic carbon promotes soil biological properties like nutrient cycling and microbial enhancement as well as soil structure, aeration, water drainage and retention there by reducing soil risk to erosion and nutrient leaching (Corning et al., 2016). This also explains why compost had the highest significant value of total bacteria in study site A, total fungi in study site A and B and diversity of fungi in site A as shown in tables 6a and 6b. Poultry manure and NPK application increased the organic carbon of soil which corroborate with results in Adeyemo et al., (2019). Hence poultry manure has the highest bacteria diversity in study site A, total bacteria in study site B and NPK has highest diversity of fungi in site B.

Among all treatments, only *Tithonia diversifolia* increased the magnesium content of soil however others were reduced which can be the utilization of the nutrient by the tomato plant. It was stated in a research conducted by Quddus et al. (2021) results showed that little or no magnesium result in low quality tomato production. According to Korb, (2022), importance of magnesium in tomato ranges from vegetative growth to flowering to its maturity (fruit ripening). The increase in *Tithonia diversifolia* could be attributed to its high Magnesium composition as shown in Table 2. All the treatments increased the soil potassium with control having the least which could be due to plant uptake. The result from the table showed that all treatments increased the exchangeable bases. This result correlates with the findings of (Samuel and Ezeh, 2017; Kobierski et al., 2017; Dayo-Olagbende et al., 2019) who stated that the application of amendments increase the exchangeable bases in the soil. The application of amendments significantly reduced the exchangeable acidity of the soil. This result corroborates with the findings of Onwuka et al., (2016). Increase in soil phosphorus content was supported by the report of (Dhaliwal et al., 2019; Adekiya et al., 2020). The moderate increase in soil acidity can be due to organic acids released during the decomposition which further explains the enhancement of microbial population and diversity as shown in tables 6a and 6b.

Increases in moisture content of soil by all amendments can be due to improvement in organic matter and other soil properties. Li et al. (2021) reported that the fertility improvement enhanced soil moisture content which is correlated by the findings of Mujdeci et al. (2019).

The bulk density recorded prior to the start of the experiment was high which was improved after the application of amendments hence increased the porosity of soil. Khalid et al. (2014) showed that density of soil was reduced by poultry manure and this increase the soil porosity and improved the stability of soil. Adeleye et al. (2010) investigations on soil physical and chemical properties using poultry manure shows that it improved bulkiness, temperature, total porosity and moisture retention capacity of soil.

**CHAPTER FIVE**

**CONCLUSION AND RECOMMENDATION**

**5.1 Conclusion**

From the results obtained in this study, it can be inferred that compost had higher plant nutrient (organic carbon, calcium, nitrogen and potassium) than other amendments used. Compost and poultry manure reduced the disease incidence in tomato more than NPK and *Tithonia diversifolia*. Compost had the least disease severity followed by poultry manure, *Tithonia diversifolia* and NPK. Compost also improves growth and yield of tomato compare to other amendments used.

Compost improves both the total number and diversity of fungi than other amendments while diversity of bacteria was improved more by poultry manure and *Tithonia diversifolia* and other amendments studied.

Compost increased the chemical properties of the soil (organic carbon, sodium, potassium and phosphorus) and had the least reduction in exchangeable acidity compare to other amendments. *Tithonia diversifolia* improved soil magnesium content than other amendments. Organic amendments increase soil acidity which could be associated to organic acids released during the mineralization process.

**5.2 RECOMMENDATION**

For the improvement of soil physical properties especially soil moisture and porosity, compost and poultry manure are recommended. For the improvement of chemical properties (organic carbon, sodium, potassium and phosphorus) compost is recommended.

To improve microbial properties of soil, compost, poultry manure and *Tithonia diversifolia* are recommended.

To reduce incidence of disease in tomato, application of poultry manure and compost are recommended while for the reduction of disease severity in tomato, compost, poultry manure and *Tithonia diversifolia* are recommended.

**REFERENCES**

Abdullahi R., Sheriff H. H., and Lihan S. (2013). Combine Effect of Bio-fertilizer and Poultry Manure on Growth, Nutrients Uptake and Microbial Population Associated with Sesame (*Sesamum indicum* L) in North-eastern Nigeria. Journal of Environmental Science, Toxicology and Food Technology, 5:5, 60-65.

Acharya S. and Kumar H. (2018). Effect of Some Organic Manure on Growth and Yield of Garlic in Greenhouse Condition at Cold Desert High Altitude Ladakh Region. Defence Life Science Journal, 3 (2), 100-104.

Adekiya A. O. (2019). Green Manures and Poultry Feather Effects on Soil Characteristics, Growth, Yield, and Mineral Contents of Tomato. Scientia Horticulturae 257, 108721.

Adekiya A. O. and Agbede T. M. (2017). Effect of Methods and Time of Poultry Manure Application on Soil and Leaf Nutrient Concentrations, Growth and fruit yield of tomato (*Lycopersicon esculentum Mill*). Journal of the Saudi Society of Agricultural Sciences. 6:4, 383-388.

Adekiya A. O., Ogunboye O. I., Ewulo B. S. and Olayanju A. (2020). Effects of Different Rates of Poultry Manure and Split Applications of Urea Fertilizer on Soil Chemical Properties, Growth, and Yield of Maize. The Scientific World Journal. Article ID 4610515, 8 pages.

Adeleye E., Samuel A., and Ojeniyi S. (2010). Effect of Poultry Manure on Soil Physico-Chemical Properties, Leaf Nutrient Contents and Yield of Yam (*Dioscorea rotundata*) on Alfisol in Southwestern Nigeria. Journal of American Science, 6 (10).

Adeyemo A. J., Akingbola O. O. and Ojeniyi S. O. (2019). Effects of Poultry Manure on Soil Infiltration, Organic Matter Contents and Maize Performance on Two Contrasting Degraded Alfisols in Southwestern Nigeria. International Journal of Recycling of Organic Waste in Agriculture, 8 (1):S73–S80.

Agbede T. M., Adekiya A. O. and Ogeh J. S. (2013). Effects of Chromolaena and Tithonia Mulches on Soil Properties, Leaf Nutrient Composition, Growth and Yam Yield. West African Journal of Applied Ecology, 21(1).

Akanbi O. S. and Ojeniyi, S. O. (2007). Effect of Siam Weed Mulch on Soil Properties and Performance of Yam in Southwest Nigeria. Nigerian Journal. Soil Science. 17: 120–125.

Antoniou A., Tsolakidou M., Stringlis I. A. and Pantelides I. S. (2017). Rhizosphere Microbiome Recruited from a Suppressive Compost Improves Plant Fitness and Increases Protection against Vascular Wilt Pathogens of Tomato. Frontiers in Plant Science, 8.

Ansari R. A., Sumbul A., Rizvi R. and Mahmood I. (2019). Organic Soil Amendments: Potential Tool for Soil and Plant Health Management ( Ansari R. A., Mahmood I., eds.), Plant Health Under Biotic Stress.

Ayilara S. M., Olanrewaju O. S., Babalola O. O. and Odeyemi O. (2020). Waste Management Through Composting: Challenges and potentials. Sustainability 12, 4456.

Babajide P. A., Akanbi W. B., Olabode O. S., Olaniyi J. O. and Ajibola, A.T. (2012). Influence of Pre- Application Handling Techniques of Hemsl. *Tithonia diversifolia* (Hemsl. A. Gray) Residues on Sesame, in South- Western Nigeria. Journal of Animal and Plant Sciences 15 (2): 2135­-2146.

Bahramisharif A. and Rose L. E. (2019). Efficacy of Biological Agents and Compost on Growth and Resistance of Tomatoes to Late Blight. Planta 249 (3), 799-813.

Basit A., Farhan M., Moa W., Ding H., Ikram M., Farooq T., Ahmed S., Yang Z., Wang Y., Hashem M., Alamri S., Bashir M. A., El-Zohri M. (2021). Enhancement of Resistance by Poultry Manure and Plant Hormones (Salicylic Acid and Citric Acid) Against Tobacco Mosaic Virus. Saudi Journal of Biological Sciences, https://doi.org/10.1016/j.sjbs.2021.03.025

Biratu G. K., Elias E., Ntawuruhunga P. and Nhamo N. (2018). Effect of Chicken Manure Application on Cassava Biomass and Root Yields in Two Agro-Ecologies of Zambia. Environmental Management 6 (7), pp. 187-194.

Blake G. R. and Hartge K. H. (1986). Bulk density. In: Klute, A., Ed., Methods of Soil Analysis, Part 1- Physical and Mineralogical Methods, 2nd Edition, Agronomy Monograph 9, American Society of Agronomy – Soil Science Society of America, Madison, 363-382.

Caban J. R., Kuppusamy S., Kim J. H., Yoon Y., Kim S. Y and Lee Y. B. (2018). Green Manure Amendment Enhances Microbial Activity and Diversity in Antibiotic-Contaminated soil. Applied Soil Ecology.

Carmassi G., Incrocci L., Incrocci G. and Pardossi A. (2007). Non-destructive Estimation of Leaf Area in Tomato (*Solanum lycopersicum L.)* and Gerbera (*Gerbera jamesonii* H. Bolus). Agricoltura Mediterranea. 137. 172-176.

Chandrashekara C. and Bhatt J.C., (2014). Suppressive Soils in Plant Disease Management. Eco-friendly Innovative Approaches in Plant Disease Management, chapter 14, pp 241-256.

Chaney C. G. S. and Ramsubhag A. (2015). Potential of Compost for Suppressing Plant Diseases. Natural Products for Sustainable Crop Disease Management (pp. 345-388). CABI eds Vadivel K., Ganesan S. and Jayaraman J.

Chege E. W. and Kimaru S. K., (2021). Effects of *Tithonia diversifolia* and *Allium sativum* Extracts on *Colletotrichum gloeosporioides*, the Causal Agent of Anthracnose in Avocado. All Life, 14:1, 209-214.

Chen G., Zhu H. and Zhang Y. (2003). Soil Microbial Activities and Carbon and Nitrogen Fixation. Research in Microbiology, 154, 393–398.

Chen C, Liu CH, Cai J, Zhang W, Qi WL, Wang Z, Yang Y. (2018). Broad-spectrum Antimicrobial Activity, Chemical Composition and Mechanism of Action of Garlic (*Allium sativum)* Extracts. Food Control, 86:117–125.

Choudhary R. S, Simon S. and Bana S. R. (2017). Efficacy of Plant Extracts Against Anthracnose (*Colletotrichum lindemuthianum)* of Green Gram (*Vigna radiata* L.). International Journal of Chemical Studies, 5(4):769–772.

Christopher Johns, (2017). Living soils: The Role of Microorganisms in Soil Health. Strategic Analysis Paper, 1-7.

Chukwuka K. S. and Omotayo O. E., (2009). Soil Fertility Restoration Potentials of Tithonia Green Manure and Water Hyacinth Compost on a Nutrient Depleted Soil in South Western Nigeria using *Zea mays L.* as Test Crop. Research Journal of Soil Biology 1 (1): 20-30.

Corning E., Sadeghpour A., Ketterings Q., and Czymmek K. (2016). The Carbon Cycle and Soil Organic Carbon. Nutrient Management Spear Program. <http://nmsp.cals.cornell.edu>.

Damicone J. P. and Brandenberger L. (2016). Common Disease of Tomatoes: part 1. Diseases Caused by Fungi. Division of Agricultural sciences and Natural Resources. (extension.okstate.edu).

Das S., Jeong S.T., Das S. and Kim P.J. (2017) Composted Cattle Manure Increases Microbial Activity and Soil Fertility More Than Composted Swine Manure in a Submerged Rice Paddy. Frontiers Microbiology 8:1702.

Dayo-Olagbende G. O., Akingbola O. O., Afolabi G. S. and Ewulo B. S. (2020) Influence of *Tithonia diversifolia* on Maize (*Zea mays* L.) Yield, Fertility and Infiltration Status of Two Clay Varied Soils. International Annals of Science, 8, 1, 114-119.

Dhaliwal S. S., Naresh R. K., Mandal A., Walia M. K., Gupta R. K., Singh R. and Dhaliwal M. K. (2019). Effect of Manures and Fertilizers on Soil Physical Properties, Build-Up of Macro and Micronutrients and Uptake in Soil Under Different Cropping Systems: A Review. Journal of Plant Nutrition, 42:20, 2873-2900.

Dordas, C.(2008). Role of Nutrients in Controlling Plant Diseases in Sustainable Agriculture. A Review. Agronomy for Sustainable Development, 28, 33–46.

Enebe M. C. and Babalola O. O., (2020). Effects of Inorganic and Organic Treatments on the Microbial Community of Maize Rhizosphere by a Shotgun Metagenomics Approach. Open access, Annals of Microbiology, 70:49.

Eneje R. C., Nwosu C. J. (2012). Cow Dung and Cassava Peel Effect on Selected Soil Nutrient Indices and Germination of Maize. Science Journal of Agricultural Research Management 152:6.

Enujeke E. C. (2013). Effects of Poultry Manure on Growth and Yield of Improved Maize in Asaba of Delta State, Nigeria. Journal of Agricultural and Veterinary Science, 4(5): 24-30.

Faissal A., Ouazzani N., Parrado J. R., Dary M., Manyani H., Morgado B. R., Barragán M. D., Mandi L. (2017). Impact of Fertilization by Natural Manure on the Microbial Quality of Soil: Molecular Approach. Saudi Journal of Biological Sciences 850.

Fawole O. B., Alori E. T. and Ojo O. A. (2016). Evaluation of Two Composts for the Improvement of Crop Yield Using Tomato (*Lycopersicon Esculentum*) as Test Crop. Journal of Agricultural Sciences, 61 (1), 37-44.

FFD (Federal Fertilizer Department) (2011). Fertilizer use and management practices for crop production in Nigeria. 4th Edition; eds V. O. Chude; S. O. Olayiwola; A. O. Osho and C. K. Daudu, Federal Ministry of Agriculture and Rural Development, Abuja, Nigeria. ISSN 115-554X.

Ferguson J. J., Rathinasabapathi B., and Chase C. A. (2016). Allelopathy: How Plants Suppress Other Plants. UF/IFAS Extension pp 1-5. <http://edis.ifas.ufl.edu>.

Francioli D. Schulz E. Lentendu G. Wubet T. Buscot F. and Reitz T. (2016). Mineral vs. Organic Amendments: Microbial Community Structure, Activity and Abundance of Agriculturally Relevant Microbes Are Driven by Long-Term Fertilization Strategies. Frontiers Microbiology 7:1446.

Gómez-Sagasti M. T., Hernández A., Artetxe U., Garbisu C. and Becerril J. M. (2018). How Valuable Are Organic Amendments as Tools for the Phytomanagement of Degraded Soils? The Knowns, Known Unknowns, and Unknowns. Frontiers in Sustainable Food Systems 2:68.

Graham E., Grandy S. and Thelen M. (2010). Manure Effects on Soil Organisms and Soil Quality. Emerging Issues in Animal Agriculture. Michigan State University Department of Crop and Soil Sciences. Michigan State University Extension.

Hafifah S., Maghfoer M. D., Prasetya B. (2016). The Potential of *Tithonia diversifolia* Green Manure for Improving Soil Quality for Cauliflower (*Brassica oleracea var. Brotrytis L*.) Journal of Degraded and Mining Lands Management, 3 (2): 499-506.

Iren O. B., Akpan J. F., Ediene V. F. and Asanga E. E., (2015). Influence of Cassava Peels and Poultry Manure-Based Compost on Soil Properties, Growth and Yield of Waterleaf (*Talinum triangulare)* in an Ultisol of South-Eastern Nigeria. Journal of Soil Science and Environmental management, 6(7): 187-194.

Jama B., Palm C. A., Buresh R. J., Niang A., Gachengo C., Nziguheba G. and Amadalo B. (2000). *Tithonia diversifolia* as a Green for Soil Fertility Improvement in Western Kenya: A review. Agroforestry System, 49: 201-221.

Jangir C., Kumar S. and Meena R. S. (2019). Significance of Soil Organic Matter to Soil Quality and Evaluation of Sustainability. Sustainable Agriculture, 357-381.

Julius A., Abel O., and Joseph-Adekunle T. (2018). Effects of Rice-Bran Compost on Growth and Yield of Soybean (*Glycine max*) on an Alfisol in Ibadan, Nigeria. Nigerian Journal of Soil Science. Doi:10.36265/njss.2018.280203.

Kato-Noguchi H., (2020). Involvement of Allelopathy in the Invasive Potential of Tithonia diversifolia. Plants, 9,766.

Kobierski M., Bartkowiak A., Lemanowicz J., and Mariusz P. (2017). Impact of Poultry Manure Fertilization on Chemical and Biochemical Properties of Soils. Plant, Soil and Environment. 63. 10.17221/668/2017-PSE.

Khalid A., Tuffour H., Bonsu M., and Parker B., (2014). Effects of Poultry Manure and NPK Fertilizer on Physical Properties of a Sandy Soil in Ghana. International Journal of Scientific Research in Agricultural Sciences. 1. 1-5.

Kolawole O. K., Awodun and, M. A. and Ojeniyi S.O. (2014). Soil Fertility Improvement by *Tithonia diversifolia* (Hemsl. A Gray) and its Effect on Cassava Performance and Yield. The International Journal of Engineering and Science 3(8): 36-43.

Korob S., (2022). Role of Magnesium in Tomato Production. Prime Tomatoes. www.yara.us/crop-nutrition/tomato.

Kranz C. N., Richard A., McLaughlin, Johnson A., Miller G. and Heitman J. L. (2020). The Effects of Compost Incorporation on Soil Physical Properties in Urban Soils. Journal of Environmental Management 261, 110209.

Lal Rattan, (2015). Restoring Soil Quality to Mitigate Soil Degradation. Sustainability 7, 5875-5895.

Larkin R. P. (2013). Green Manures and Plant Disease Management. CAB Reviews 8, 037.

Larkin, R. P. (2015). Soil Health Paradigms and Implications for Disease Management. Annual Review Phytopathology, 53, 199–221.

Larney F. J. and Angers D. A., (2011). The Role of Organic Amendments in Soil Reclamation: A Review. Canadian journal of soil science, 92: 19-38.

Lee C. H., Park S. J., Hwang H. Y., Kim M. S., Jung H., Luyima D., Hong S. Y., Oh T. K. and Kim S. H. (2019). Effects of Food Waste Compost on the Shift of Microbial Community in Water Saturated and Unsaturated Soil Condition. Applied Biological Chemistry, 62:36.

Li D., Zhou J., Zhang Y., Sun T., An S., and Jia, H. (2021). Effects of Amendments on Physicochemical Properties and Respiration Rate of Soil from the Arid Region of Northwest China. Sustainability, 13, 5332.

Liu M., Hu F., Chen X., Huang Q., Jiao J., Zhang, B., and Li H. (2009). Organic Amendments with Reduced Chemical Fertilizer Promote Soil Microbial Development and Nutrient Availability in a Subtropical Paddy Field: The Influence of Quantity, Type and Application Time of Organic Amendments. Applied Soil Ecology, 42 (2) 166–175.

Logsdon S. D., Sauer P. A. and Shipitalo M. J. (2017). Compost Improves Urban Soil and Water Quality. Journal of Water Resources Protection, 9, 345-357.

Lucasa S. T., D’Angeloa E. M., Mark A. and Williams (2014). Improving Soil Structure by Promoting Fungal Abundance with Organic Soil Amendments. Applied Soil Ecology, 75, 13– 23.

Lyon, C.J., (1948). A factor method for the leaf area of tomato leaves. Plant Physiology, 23(4),

634–635.

Mapa M. H. M. N., Damunupola J. W. and Jayasundera A. C. A., (2016). Efficacy of Leaf Extracts of Invasive *Tithonia diversifolia* Against Selected Fungal Pathogens Causing Leaf Spot Diseases. Proceedings of the International Forestry and Environment Symposium. Department of Forestry and Environmental Science, University of Sri Jayewardenepura, Sri Lanka.

Masmoudi S., Magdich S., Rigane H., Medhioub K., Rebai A. and Ammar E. (2020). Effects of Compost and Manure Application Rate on the Soil Physico-Chemical Layers Properties and Plant Productivity. Waste and Biomass Valorization 11(17–18):1-12.

Melero-Vara J. M., López-Herrera C. J., Prados-Ligero A. M., Vela-Delgado M. D., Navas-Becerra J. A. and Basallote-Ureba M. J., (2011). Effects of Soil Amendment with Poultry Manure on Carnation Fusarium wilt in Greenhouses in Southwest Spain. Crop Protection, 30: 970-976.

Michel V. V., Ancay A., Fleury Y. and Camps C. (2014). Green Manures to Control Soil Borne Disease in Greenhouse Production. Acta Horticulturae, 1041,21.

Mierzwa‑Hersztek M., Klimkowicz‑Pawlas A., and Gondek K. (2018). Influence of Poultry Litter and Poultry Litter Biochar on Soil Microbial Respiration and Nitrifying Bacteria Activity. Waste Biomass Valor, 9:379–389.

Moahmed A. E. H and Kamal A. M. A. (2013). Impact of compost application on Fusarium wilt Disease Incidence and Microelements Contents of Basil Plants. Archives of Phytopathology and Plant Protection, DOI:10.1080/03235408.2013.780696.

Mohammad S. F., Brown V. K., Heitman J. L., McLaughlin R. A. (2016). Effects of Tillage and Compost Amendments on Infiltration in Compacted Soils. Journal of Soil Water Conservation 71 (6), 443-449.

Mujdeci M., Simsek S. and Uygur V., (2019). The Effects of Organic Amendments on Soil Water Retention Characteristics Under Conventional Tillage System. Fresenius Environmental Bulletin, 26. 6205-6211.

Murphy, B, W, (2014). Soil Organic Matter and Soil Function – Review of the Literature and Underlying Data. Department of the Environment, Canberra, Australia.

Musyimi D. and Kahihu S. W. (2012). Allelopathic Effects of Mexican Sunflower (*Tithonia diversifolia* (Hemsl) A. Gray) on Germination and Growth of Spiderplant (*Cleome gynandra L.*). Biology, Corpus ID: 54704408.

Mwangi P. M. and Mathenge P. W. (2014). Comparison of Tithonia (*Tithonia diversifolia*) Green Manure, Poultry Manure and Inorganic Sources of Nitrogen in the Growth of Kales (*Brassicae oleraceae*) in Nyeri Country, Kenya. African Journal of Food, Agriculture, Nutrition and Development, 14 (3).

Nayak, A. K., Gangwar, B., Shukla, A. K., Mazumdar, S. P., Kumar, A., Raja, R., Kumar A., Kumar V., Rai P.K. and Mohan U. (2012). Long-term Effect of Different Integrated Nutrient Management on soil Organic Carbon and its Fractions and Sustainability of Rice–Wheat System in Indo Gangetic Plains of India. Field Crops Research, 127 (27) 129–139.

Ndaeyo N. U., Ikeh A. O., Nkeme K. K., Akpan E. A. and Udoh E. I. (2013). Growth and Foliar Yield Responses of Water leaf (*Talinum triangulare* Jacq) to Complementary Application of Organic and Inorganic Fertilizers in a Ultisol. American Journal of Experimental Agriculture, 3(2):324-335.

Olabiyi T. I. and Oladeji O. O. (2014). Assessment of Four Compost Types on the Nematode Population Dynamics in the Soil Sown with Okra. International Journal of Organic Agriculture Research and Development. Vol. 9: 146-155.

Olaniyi J. O and Ajibola A. T., (2008). Effects of Inorganic and Organic Fertilizers Application on the Growth, Fruit Yield and Quality of Tomato (*Lycopersicon lycopersicum).* Journal of Applied Biosciences, 8 (1): 236 – 242.

Olowoake A. A., Osunlola O. S. and Ojo J. A. (2018). Influence of Compost Supplemented With Jatropha Cake on Soil Fertility, Growth, And Yield of Maize (Zea Mays L.) In a Degraded Soil of Ilorin, Nigeria. International Journal of Recycling of Organic Waste in Agriculture, 7:67–73.

Oludare A. and Muoghalu J. I. (2014). Impact of *Tithonia diversifolia* (Hemsly) A. Gray on the Soil, Species Diversity and Composition of Vegetation in Ile-Ife (southwestern Nigeria), Nigeria. International Journal of Biodiversity and Conservation, 6(7), 55-562.

Onwuka M., Ozurumba U., and Nkwocha O. (2016). Changes in Soil pH and Exchangeable Acidity of Selected Parent Materials as Influenced by Amendments in South East of Nigeria. Journal of Geoscience and Environment Protection, 04. 80-88.

Orji O. J., Ibeawuchi I. I., and Obilo O. P. (2015). Effect of Poultry Manure on Incidence and Severity of Foliar Diseases and Weed of Telfairia occidentalis (Ugu) Intercropped with Cassava and Maize. Journal of Biology, Agriculture and Healthcare, 5 (13).

Oshunsanya S, (2019). Relevance of Soil pH to Agriculture. Intech Open Access, 82551.

Oyedeji S., Animasaun D. A., Bello A. A. and Agboola O. O., (2014). Effect of NPK and Poultry Manure on Growth, Yield, and Proximate Composition of Three Amaranths. Journal of Botany. Article ID 828750. <http://dx.doi.org/10.1155/2014/828750>

Pan X., Mihail J. D., Kremer R. J. and Xiong X., (2019). Fungistatic Effect of a Chicken Manure-Based Organic Fertilizer for Suppression of a Soilborne Pathogen (*Rhizoctonia Solani* Kühn). Journal of Soil and Plant Biology (1): 61-72.

Peddi D. P., Kumar R., Kumar R., Bhatt J. C. and Kn C. (2012). Suppressive Soils in Plant Disease Management. Eco-friendly Innovative Approaches in Plant Disease Management, 241-256. International Book Distributors: Vaibhav K. Singh, Yogendra Singh, Akhilesh Singh.

Popoola A., Durosomo H., Afolabi C. G. and Idehen E. (2015). Regeneration of Somaclonal Variants of Tomato (*Solanum lycopersicum L.)* for Resistance to Fusarium Wilt. Journal of Crop Improvement, 29(5):636-649.

Pugliese M., Gilardi G., Garibaldi A., and Gullino M.L. (2015) Organic Amendments and Soil Suppressiveness: Results with Vegetable and Ornamental Crops. Soil Biology 46.

Quddus, M. A., Siddiky, M. A., Hussain, M. J., Rahman, M. A., Ali, M. R., and Masud M. T., (2021). Magenisuim Influence Growth, Yield, Nutrient Uptake, and Fruit Quality of Tomato. International Journal of Vegetable Science.

Reeve, J. R., Hoagland, L. A., Villalba, J. J., Carr, P. M., Atucha, A., Cambardella,C., et al. (2016). “Organic Farming, Soil Health, and Food Quality: Considering Possible Links,” In Advances in Agronomy. (D. L. Sparks ed.) 137: 319–367.

Rousk J., Brookes P., and Bååth E. (2009). Contrasting Soil pH Effects on Fungal and Bacterial Growth Suggest Functional Redundancy in Carbon Mineralization. Applied and Environmental microbiology, 75, 1589-96.

Ruano-Rosa D. and Mercado-Blanco J. (2015). Combining Biocontrol Agents and Organics Amendments to Manage Soil-Borne Phytopathogens. Organic Amendments and Soil Suppressiveness in Plant Disease Management, Soil Biology 46.

Sachdev S. and Singh R. P., (2017). Sustainable Management of Soil Borne Pathogens of Tomato. International Journal of Science, Technology and Society. Vol 3(2):36-40.

Samuel A., and Ezeh O. (2017). Comparative Effect of NPK 20:10:10, Organic and Organo-mineral Fertilizers on Soil Chemical Properties, Nutrient Uptake and Yield of Tomato (Lycopersicon esculentum). 111-116.

Sax M.S., Bassuk N., Van Es H. and Rakow D. (2017). Long Term Remediation of Compacted Urban Soils by Physical Fracturing and Incorporation of Compost. Urban for. Urban Green. 24, 149-156.

Scotti, R., Bonanomi, G., Scelza, R., Zoina, A., and Rao, M. A. (2015). Organic Amendments as Sustainable Tool to Recovery Fertility in Intensive Agricultural Systems. Journal Soil Science and Plant Nutrition, 15 (2) 333–352.

Shaji H., Chandran V. and Mathew L. (2021). Organic Fertilizers as a Route to Controlled Release of Nutrients. Controlled Release Fertilizers for Sustainable Agriculture, 231-245.

Somerville P. D., May P. B. and Livesley S. J. (2018). Effects of Deep Tillage and Municipal Green Waste Compost Amendments on Soil Properties and Tree Growth in Compacted Urban Soils. Journal of Environmental Management, 227, 365-374

Sun R., Zhang X. X., Guo X., Wang D., and Chu, H. (2015). Bacterial Diversity in Soils Subjected to Long-Term Chemical Fertilization can be More Stably Maintained With the Addition of Livestock Manure than Wheat Straw. Soil Biology Biochemistry, 88, 9–18.

Taiwo, L. B. and Makinde J. O., (2005). Influence of Water Extract of Mexican Sunflower (*Tithonia Diversifolia*) on Growth of Cowpea (*Vigna unguiculata*). African Journal of Biotechnology, 4 (4), pp. 355-360.

Tejada M., Hernandez M.T. and Garcia C. (2009). Soil Restoration Using Composted Plant Residues: Effects on Soil Properties. Soil and Tillage Research 102, 109–117.

Testen A. L. and Miller S.A. (2017). Identification and Management Soil Borne Diseases of Tomato. College of Food, Agricultural, and Environmental sciences.

Tuğrul K. M. (2019). Soil Management in Sustainable Agriculture In: Hasanuzzaman M., Filho M. C. M. T., Fujita M. and Nogueira T. A. R. eds. Sustainable Crop Prodution. Intechopen.

Turmel M. S., Speratti A., Baudron F., Verhulst N., and Govaerts B. (2015). Crop Residue Management And Soil Health: A Systems Analysis. Agricultural System, 134, 6–16.

Wade S. M. S., (2019). Efficacy of Organic Amendments Used in Containerized Plant Production: Part 1- Compost-Based Amendments. Scientia Horticulturae, 266, 108856.

Yagoub S. O., Ahmed W. M. A. and Mariod A. (2012). Effect of Urea, NPK and Compost on Growth and Yield of Soybean (Glycine max L.), in Semi-Arid Region of Sudan. Agronomy (1-2). DOI:10.5402/2012/678124.

Ye L., Zhao X., Bao E., Li Ji., Zou Z.and Cao K. (2020). Bio-Organic Fertilizer With Reduced Rates of Chemical Fertilization Improves Soil Fertility and Enhances Tomato Yield and Quality. Scientific Reports, 10:177.

Ye X., Liu H., Li Z., Wang Y., Wang Y., Wang H. and Liu G. (2014). Effects Of Green Manure Continuous Application On Soil Microbial Biomass And Enzyme Activity. Journal of Plant Nutrition, 37:4, 498-508.

Zaccardelli M., Sorrentino R., Caputo M., Scotti R., De Falco E. and Pane C. (2020). Stepwise-Selected *Bacillus* *amyloliquefaciens* and *B. subtilis* Strains from Composted Aromatic Plant Waste Able to Control Soil-Borne Diseases. Agriculture (2020), 10, 30 [www.mdpi.com/journal/agriculture](http://www.mdpi.com/journal/agriculture).

Zhao J., Liu J., Liang H., Huang J., Chen Z., Nie Y., Wang C. and Wang Y. (2018). Manipulation of the Rhizosphere Microbial Community Through Application of a New Bio-Organic Fertilizer for Improved Watermelon Quality And Health. PLOS ONE 13(2): e0192967.

Zhang Q., Zhou W., Liang G., Wang X., Sun J., He P. and Li L. (2015). Effects of Different Organic Manures on the Biochemical and Microbial Characteristics of Albic Paddy Soil in a Short Term Experiment. PLOS ONE 10(4):E0124096.

Zhong, W., Gu T., Wang W., Zhang B., Lin X., Huang Q. and Shen W. (2009). The Effects of Mineral Fertilizer and Organic Manure on Soil Microbial Community and Diversity. Plant and Soil, 326, 511-522.

Zwieten L. van (2018). The Long-Term Role of Organic Amendments in Addressing Soil Constraints to Production. Nutrient Cycling Agroecosystems, 111:99–102.