

Effect of Different Manure Sources on Soil Chemical Properties, Performance and Yield of Maize on a Degraded Land

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Authors' contributions

Author OAD wrote the first draft of the manuscript, managed the literature search and coordinated all the activities. Author IOF managed the experimental plot, collection of agronomic data and statistical analysis. Author KSA designed the study and wrote the protocol. Author AOO performed the analysis of soil samples. Author ODA performed the soil evaluation and edited the manuscript. All authors read and approved the final manuscript.

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ABSTRACT

Application of manure for soil amendment plays important roles in reclaiming and improving soil properties of degraded soils. This study assessed the effects of composted and non-composted manures on a degraded soil under continuous maize production. The treatments applied consisted of composted manures in form of cassava based compost (CBM) and verticompost (VC) at the rate of 0, 30, 60 and 120 tons/ha, non-composted manure (NC) applied as poultry manure (PM), and an un-amended control plot. These treatments were laid out in a randomized complete block design replicated three times. Soil physical and chemical properties were determined for two consecutive seasons, with maize (SUWAN 1-SYR) planted as test crop. The CBM, VC and PM treatments increased the soil organic carbon content by 18.2, 24.1, and 22.3 % respectively. Corresponding increases observed in cation exchange capacity (CEC) were 13.6, 15.7, and 15.2 %. The comparison of the soil chemical properties measured indicated positive effects from the

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amendments on the soil properties in the order: CBM < PM < VC. The maize grain yield of cassava based fertilized plot consistently and significantly was higher than the other treatments in both cropping seasons. However, both the composted and non-composted manures favored improved maize growth and resulted in higher grain yields (4.62 – 6.03 t ha⁻¹) than the un-amended control treatment (3.69 t ha⁻¹). The study therefore showed that the incorporation of manures, whether composted or non-composted, is beneficial to soils, improving one or more essential soil attributes thus reducing soil degradation.

Keywords: Land degradation; soil amendment; continuous cultivation; poultry manure.

1. INTRODUCTION

Agricultural productivity and sustainability is becoming a major concern in many part of the world with more emphasis in the tropics. This is due primarily to the increased pressure on the demand for land arising from expanding human population. This problem has led to continuous and intensive cultivation of available lands leading to drastic reduction in the inherent soil fertility [1]. This results in the soil being degraded, land degradation can thus be defined as the decline in soil quality caused by its improper use, usually for agricultural, pasture, industrial or urban purposes. Soil degradation is a serious global environmental problem and may be exacerbated by climate. It encompasses physical, chemical and biological deterioration. Examples of soil degradation include loss of organic matter, decline in soil fertility, decline in structural condition, erosion, and adverse changes in salinity, alkalinity and the effects of toxic chemicals, pollutants or excessive flooding. Soils become prone to degradation whenever inappropriate land use and management practices are adopted. Similarly, overgrazing of natural pastures resulting from increasing livestock population and poorly managed grazing exceeding the land's carrying capacity, causes decrease in vegetative cover leading to wind and water erosion. Soil degradation can be reduced through conservation tillage, constructing wind breakers such as fences, bushes, hedges and trees can prevent gusty winds from damaging the soil and application of organic manure to the soil which helps in ameliorating the soil.

It is generally believed that without the addition of commercial fertilizers, along with other agricultural inputs such as improved seed varieties and pesticides, food production will continue to fall short of its demand. To achieve sustainable crop production, judicious use of inputs such as improved germplasm and fertilizers are very crucial. However the high cost of purchasing inorganic fertilizers has been a

huge problem for most resource poor farmers until recently with the advent of fertilizer subsidies by the government. There has therefore been an increase in the use of mineral fertilizers by farmers as they have become more economical, affordable, easy to use and quick in response. However, overtime, their intensive application has led to land degradation, deterioration of soil health and leaching of nutrients into the underground water thereby posing environmental risks to human and animal health. The limitations of these inorganic fertilizers have led to the search for alternate fertilizer sources which are cheaper and hence the reliance on organic manure [2].

Crop production in the south-western part of Nigeria is characterized by low productivity due to declining soil fertility resulting in land degradation. The high cost of inorganic fertilizers coupled with the resource poor status of most farmers within this locality cannot allow adequate amounts of inorganic fertilizer to be supplied on their farms. Hence, organic fertilizers (composted and non-composted) is suggested as an alternative source of soil nutrients. Rejuvenation of the soil with the use of organic fertilizer is an important aspect of combating land degradation. It is a low cost, readily available and an environmentally responsive means to restore soil fertility. Different plant and animal materials are accessible to farmers which can be used as organic fertilizers to improve soil properties and plant growth thereby increasing yield of crop.

In recent times, the use of organic manure has been considered as another possible tool for the maintenance and the improvement of soil. Organic wastes such as animal manures, by-products of several kinds and composted residues can be used as soil amendment. These organic wastes are considered as non-composted organic materials and have been found to be important sources of nutrients for growing crops and enhancement of the overall soil quality [3]. According to [4] as reported

by [2], the cheapness, readily availability of its raw materials and effectiveness of organic manure are the reasons behind their use as fertilizers.

Compost fertilizer is made from plant and animals remains with the objectives of recycling the remains for crop production. Compost consists of the relatively stable decomposed organic materials resulting from the accelerated biological degradation of organic materials under controlled aerobic conditions [5].

Compost are rich source of nutrients with high organic matter content which helps in improving the physical and chemical properties of the soil which ultimately increases crop yields. Composted organic materials, green manures and poultry manures has been reported to increases soil organic matter (S.O.M), provides nutrients for plant growth, alleviate aluminium toxicity, and render phosphorous more available to crops. Also, the application of composts as a fertilizer source is being widely used in many researches as it does not only provide essential nutrients to plants, it also improves soil quality and effectively helps in the disposal of wastes [6].

With evidence of the ability of composted and non-composted organic materials to supply nutrients, this study was carried out to assess the effects of the application of composted and non-composted organic material on some soil properties of a degraded land.

2. MATERIALS AND METHODS

The study was carried out on a piece of land that has been intensively cultivated for over five years within the premises of the Institute of Agricultural Research and Training (IAR&T) Ibadan (7° 23' N; 3° 51' E and 160 m above mean sea level) Nigeria. The area is characterized by a tropical climate marked with wet and dry seasons, it is characterized by a bimodal rainfall pattern with rainfall peaks occurring mostly in June and September while annual temperature ranges from 21.3⁰ C to 31⁰ C.

2.1 Field Work and Soil Sampling

A reconnaissance survey of the site was carried out with the aid of existing soil map of the area which was used to identify the soil type. The most dominant soil type was identified by auger soil examinations and a profile pit measuring (1m

× 1m × 1.5m) was dug on the dominant soil type identified, this was used to characterize the area prior to land preparation and the soil profile was described according to the FAO guidelines [7]. Pre-field soil samples were taken from the experimental field with the aid of a soil auger at depth of 0-15cm. This was also repeated on each plot at the end of the experiment for the post field evaluation.

2.2 Land Preparation

The experimental site measuring 31m by 30m was manually cleared with the use of cutlass and debris were packed from the experimental field. After land clearing, Herbicide (Paraforce) was sprayed on the experimental field to reduce and suppress the growth of weeds.

2.3 Field Layout and Experimental Design

The experimental plots were mapped out into twelve (12) different plots measuring 2m x 30m with an alley of 0.5m. Treatments (composted and non-composted manure), were then imposed on each plot using randomized complete block design replicated three times. The treatments are as follow poultry manure (non- composted), cassava based manure (composted), vetiver compost (composted) and control (no treatment). C- Control (unamended), P. M – Poultry Manure, C. B. M. – Cassava based compost, V. C. – Vetiver compost

2.4 Preparation of Organic Manure

Compost was produced and prepared at the Institute of Agricultural Research and Training (IAR&T) through PACT (Passively Aerated Composting Technique) method. Two types of composts namely cassava based compost and verti compost was applied to the degraded land. Cassava based compost was prepared from cassava peels and poultry manure while verti-compost was prepared using vertiver grass and poultry manure.

2.5 Incorporation of Treatments

The prepared cassava based compost, Vetiver-compost and poultry manure were applied and incorporated at the rate of 0, 30, 60 and 120 tons/ha on each of the plots as soil amendment. The field was left to allow initiation of decomposition and mineralization of the compost and release of nutrients into the soil.

2.6 Planting

Maize seeds were planted and monitored for growth performance and yield. The seeds were sown at a spacing of 50cm by 75cm at two seeds per hole to give a plant population of 320 plants /plot.

2.7 Agronomic Parameters

Agronomic parameters such as plant height, stem girth and number of leaves and these were taken and recorded at two -weeks interval. This was taken four times before harvest. The plants to be measured were selected randomly within the experimental plots and identified with the use of red tags while the measurements were taken with the use of tape rule and vernier calipers.

2.8 Harvesting

At maturity, matured maize cobs were harvested after 12 weeks of planting, data taken immediately after harvesting were; stover weight (i.e weight taken with the maize stands, cobs + maize), cobs weight (i.e weight taken with the maize + cobs only), ear weight (i.e weight taken with the maize only (exception of cobs), numbers of cobs and number of plant stands.

2.9 Determination of Soil Physical and Chemical Analysis

The soil samples were air-dried, crushed and allowed to pass through a 2mm sieve. Particle size distribution was determined using hydrometer method [8]. The soil pH was determined in both water and 0.01N potassium chloride (KCl) solutions (1:1) using glass electrode pH meter [9]. Available P was determined by the method described by [10]. Total N was determined by the Kjeldahl method [11]. Conversions between values of organic carbon and organic matter was made using Van Bemmelen factor of 1.724 on the assumption that, on average, SOM contains 58% of organic carbon. Exchangeable cations were extracted with 1 N NH_4OAC (pH 7) .0) to determine exchangeable K, Na, Ca and Mg while reading was done on the flame photometer and atomic absorption spectrophotometer [12]. The micro-nutrients were extracted using Diethylenetriamine pentaacetic acid (DTPA) while the estimation of elements in the extract is done with the help of an AAS [13].

2.10 Statistical Analysis

Data collected were subjected to analysis of variance (ANOVA) using GenStat Discovery Edition 4,10.3DE statistical software, and where the F-value was found to be significant, the means were separated at $P \leq 0.05$ level of significance using Fisher least significant differences (LSD) [14].

3. RESULTS AND DISCUSSION

3.1 Pre-field Soil Properties

The dominant soil type in the study area is Iwo (Typic Kandiuclaf, Haplic Lixisol) and occurs at the upper position of the toposequence. The profile encountered was dark brown to red in color and had sandy loam texture within the first 15 cm; it is fairly clayey to clayey texture downwards. Below 20 cm depth, there are many quartz stones, gravels and ironstone concretions. The soil is characterized by coarse sand fractions which are coarser than other soils with similar characteristics.

The data presented in Table 1 shows the values of physical and chemical properties of the soils used for the experiment. The textural class of the soil in the experimental field belongs to the class Sandy Loam with 780 g kg^{-1} sand.

Table 1. Pre-field soil analysis

Soil property	Value
Sand (g kg^{-1})	78
Silt (g kg^{-1})	10
Clay (g kg^{-1})	12
Textural Class	Sandy Loam
pH (H_2O)	6.2
Ca cmol/Kg	1.17
K cmol/Kg	0.30
Na cmol/Kg	0.28
Mg cmol/Kg	0.66
H+	0.11
Av. P (mg kg^{-1})	11.47
Organic C (g kg^{-1})	7.3
Organic Matter (g kg^{-1})	12.6
Total N (g kg^{-1})	1.3
Cu (mg kg^{-1})	2.69
Fe (mg kg^{-1})	62.48
Zn (mg kg^{-1})	2.75
Mn (mg kg^{-1})	83.67

The corresponding chemical properties observed was pH of 6.2, which implies that the soil is slightly acidic and within range that permits soil

nutrients availability. The total nitrogen determined in the soil was 1.3 g kg^{-1} , indicating low availability of nitrogen in the soil. The organic carbon and organic matter of the soil were 7.3 g kg^{-1} and 12.6 g kg^{-1} respectively which contribute significantly to the cation exchange capacity of soils. They are also the storehouse for carbon, nitrogen, phosphorous and sulphur which are released by mineralization. The available P was 11.47 mg kg^{-1} indicating very low availability of phosphorus in the soil. The exchangeable bases which is a measure of the general fertility of the soil was 0.30, 0.28, 0.66 and $1.17 \text{ (cmol kg}^{-1}\text{)}$ for K, Na, Mg, and Ca respectively. This indicates that the exchangeable bases were moderately available in the soil. Manganese (Mn) in the soil was 83.67 mg kg^{-1} indicating moderate availability in the soil while Zinc (Zn) was 2.75 mg kg^{-1} indicating high availability of Zn within the topsoil [15;16].

3.2 Effect of the Manure Sources on the Soil Chemical Properties

The effects of the composted and non-composted organic fertilizers as they influence the soil chemical properties were analyzed and the results are presented in Table 2. The effect of soil amendments on soil properties soil showed no significance difference among each other however there were increases obtained from the addition of the amendments on the soil properties.

3.2.1 pH

Addition of compost as manure has been reported to both increase and decrease soil pH and the ability to also buffer soil pH depending on environmental conditions [17;18]. In this study, compost application influenced the Soil pH through increasing and decreasing the soil pH values. This follows as veti-compost recorded increase in pH value from 6.20 to 6.42 followed by poultry manure which has a value of 6.22, all values were however not significantly different from each other at $p < 0.05$. A decrease in the soil pH was however obtained in the cassava based compost plot to a value of 6.03 whereas there was no change in the plot that received no treatment. The increase in soil pH can be attributed to either ammonification or production of NH_3 during decomposition of the added compost [19]. Additionally, adsorption of H^+ ions, development of reducing conditions due to increased microbial activity and displacement of hydroxyls from sequioxide surfaces by organic anions can lead to pH increase in soils amended

with compost [20]. Also, soil pH has been found to decrease after application of compost due to the release of H^+ via nitrification and/or the production of organic acids during decomposition [21; 22].

3.2.2 Exchangeable bases

An increase in the cation exchangeable capacity of the soil was observed similar to the result of [23] where it was observed that the addition of compost increases the exchangeable bases of a soil. Plots with verticompost had the highest value of 4.87 cmol/kg , followed by poultry manure with 4.96 cmol/kg while the control which is the plot with no manure had the lowest value 3.85 cmol/kg . This increases also followed for Ca and Na, with verticompost having the highest 2.39 and 0.39 cmol/kg respectively followed by poultry manure having 2.33 and 0.38 cmol/kg respectively. On the other hand, for Mg and K, verticompost had the highest value (1.37 and 0.81 cmol/kg respectively) while cassava based compost followed with 1.33 and 0.66 cmol/kg respectively. For all treatments, the control plots had the lowest values as regards the exchangeable bases.

3.2.3 Soil Organic Carbon (SOC)

The soil organic carbon content of the soil was initially low before the application of the treatments. However, increases in the organic carbon content was observed after application of the treatments. Incorporation of organic waste into soil had been found to increase SOC content [23; 24]. Verticompost had the highest soil carbon with a value of 17.1 g/kg . This is closely followed by poultry manure which had a value of 15.9 g/kg for SOC. Among the manures applied soil which receive the cassava based compost had the lowest SOC nevertheless its content was still higher than the control plots which obtained the lowest of all treatments.

3.2.4 Available Phosphorus (P)

The mean available phosphorus content was not significantly different across all the treatments used. However, the highest value of available P was observed the in cassava based manure plot with a value of 12.30 g/kg followed by poultry manure while the lowest value was recorded in the control plot (8.10 g/kg). The high P content of the poultry manure and cassava based compost could be attributed to the high P content in poultry droppings which might have caused increased microbial decomposition and release of organic forms of P as reported by [25].

3.2.5 Total Nitrogen (TN)

The total nitrogen content obtained for all the treatments used was generally low ($1.0 - 1.3 \text{ g kg}^{-1}$) and this falls far below the critical limits (1.5 g kg^{-1} [15, 16] expected in soils. The TN content of the soil after harvest was observed to have reduced from the initial (1.3 g kg^{-1}) status observed in the soil before planting. Nevertheless, Verticompost had highest value (1.3 g/kg) when compared to the other treatments ($1.0 - 1.2 \text{ g kg}^{-1}$). The low N content in the soils could be due to the low N content in the respective manures which of course might have great consequence on the microbial activities and the further mineralization of N [26].

3.2.6 Micro-nutrients (Mn, Fe, Cu and Zn)

The values for the micro nutrients were not significantly different across all the treatments however, the values obtained were still within the acceptable limits required for crop production. Mn and Zn content increased under effect of verticompost while a reduction was observed in their content within the soil after harvest under poultry manure, cassava based compost and control in no particular order. On the other hand, Fe content were observed to increase from the initial status of the soil under all treatment type after harvest. Whereas, Cu content of the soil were observed to reduce from the initial status under all treatment imposed.

3.3 Plant Growth and Yield Parameters

Growth and yield attributes of maize were substantially affected by composted and uncomposted sources of nutrients (Figs. 1, 2, 3 and Table 3). A similar result was reported by [27, 28] who observed significantly taller plants and larger leaves as a result of compost application

3.3.1 Effect of the treatments on number of leaves

The trend observed from the influence of the applied manures on the number of leaves of the maize plant is as shown in Fig. 1. The control plot had the lowest number of leaves in all the applied treatments while the highest number of leaves was recorded in the cassava based plot at 8 weeks

after planting (WAP). There was no significant difference at 2WAP, 4WAP and 8WAP while significant differences were recorded at 6 WAP.

3.3.2 Effect of the treatments on the plant height

The trend observed from the influence of the applied manures on the plant height of the maize plant is as shown in Fig. 2. No significant difference was observed among all the treatments used however at 8 WAP poultry manure recorded the highest value in terms of height with a value of 129.5 cm.

3.3.3 Effect of the treatments on stem girth

The trend observed from the influence of the applied manures on the stem girth of the maize plant is as shown in Fig. 3. The applied manure also did not show significant differences on the stem girth of the crop. However, poultry manure was observed to have the highest value of 6.64cm at 6 WAP.

3.3.4 Effect of the treatments on the yield of maize

Stover weight and ear's weight per hectare also showed no significant differences to treatment imposed (Table 3). Nonetheless, plants grown with poultry manure produced the largest stover and ear weight (4.04 ton/ha , 3.0 ton/ha), followed by cassava based compost (3.94 ton/ha , 1.56 ton/ha) and then verti-compost (2.36 ton/ha , $0, 87 \text{ ton/ha}$), while the control plot produced the lowest values (2.19 ton/ha , 0.74 ton/ha) (Table 3).

In likewise manner, number of cobs and cob's weight per hectare also showed no significant difference despite treatment imposed. However, Plants grown with poultry Manure produced largest number of cobs and cob weight ($14,667/\text{ha}$, 1.078 ton/ha) but not significantly different ($14,489/\text{ha}$, 0.936 ton/ha) from what was observed from the plot that received cassava based compost. However, both treatments produced significantly more than when verticompost was applied ($10,800/\text{ha}$, 0.422 ton/ha) while the control plot produced the lowest value ($8,222/\text{ha}$, 0.416 ton/ha) in terms of number of cobs and cob's weight per hectare respectively (Table 3).

Table 2. Effect of composted and un-composted organic fertilizer on soil chemical properties

Treatment	pH _(H2O)	Ca cmol/kg	Mg cmol/kg	K cmol/kg	Na cmol/Kg	CEC	H+	P mg/kg	OC g/kg	OM g/kg	T.N g/kg	Mn mg/kg	Fe mg/kg	Cu mg/kg	Zn mg/kg
Intial	6.20	1.17	0.66	0.33	0.28	2.44	0.11	11.47	7.3	13.1	1.3	83.67	62.48	2.62	2.75
Control	6.20a	1.61a	1.25a	0.70a	0.30a	3.85	0.10a	8.10a	13.6a	24.4	1.0a	76.20a	193a	1.68a	2.39a
Cassava based	6.03a	2.11a	1.33a	0.66a	0.31a	4.41	0.10a	12.30a	14.3a	25.6	1.2a	74.80a	172a	1.93a	2.72a
Poultry manure	6.22a	2.33a	1.31a	0.47a	0.38a	4.49	0.10a	12.00a	15.9a	28.5	1.1a	82.10a	168a	2.30a	2.49a
Veti- compost	6.42a	2.39a	1.37a	0.81a	0.39a	4.96	0.10a	9.40a	17.1a	30.6	1.3a	88.20a	177a	1.95a	2.76a

Means followed by the same letters are not significantly different from each other *= ($p < 0.05$); **= ($p < 0.01$); ***= ($p < 0.001$); NS= Not Significant

Table 3. Effect of composted and uncomposted organic fertilizer on yield of maize crop

Treatments	No. of Cobs per ha	Stover Weight (ton/ha)	Ear's Weight (ton/ha)	Cob's Weight (ton/ha)	Grain Yield (ton/ha)
CONTROL	8222 b	2.19 a	0.74 a	0.416 b	3.69 b
CASSAVA BASED POULTRY MANURE	14489 a	3.94 a	1.56 a	0.936 a	6.03 a
VETI COMPOST	10800 ab	2.36 a	0.87 a	0.422 b	4.62 ab
LSD	4400.3*	2.003 ^{ns}	2.462 ^{ns}	0.445*	1.996*

Means followed by the same letters are not significantly different from each other *(p = .05); ** (p = .01); *** (p = .001); NS = Not Significant

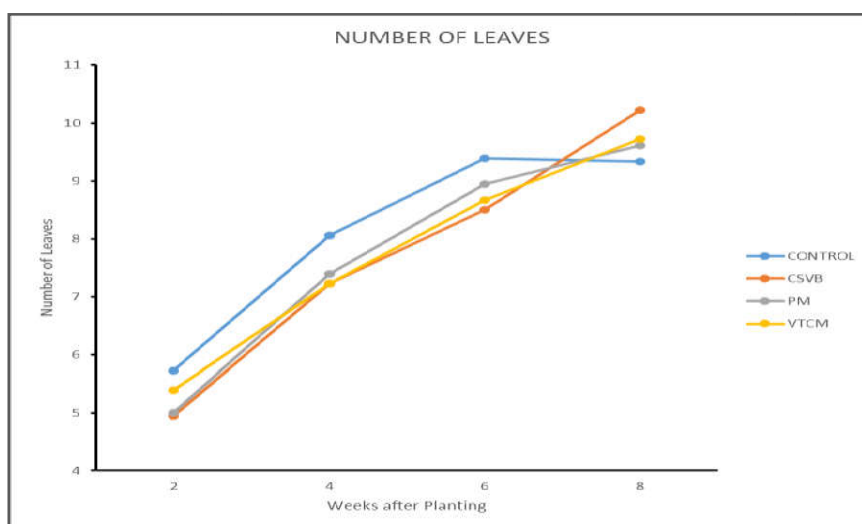


Fig. 1. Effect of the treatments on the number of leaves weeks after planting

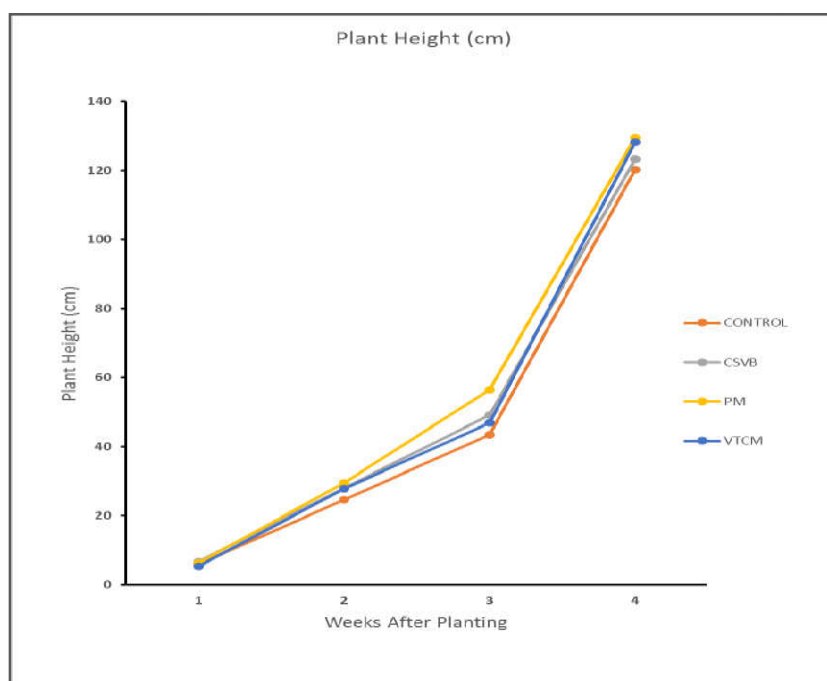


Fig. 2. Effect of the treatments on the plant height weeks after planting

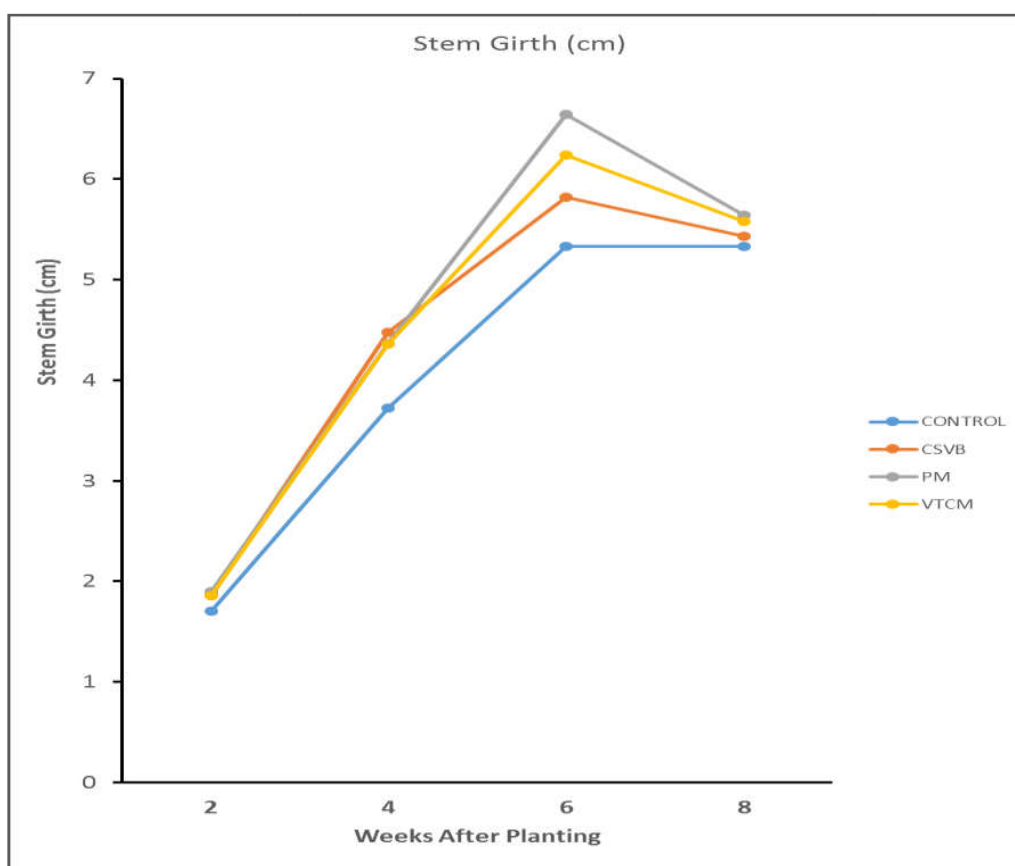


Fig. 3. Effect of the treatments on the stem girth weeks after planting

Plants grown with cassava based compost produced the highest grain yield per hectare (6.03 ton/ha) (Table 3). However, no significant difference was observed among plants grown with cassava based compost, poultry manure and vermicompost, while significant difference was observed between cassava based compost and the control, which produced the lowest grain yield per hectare (3.69 ton/ha). However, the plot that received poultry manure and vermicompost produced more grain yield per hectare than the control plot although no significant difference existed between them (Table 3).

4. CONCLUSION

From this study it was observed that the soil properties increased after the application of the various treatments. In terms of the total nitrogen, available phosphorus and potassium values the post field analysis after the application of organic fertilizers showed an increase in the quality of the soil.

Composted and non-composted fertilizer application increased soil nutrient content of pH,

this may be due to the reduced exchangeable acidity and the increased levels of exchangeable bases like K, Ca and Mg. Compost application also increased the nutrient content of P, K, Ca, Mg and Na in the topsoil but this increment was not significant. This however shows that with constant application of either composted or non-composted manures the land degradation status of the soil can be reversed. The observed increase in maize yield with application of organic fertilizer compared to the control establishes that composted and non-composted fertilizer contributes to an improved crop production. It will therefore benefit the farmers greatly to use organic fertilizer as an alternative source of soil nutrient aimed at combating the declining soil fertility.

5. RECOMMENDATION

From the result of this study veti – compost can be recommended as the most suitable due to its potentials in enhancing soil properties through addition of plant nutrient and also its consequential influence on growth and yield of maize.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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