THE JOURNAL OF AGRICULTURE AND NATURAL RESOURCES SCIENCES

Journal homepage: http://www.journals.wsrpublishing.com/index.php/tjanrs

Online ISSN: 2383-238X Print ISSN: 2423-4397

Original Article

Growth and productivity of pepper plants using vermicompost and other fertilizers

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ABSTRACT

Increase in application of inorganic fertilizers in agriculture has detoriated the soil quality even though productivity is increase. Vermicompost as a soil conditioner has been emerging as a potential end use for maintaining soil productivity. This study was carried out during the year 2014-2015 at the National Agricultural Research and Extension Institute (NAREI) to determine the effect of vermicompost and other fertilizers on the growth and productivity of pepper plants (*Capsicum chinense*). Plants were treated with five different treatments namely T_1 (Promix), T_2 (Vermicompost), T_3 (189), T_4 (189+Vermicompost) and lastly control which had no fertilizers. T_1, T_3 and T_4 were inorganic fertilizers and T_2 was organic. All treatments were replicated three times in a randomized block design method. Results obtained showed that T_3 (chemical fertilizer) have a significant effect on the growth of pepper plants producing plants with better plant height, number of leaves, number of branches and stem diameter. Plants treated with this treatment also had higher fruit yield, fruit weight and fruit diameter. Mineral nutrients were highest in plants treated with inorganic fertilizers as compare to the organic fertilizer. Maximum chlorophyll level was present in plants treated with T_2. There were relatively high levels of pest and diseases in plants treated with chemical fertilizers, delayed flowering and fruiting period and high levels of leaf and fruit abscission as compare to plants treated with organic fertilizer (T2). Moreover, T_3 have proven to have a greater effect on the growth parameters of pepper plants but not the quality of plants produce.

Keywords: Vermicompost; Organic Agriculture; Chemical fertilizers; Plant productivity; Pepper.

1.0. INTRODUCTION

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How to Cite this Article: Ganeshnauth, V., Jaikishun, S., Ansari, A., & Homenauth, O. (2019). Growth and productivity of pepper plants using vermicompost and other fertilizers. *The Journal of Agriculture and Natural Resources Sciences,* 6(1), 47-66.
Retrieved from http://www.journals.wsrpublishing.com/index.php/tjanrs/article/view/417

Article History: Received: 2017-12-27 Accepted: 2019-02-18

Peppers (*Capsicum chinense*) belongs to the Solanaceae family. They are grown worldwide and are widely appreciated for their spicy flavor and nutritional value. Peppers were usually grown using conventional applications of inorganic fertilizers and pesticides. However, due to the rising awareness of the adverse economic and environmental impact of chemicals in crop productions, the utilization of organic farming has been stimulated as the main farming method today. Organic farming involves the use of organic materials without chemical contributions for growing crops (Arancon *et al.*, 2003).

Organic manures for growing crops are a composition of waste materials. Due to the steady increase in population size and improved living standards around the world, the built up of waste materials is becoming a burgeoning problem since these waste materials emits harmful substances to the atmosphere when burnt. Burning also kills the microbial population of the soil, destroys the soil organic matter and affects the overall physical composition of the soil (Ansari, 2012). Thus, proper waste management can be maintained by using these organic waste as substrate in agriculture through organic farming.

Composting of organic waste offers solution to large amounts of waste worldwide. Composting is a natural process of recycling decomposed organic materials into a rich soil known as compost. Traditional composting of organic wastes has been known for years but new methods of thermophilic composting have become much more common in organic waste treatment (Arancon and Edwards, 2005). One such composting technique is vermicomposting. Vermicomposting is a type of organic farming by which earthworms breakdown organic waste materials, stimulate microbial activity and at the same time increases the rate of mineralization of the soil. These activities convert waste materials into humus-like substances called vermicompost. Vermitechnology is the use of surface and subsurface local varieties of earthworms (Ansari and Sukhraj, 2010). Earthworms play a major role in breaking down waste materials to form vermicompost. Vermicompost are finely divided peat like materials with high water holding capacity, perfect structure, porosity and aeration. Vermicompost is an organic fertilizer that is rich in nutrients, poor in readily biodegradable carbon, and relatively free of any plant and human pathogens (Dominquez and Edwards, 2011). It has greatly increased surface area which provides greater area for microbial activity to take place and strong adsorption and retention of nutrients (Ansari and Ismail, 2012).

The activity of organic farming through the use of vermicompost would be an unpreventable practice for years to come for sustainable agriculture since, vermicompost releases nutrients at a slow rate that allows for easy uptake by plants, and improves the moisture holding capacity of the soil that results in better quality of crops produce (Najar and Khan, 2013). Ansari (2012) outlined different sources of recyclable organic waste and he classified these waste as either agricultural waste, animal waste, urban solid waste or agro industrial waste. Animal manure, categorized as animal waste is a valuable resource as soil fertilizer since it provides relatively large amounts of macro- and micronutrients for crop growth and production and at the same time providing an environmentally friendly alternative to mineral fertilizers (Lazcano and Dominguez, 2011).

Heavy use of agrochemicals since 1960s increased food productivity at the cost of environment and society. It killed the beneficial soil organisms and destroyed their natural fertility, weakened the power of 'biological resistance' in crops making them more susceptible to pests and diseases. Since then, the revolution of vermicomposting studies have been on the go for improving crop production. (Adhikary, 2012). The use of vermicompost for planting has been highlighted in agriculture as a beneficial medium for improving plant growth and yield and the maintenance of soil fertility. This organic matter has proven to improve the overall soil structure, soil fertility and crop yield (Arancon and Edwards, 2005).

The aim of this project is to investigate the effect of vermicompost and other fertilizers on the growth and productivity of pepper plants (*C. chinense*).

Organic farming is greatly beneficial and is more economically viable than inorganic farming. Organic farming controls pest and diseases without harming the environment, prevents pollution, and increases soil fertility so that crops produce will contain adequate nutrients and better marketable price will be offered. Vermicompost is one of the best organic medium for planting. Vermicompost is highly organic and contains no chemicals so it is environmentally friendly. It is more nutritious and releases nutrients at a slow rate that is easily taken up by plants and it eliminates the need for application of pesticides since plants are healthy and free from any pest and diseases. The aim of this research is to determine the effect of vermicompost and other fertilizers on the growth of pepper plants. It will demonstrate how common organic waste can be converted into a nutrient rich substrate that is chemical free and has a massive impact on the quality of crops produce. This research will be of major benefits to farmers in improving their understanding on how vermicomposting can improve the quality of crops produce, increased the fertility of the soil and reduce the cost needed to purchase synthetic fertilizers for growth since vermicompost contains all the essential nutrients that support maximum growth. Not only will this research benefit farmers but it will also benefit the environment by reducing pollution rate since waste materials can be used as substrate for enhancing soil fertility. Organic farming plays a major role in agriculture today and will be a great influence in the future for safe and good quality of crops. Several researches done have proven the importance of vermicompost and its impact on crop production as compared to other fertilizers.

2.0. MATERIALS AND METHOD

Vermicomposting unit was set up at the National Agricultural Research and Extension Institute (NAREI) at Mon repos, Georgetown. All plants were planted at NAREI. Physico-chemical analysis and microbial analysis of planting substrates were done at The University of Guyana, Faulty of Natural Sciences Biology Laboratory. The chemical analysis of fruits were done at the Fruit and Drug Department.

2.1. PREPARING THE VERMICOMPOSTING UNIT (ANSARI AND SUKHRAJ, 2010)

1. A vermicomposting unit of dimensions 2.1 x 2.1 x 1m^3 was set up
2. The floor of the unit was covered with 5 inches of pebbles followed by 10 inches of sand to ensure proper drainage. A 10inch layer of moisten loamy soil was then placed at the top.
3. 500 locally species of earthworms (*Eisenia foetida)* were introduced into the soil.
4. After inoculation of worms, cattle dungs were scattered over the soil followed by a 10cm layer of dried grasses and leaf clippings from NAREI Campus. The dried grass along with cattle dung was turned on a weekly basis.
5. After 60 days, the vermicompost was harvested and the pH was tested and stabilize with calcium carbonate to maintain a neutral pH.
6. The vermicompost was then ready to use as a fertilizer for planting.

2.2. PHYSICO-CHEMICAL ANALYSIS OF PLANTING SUBSTRATES BEFORE AND AFTER PLANTING

Each planting substrate was subjected to physico-chemical analysis where both the initial soil and soil obtained after planting were analysed. Planting substrates were analysed for the following parameters at two different laboratory (Homer, 2003):

i. pH electrical, conductivity (EC)- (done in the Biology Lab at the University of Guyana)

ii. Organic carbon, Nitrogen, Phosphorus and Potassium- (done at Food and Drug Department)

2.3. MICROBIAL ANALYSIS

All microbial analysis steps were repeated for each treatments on the initial planting substrate, substrate obtained from seedlings before transplanting to potting media, and substrate obtained after harvesting. Total microbial count was done by culturing microbes on nutrient agar following the procedure as described by Aneja, (1996). The modified Winogradsky medium was used for growing and counting *Nitrosomonas* bacterial colonies. Isolation and enumeration of *Azotobacte*r colonies was done using Ashby's medium (Aneja, K.R.1996).

2.4. SETTING UP PLANTING MEDIUM

Step 1: Setting up seedling trays (Germination of seeds)

Pepper seeds were planted in a seedling tray of dimensions 53 x 53 cm^2 with a total of 128 holes per tray. The experiment was done following the Randomized Block Design method with three replications for each treatment. Five treatments (Table 1) were involved in the replication process:

Table 1. Different treatments used in the experiment

Treatments(Planting substrate)	**Components of each treatment**
$T_{1:}$ Promix (Organic)	Canadian sphagnum peat moss, perlite, vermiculite, macro nutrients and micronutrients, limestone, wetting agents and mycorrhizae.
$T_{2:}$ Vermicompost(Organic)	Loamy soil, cow manure and dry grasses
$T_{3:}$ 189 (Inorganic)	450g of sand, 550g sawdust, 90g chicken litter, 20g triple super phosphate (tsp) ,8g urea, 0.013g of calcium carbonate ($CaCO_3$) and 0.4g molybdenum potash (MoP)
$T_{4:}$ 189+Vermicompost(Organic and Inorganic)	189+Vermicompost components
Control	Black sand

Table 2. Amount of vermicompost applied during different stages of planting

Treatment	**Amount of vermicompost applied (g)**				
	Germination	Potting media	Field	Flowering	Fruiting
T1	50	250	400	150	150
T2	50	250	400	150	150
T3	50	250	400	150	150
T4	50	250	400	150	150

Table shows the amount of vermicompost applied during the different stages of planting. 12 holes were allocated per treatment where each set of the 12 holes were filled 50g of the different planting substrate. Seedlings were planted in each holes and the seed tray was placed in a partially covered area where there was little sunlight penetration and protection from excess rainfall. After 8 days of planting, the seeds have started germinating.

Step 2: Setting up potting media
After 4 weeks of growth in seed trays, the seedlings were transplanted into potting media. Each pots were filled with 3kg of dry soil and 250g of each treatments were applied to each pots. A total of nine pots was allocated per treatment.

2.5. GROWTH PARAMETERS

The recording of growth parameters began after transplanting seedlings into potting media, Growth parameters such as plant height, number of leaves and leaf fall were taken on a weekly basis along with observation for any pest attack. After being placed in potting media for five weeks, plants were transferred out to the field just before the beginning of flowering. Each plants were planted in bins where field observation was completed. Each planting bins were of dimensions 430cm length by 90cm breadth. 400 g of each treatments were applied at the beginning of planting in the field, 150g at the onset of flowering and 150g at the beginning of fruiting. The following analysis were taken in the field trials:

- Number of leaves
- Plant height: measured using a measuring ruler (cm)
- Diameter of main stem: measured using a ruler(cm)
- Number of branch
- Bolting period
- Number of fruits and fruit setting

2.6. APPLICATION OF NEEM EXTRACT TO AVOID PEST

0.6Kg (600g) of neem leaves *(Azadirachta indica*) were collected and boiled with 1 liter of water. After boiling, the mixture was diluted with 5 liter of water and mix with 50ml of soap. The neem extracts were then filled into spray bottles and applied to plants three weeks after planting, before transferring to the field and before flowering and fruiting.

2.7. HARVESTING

After harvesting, the following analysis were taken:

- Root and shoot biomass which involves both wet and dry weight
- Shoot length ,Number of leaves, diameter of stem and number of branch
- Total fruit weight, fruit diameter(cm)
- Biochemical analysis of fruit: Fruit samples obtained were dried in an incubator at temperature range 46-50^{0}C and weighed each day until a constant weight was obtained. After drying, the samples were crushed using a mortar and pestle and stored in a dry place until it was ready for analysis. Samples were analysed for Vitamins C at the Food and Drug Department following methods outlined by Thangjam, 1996. Samples were also analysed for Potassium, Sodium and Phosphorus at the Guysuco Laboratory, LBI.
- Vitamin C and Chlorophyll content.

3.0 RESULTS AND DISCUSSION

Plants need nutrients from fertilizers for growth and survival since most soil does not provide sufficient nutrients for optimum growth. Fertilizers are essential part of modern farming. Fertilizers may be organic or inorganic and their effect on plant growth depends upon the necessary nutrients they contain. Organic farming is eco-friendly, improves soil fertility, and sustains higher yield. Chemical farming on the other hand, have positive effect on crop growth once use in the correct proportion but intensive use can jeopardize the conservation of soil and invites new problems which may post health hazard to the environment. Fertilizers in general are essential in modern farming and the fertility status of the soil is likely to decline unless adequate amount of nutrients are added to the soil.

The aim of this project was to investigate the effect of vermicompost and other fertilizers on the growth of pepper plants. Results obtained are tabularized along with statistical data.

Plants were treated with four different treatments plus a control medium:

T_1: Promix (Inorganic)

T2: Vermicompost (Organic)

T3: 189(Inorganic)

T4: 189+ Vermicompost (Organic+ Inorganic)

Control: Black sand

Promix is a light-weight, ready-made mixture with high nutrient retention and water holding capacity to support plant growth. It is made up of perlite and vermiculite which improves moisture and aeration of the soil, Canadian sphagnum peat moss aids in absorption, limestone for pH neutralization, and micro and macro nutrients. Vermicompost, the second treatment (T_2), is a composition of organic matter form from the decomposition of waste product by the action of earthworms. It is an ideal organic manure for better growth and yield of many plants. 189, the third treatment (T_3), is a newly formulated mixture compose of sawdust, sand, urea, TSP, MOP, chicken litter and calcium carbonate. Sawdust when mixed with these fertilizers provides an ideal medium for plant growth since these chemicals are weighed and mixed in the correction proportion require for better plant growth and production.

Physico-chemical parameters were conducted on both the initial and final planting substrate to determine their physico-chemical composition [Fig. 1 (a)-(f)]. For the initial treatment, pH ranges from neutral to alkali for all treatments except for T_1 and control which was slightly acidic. All pH levels except T3 were within the pH ranges 6.5- 7.5 which is the pH that most plant nutrients are optimally available for plant growth, this this pH range is very compatible to plant growth (IPNI, 2015). The electrical conductivity was lowest for control and highest in T_3. Electrical conductivity is a good indication of the nutrient status of the soil. High electrical conductivity means that there are more nutrients present in the soil hence more dissolve ions leading to a high electrical conductivity. Organic carbon was highest in T_1 and lowest in control. Phosphorus and potassium level was highest in T_2 and lowest in control. The control medium was relatively low in all nutrients. Analysis done on post-harvest soil was not done on the control substrate since there was no plant survival in this treatment. The results for post-harvest analysis showed that the level of pH increases among all the treatments except for T_3 where there was a decrease in pH level from alkali to neutral. Electrical conductivity decreases among all the treatments with T_2 having the highest conductivity level and T_4 the lowest. There was a decrease in nitrogen, phosphorus and potassium levels in T_1 and an increase among T_2, T_3 and T_4 with T_3 having the highest level of these macronutrients, and T_1 the lowest. Vermicompost are products from depredated organic matter broken down by earthworms. This process alters the rate of decomposition of organic matter and lowers the C: N ratio (Mathivanan *et al*, 2013). For this reason, vermicompost had low percentage of carbon and nitrogen as compared to the inorganic fertilizer (T_3). Sawdust is a great absorber of nitrogen and absorb nitrogen from the soil away from plants and urea is comprise mainly of nitrogen accounting for the high nitrogen level in T_3. The high phosphorus levels in T_3 is due to the presence of TSP. Moreover, the high levels of macronutrients present in T_3 are due to the chemical composition of the substrate.

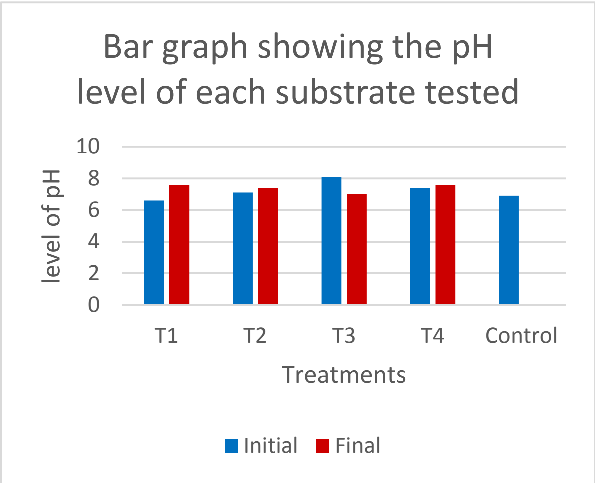

Fig. 1 (a)

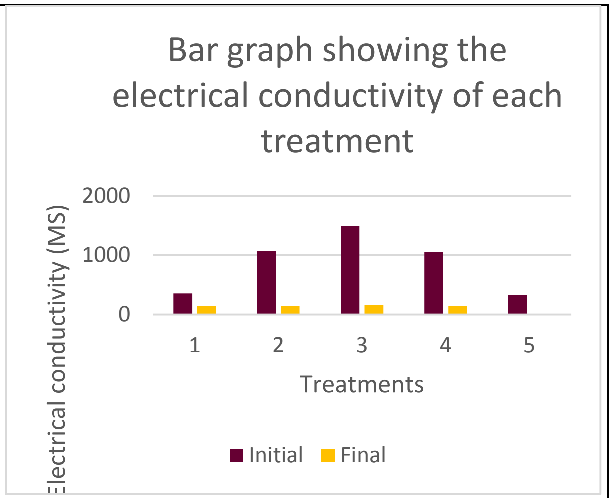

Fig. 1 (b)

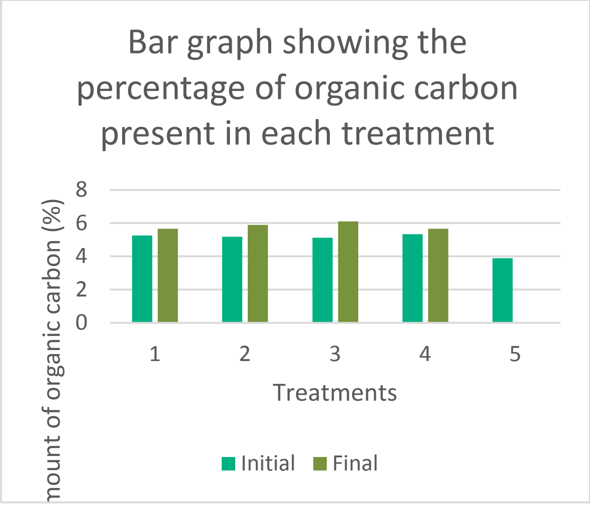

Fig. 1 (c)

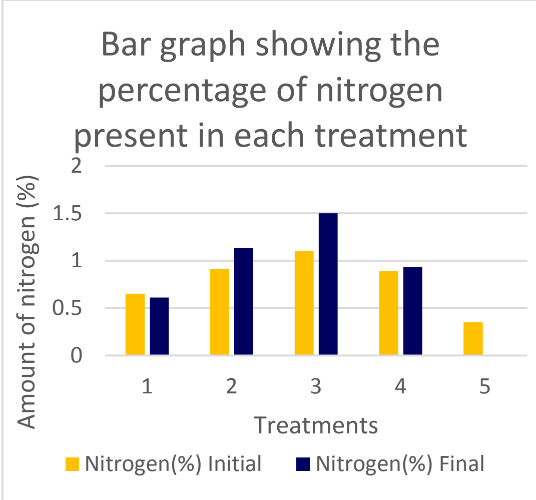

Fig.1 (d)

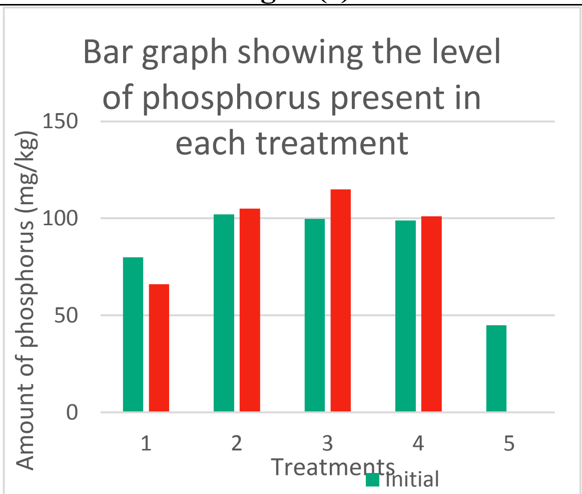

Fig. 1(e)

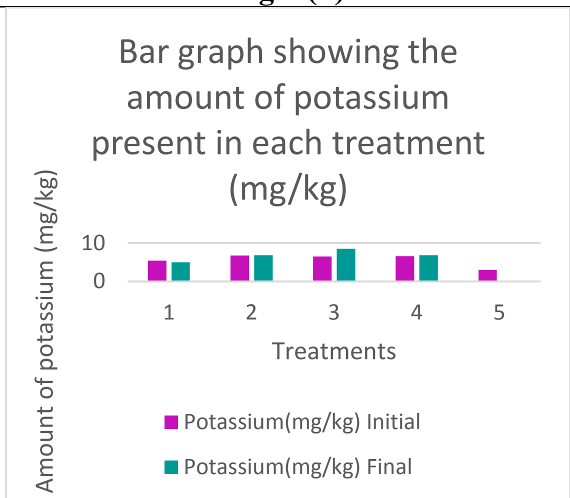

Fig. 1(f)

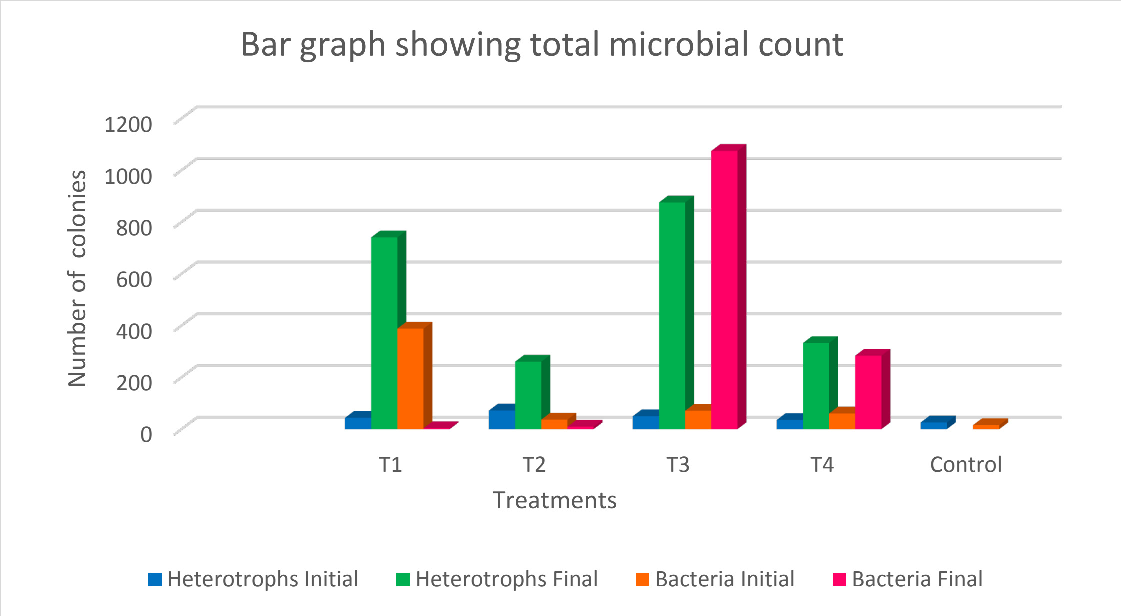

Fig.2

Fig. 2 show the results obtained from microbial analysis of both the initial and final planting substrate represented in the form of mean± standard deviation. The studies of microbial analysis of soil was done before the planting of pepper plants and after harvesting. This gave an idea on the initial microbial count of each substrates, and the microbial count after planting. Total microbial count done on the initial soil sample showed that T_2 had the highest amount of heterotrophs as compared to the other treatments, and T_1 had the highest amount of bacteria. For the final microbial analysis no microbial count was done on the control soil because there was no survival of pepper plants in this treatment. Results obtained from the final microbial analysis showed that T_3 had the highest amount of heterotrophs as well as the highest amount of bacteria as compared to the other soil samples

The high microbial count in T_2 for the initial soil sample is due to the presence of microbes deposited from earthworms casting and microbes naturally present in the soil. Sawdust is rich in fungi and chicken litter comprises of high amount of bacteria whereby some might be parasitic but have never shown any effect on human health when amended as a fertilizer for plant growth (Wilkinson *et al*, 2011). This mixture forming the 189 treatment have accounted for the high microbial population present in this treatment due to the continuous application of treatments at different stages of plant growth which increases the final amount of microbes present in the soil. In addition, the chemical composition of T_3 is acidic but with the presence of organic matter (chicken litter) and calcium carbonate, the acidity of the mixture is reduce thereby supporting the growth of more microorganisms (Monroe, 2015). T1 had the second highest heterotrophs for the final microbial analysis which is due to the presence of mycorrhiza which is a composition of the promix mixture that creates a symbiotic relationship with plant roots.

Statistical analysis done for results obtained on both the initial and final soil sample showed that the results were not statistically significant. Statistical analysis done on the initial soil sample showed that the P- value (0.50) is greater than 0.05 for the treatments, and P (0.38) is greater than 0.05 for the different microbes. Analysis done on the final soil sample showed that there was no significant difference between the microbes counted neither between the treatments since P-value (0.17) is greater than 0.05 for the different treatments and P-value (0.36) is greater than 0.05 for the microbes. After microbial count was done, gram staining was done on the different bacterial colonies present. All bacteria stained from both initial and final soil sample were gram- negative rods and cocci.

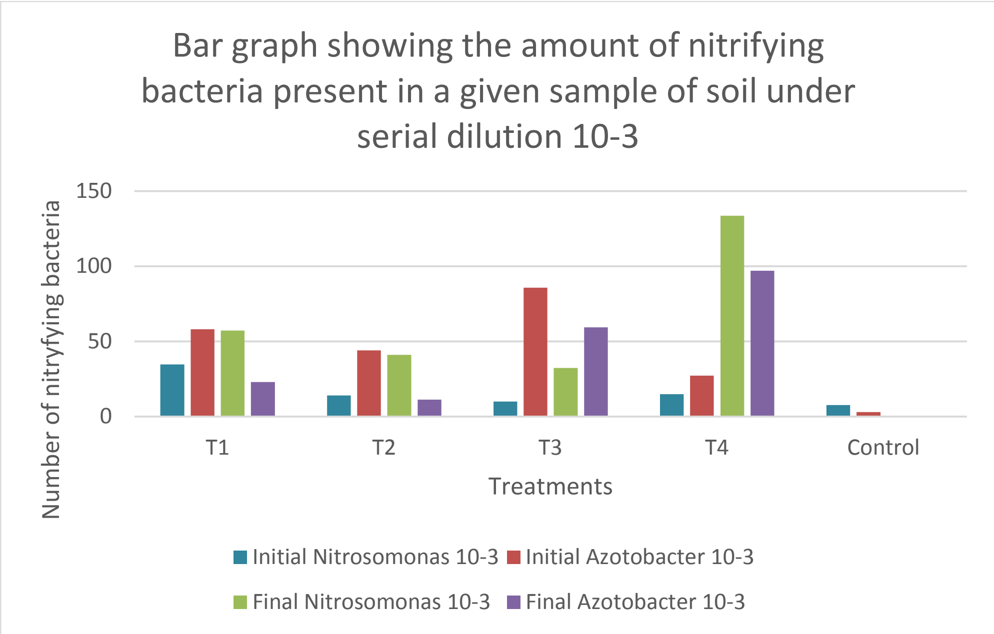

Fig.3

Fig. 3 shows results obtained from nitrifying bacteria through serial dilutions. *Nitrosomonas* and *Azotobacter* are beneficial bacteria that aggressively colonize plant roots and enhance plant growth by a variety of mechanisms which includes phosphate solubilization, antifungal activity, etc. (Ibiene *et al,* 2013). These nitrogen fixing bacteria are important for the conversion of nitrogen gas to solid nitrogen which is useable by plants. After total microbial count, serial dilutions were done both on the initial soil samples and final soil samples to determine the total *Azotobacter* and *Nitrosomonas* count in a given amount of soil sample. Dilutions were done at $10^{-3.}$ Dilutions done on the initial soil samples showed that T_3 had the highest *Azotobacter* count and the second lowest *Nitrosomonas* count. T_3 was followed by T_1 with the second highest Azotobacter count as well as *Nitrosomonas* count,T_2 having the third highest *Azotobacter* count but not *Nitrosomonas* count since T_4 had almost one times more that of T_2, T_4 the fourth highest *Azotobacter* count and lastly control with the lowest *Azotobacter* and *Nitrosomonas* count.

For the final dilutions, there was no serial dilution done on the final soil sample for the control treatment since there was no plants survived. Results obtained showed that T_4 had the highest *Nitrosomonas* as well as *Azotobacter* count, followed by T_1 with the second highest *Nitrosomonas* count but not the second highest Azotobacter count since T_3 had one and a half times more of T_1. T_2 had the third highest *Nitrosomonas* count and the lowest *Azotobacter* count followed by T_3 which had the least amount of *Azotobacter.* Overall, for the initial dilution, T_1 had the highest *Nitrosomonas* count and T_3 had the highest *Azotobacter* count. For the final dilution, T4 had both the highest *Nitrosomonas* count and *Azotobacter* count. These results indicated that T4 had good nitrogen fixation process taking place than the other treatments. The results were not statistically significant for the initial soil analysis since P-value (0.43) is greater than 0.05 between the different treatments, and P-value (0.15) is greater than 0.05 between the different bacteria cultured under serial dilution techniques. Results obtained from the final dilution was not statistically significant neither between the different treatments nor between the different type of bacteria since P-value (0.07) is greater than 0.05 between treatments, and P (0.29) is greater than 0.05 between the different type of bacteria.

Table 3. Rate of germination in triplicates

Treatments	Rate of germination (%)
T_1	83.3
T_2	100
T_3	75
T_4	83.3
Control	41.67

Table 4. Survival and mortality rate of pepper plants planted in each treatment in triplicates

Treatment	Initial amount of plants allocated per treatment	Survival rate in potting media (%)	Survival rate in the field (%)
T_1	9	100	100
T_2	9	100	88.89
T_3	9	100	77.78
T_4	9	100	100
Control	9	0	0

Table 3 shows the rate of germination for different treatments. Table 4 shows the survival and mortality rate of pepper plants during the different stages of planting. After vermicompost was harvested, all planting substrate were prepare for planting**.** Pepper seeds were planted on a seedling trays filled with the different treatments where a total of 9 seeds were allocated per treatment. From the germination results, T_2 had the highest germination rate followed by T_1, T_4, T_3 and lastly control. T_2 has the highest germination rate because vermicompost contains higher amounts of essential nutrients such as phosphorus and potassium which stimulates the emergence of plants (Joshi *et al,* 2014).

Germination of pepper seeds was followed by transplanting when seedlings have attained the two leaf stage. Seedlings were transplanted to potting media where the recording of results began. There was no survival of pepper plants grown in the control medium so there was no plants to transfer to potting media. This is so because based on results obtained from physico-chemical analysis, there was not enough nutrients present in the control medium neither were there enough microbial activity. In the potting media, there was 100% survival of all plants. After transplanting to the field from potting media, there was a change in survival rate among some of the treatments. T_1 and T_4 had 100% survival, 88.89% of plants survived in T_2 and 77.78% in T_3**.** The change in survival rate is due to the exposure of plants to direct climatic conditions which they were not exposed to before. Plants that have died in the field conditions were dry and yellow which is due to direct contact with the sun. There was a low survival rate in T3 after transplanting to the field. Firstly this may be due to the pH range of the substrate which was initially 8.1 , a pH range where not sufficient nutrients are available for plant growth (IPNI, 2015) Secondly, since T3 is compose of sawdust, sawdust as mentioned earlier absorbs nitrogen away from plants which limits foliage growth causing leaves to yellow and die. T_3 had a much higher electrical conductivity than the other treatments. High electrical conductivity lowers osmotic potential of soil water and consequently the availability of soil water to plants causing plants to become dry. However, the tolerance of plants to salinity depends upon the plant species as well as the developmental stages (Patel *et al,* 2014).

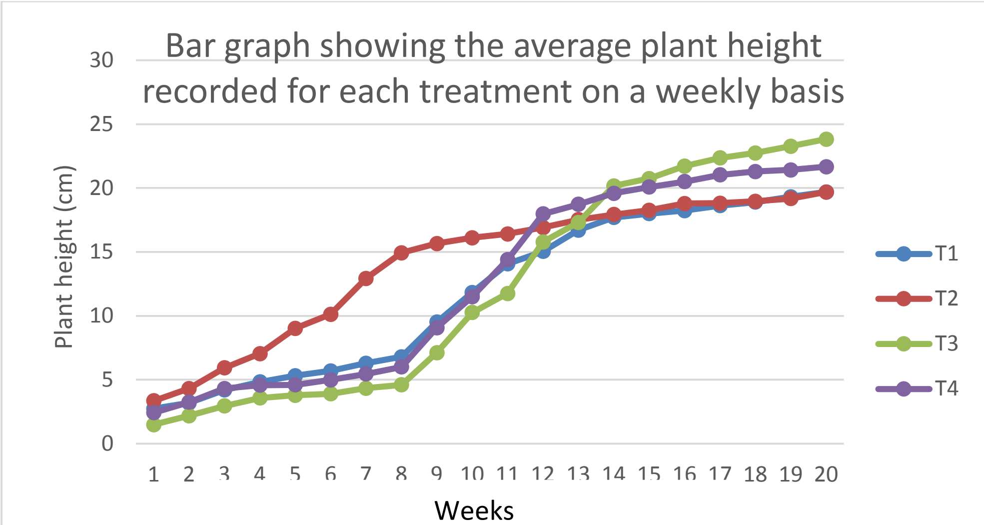

Fig. 4

Fig. 4 shows the average plant height obtained from pepper plants grown in five different treatments for a period of 20 weeks. Plant heights were measured on a weekly basis for 20 weeks. There was a significant difference between plant heights recorded over the 20 weeks period.T_2 (3.34) had the greatest initial plant height followed by T_1 (2.73), T_4 (2.42) and lastlyT_3 (1.49). The final plant height recorded was higher in T_3 followed by T_4 and lastly T_2 and T_1 with equal average plant height. The percentage change in plant height from initial to final height over the 20 weeks period was greatest in T_3, followed by T_4, T_1 and lastly T_2. The results obtained are similar to results obtained from a study conducted by Locascio *et al*, 2008 where the effect of sawdust on the growth of corn was similar to that of pepper. The initial application of sawdust decreases the yield of plant where in this instance it decreases the rate of plant growth. This was so because sawdust absorbs nitrogen from the soil away from plants thus limiting plant growth. As application increases, there was an increase in nitrogen level which was sufficient enough to cause decomposition and increase the amount of nitrogen available for plant growth. This combine with the amount of nitrogen provided from urea increases the nitrogen level of the soil and subsequently increases the overall plant growth parameters and yield of produce (Iderawumi, *et al*, 2012). Results obtained were statistically significant between each treatments as well as between each weeks of growth since P- value (0.0059) is less than 0.05 between treatments and the P-value(3.24×10^{-27}) is less than 0.05 between the different weeks.

Fig. 5 shows the average leaf number obtained from pepper plants grown in five different treatments for a period of 20 weeks. Values in the table are represented in the form of mean $\pm$ standard deviation (SD). The plants with the greatest overall change in leaf numbers were those grown in T3 followed by T4, T2 and lastly T1. The treatment with the highest amount of leaves was T_3 which had a sharp increase from week 16 then decreases back at week 19 and 20, but still remained the treatment with the highest average number of leaves. T_3 was followed by T_2 which had a greater overall leaf number than T_1 and T_4 since it started off having a higher leaf number from weeks 1-16 but at weeks 17-20 there was a reduction in leaf number as compared to T_4. T_4 was the next treatment that has plants with a greater leaf number after T_2 where there was a continuous increase in leaf number until the final week. Lastly, T_1 had the lowest number of leaves where there was a slow increase in leaves until week 20 where it decreases. There was an increase and decrease in leaf number due to leaf abscission. There was a significant difference between each treatments as well as between each weeks since P-value (0.0016) is less than 0.05 between each treatments and P- value (0.0012) is less 0.05 between each weeks.

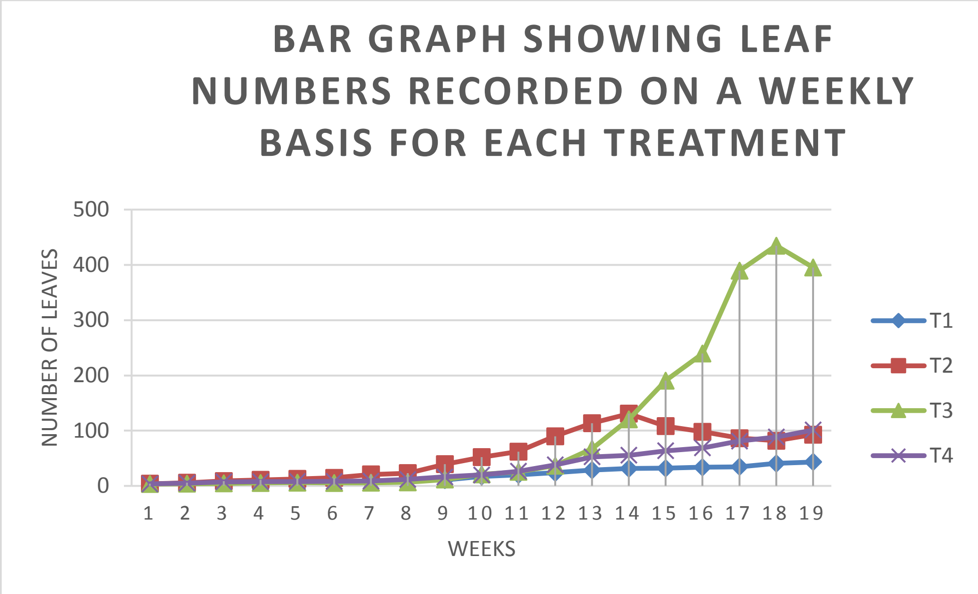

Fig.5

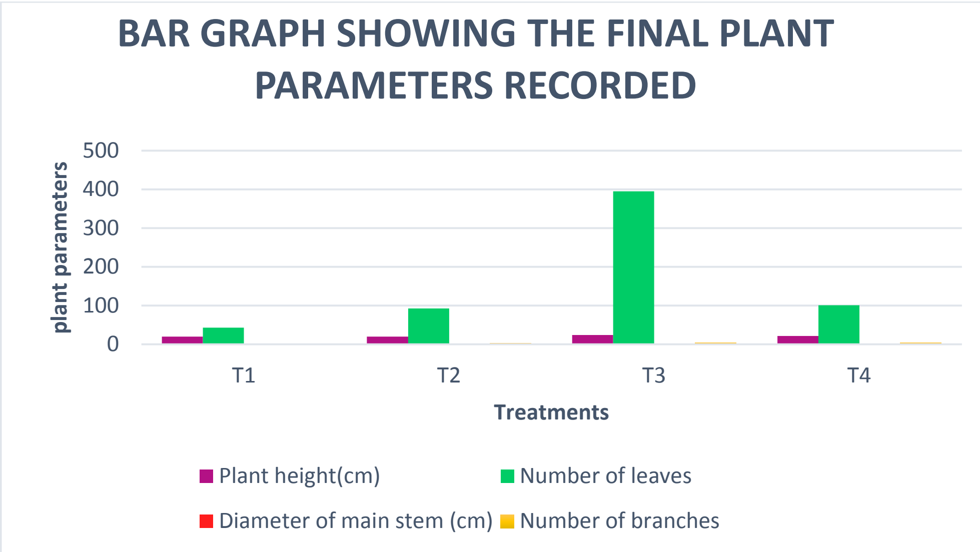

Fig.6

Fig. 6 shows the final plant parameters recorded after harvesting of pepper plants from each treatments. The values are represented in the form of mean $\pm$standard deviation. Final plant growth parameters such as plant height, number of leaves, diameter of main stem and number of branches were greater in plants treated with T_3 followed by T_4, T_2 and T_1 respectively. The results obtained are similar to results obtained from a study carried out by Joshi *et al,* 2014 on wheat where the use of chemical fertilizers have given better growth rate, yield and quality of produce than vermicompost. Chemical fertilizers have greater availability of salts like nitrate, phosphate and potash which significantly increase the rate of plant growth (Ansari and Sukhraj, 2010). So T_3, having chemical composition gave better results followed by the mixture of chemical and organic fertilizer (T_4) which had equal proportion of organic and chemical fertilizers to support good plant growth, then T_2 –vermicompost, which has humic acids and adequate nutrients for maximum growth but not enough micronutrients such as nitrogen, phosphorus and potassium to produce maximum yield. In addition , since treatments were apply at different stages of planting, Chamani *et al*, 2008, concluded from their studies that once vermicompost reaches a certain concentration, the rate of plant growth decreases probably due to the high concentration of soluble salts in the vermicompost, poor porosity and/or poor aeration. T_1 –promix didn't had the least average plant growth parameters recorded which might have due to the presence of insufficient nutrients. Statistical analysis done on the final parameters recorded showed that results were not statistically significant between the different treatments neither between the different parameters recorded since the p-value was 0.4 between the different treatments and 0.06 between the different parameters recorded.

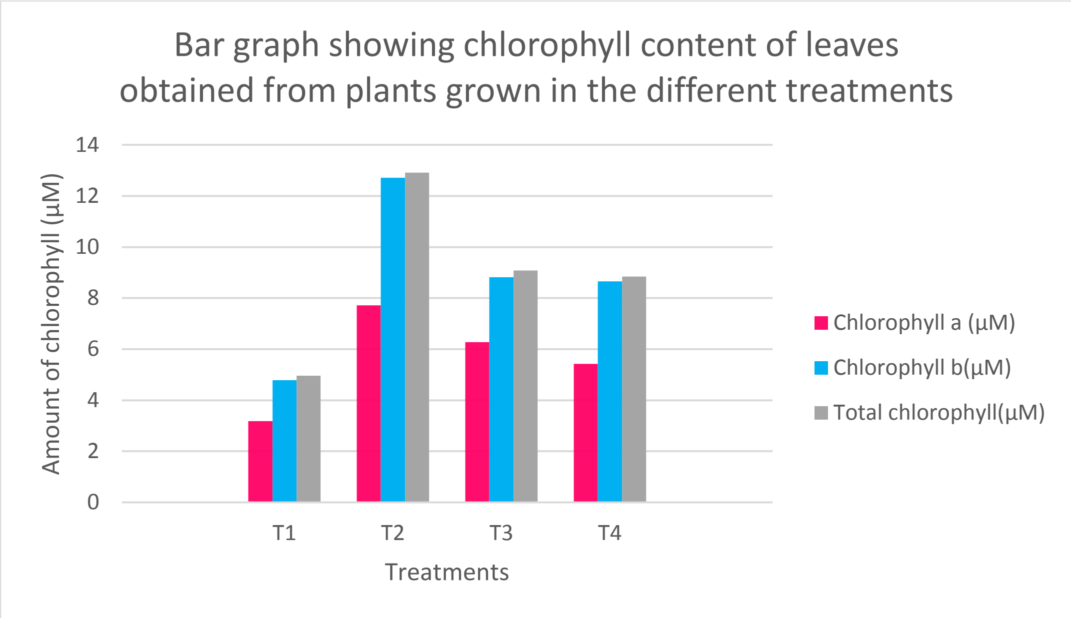

Fig. 7

Fig. 7 shows results obtained from analysis of the chlorophyll content of leaves obtained from peppers plants grown in the different treatments. There was a low standard deviation among all the values which indicates that the values did not deviate much from the mean value. The presence or absence of chlorophyll in plants greatly affects the production of secondary metabolites and other essential plant constituents. In the present study, chlorophyll content in pepper leaves were maximum in T_2 followed by T_3, T_4 and T_1 respectively. Nitrogen is required for cellular synthesis of enzymes, proteins, chlorophyll, DNA and RNA, and is therefore important in plant growth and production of food. Nitrogen fertilization increases growth and leaf area of plants which in turn increases absorption of light leading to an increase in the production of chlorophyll (Joshi *et al*, 2014). Even though T_2 didn't have the highest nitrogen level, it had sufficient to support maximum chlorophyll production followed by T_3, T_4 and lastly T_1 which had the lowest nitrogen level thus the lowest amount of chlorophyll. The results from the anova statistical test showed that there was indeed a significant difference between each treatments as well as the different type of chlorophyll ('a' and 'b') and the total chlorophyll content in leaves obtained from the different treatments. There was a significant difference between each treatment since F (34.12) is greater than F crit (4.76) and the P value (0.00036) is less than 0.05, and significance between the amount of chlorophyll present since F (20.08) is greater than F crit (5.14) and the P value (0.0012) is less than 0.05.

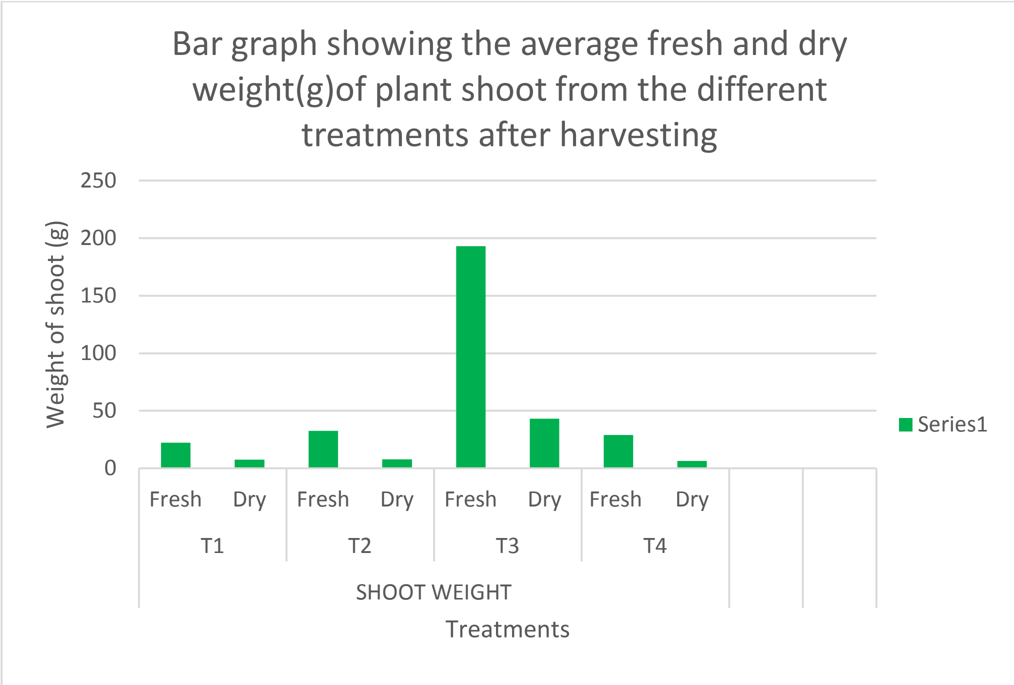

Fig. 8 (a)

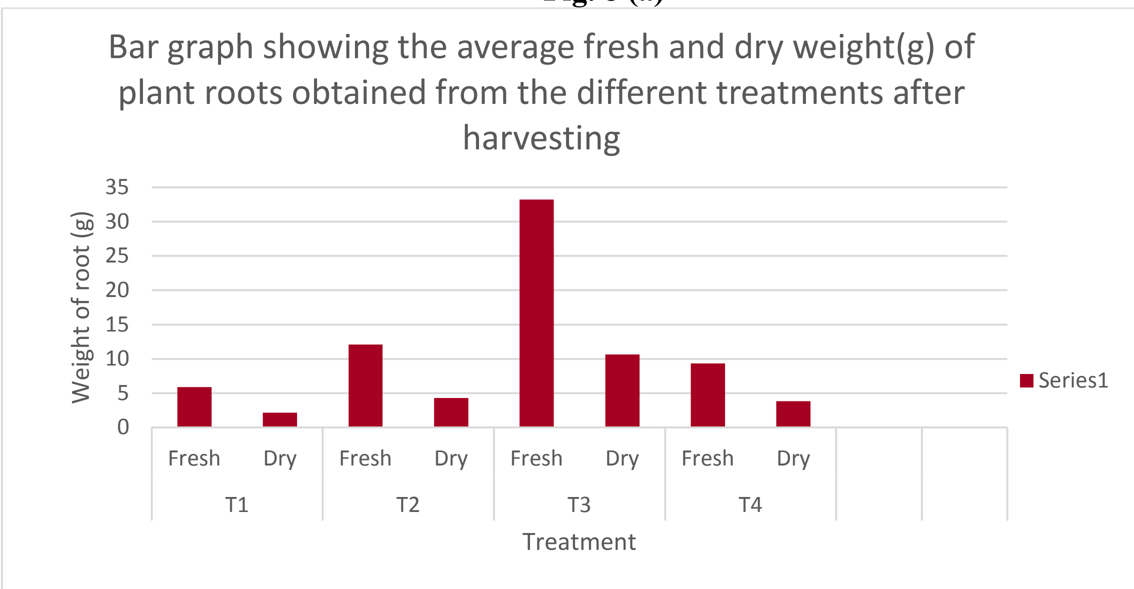

Fig. 8 (b)

Fig. 8 (a)-(b) show the fruit weight and shoot and root weight of pepper plants after harvesting. Results are represented in the form of mean $\pm$ standard deviation where a low standard deviation indicates better results rather than a high standard deviation.

The fresh and dry weight of plant root and shoot was recorded. The results recorded in Table 10 showed that plants treated with the different treatments had a significant effect on the fresh and dry weight of plants root and shoot. The favourable effect of fertilizer application was most apparent in plants treated with T_3 which had the heaviest fresh and dry shoot weight followed by T_2, T_4 with the third heaviest fresh shoot weight and the lowest dry weight, and lastly T_3 with lowest fresh weight and higher dry weight than T_4. In terms of the root weight, T_3 also had the highest fresh and dry root weight followed by T_2, T_4 and lastly T_1.

T_3 had the highest root and shoot weight which is probably due to the high phosphorus level present in the soil. T_2, vermicompost, had the second highest shoot and fruit weight. According to (Bachman and Metzger 2007) hormone like activity of vermicompost leads to an increase in root biomass, root initiation and better growth and development of plants. Vermicompost is a rich source of humic acids and humic acid increase plant growth and root biomass (Joshi *et al*, 2014). Flowering period for the different treatments varied. T_2 had the earliest bolting period, followed by T_3, T_4 and lastly T_1. The period of flowering and fruiting also varied among the different treatment, where all treatments except for T_3 have a short fruiting time of one week. According to Taleshi *et al*, (2011), increase in N levels, microbial activity on adding vermicompost leads to greater root expansion, which in turn leads to greater uptake of nutrients, water and rate of photosynthesis, ultimately leading to better flowering and heading. For this reason, T_2 had an early flowering period.

Table 5. Flowering and fruiting period of pepper plants

Treatment	Flowering period	Fruiting Period
T_1	Week 16	Week 17
T_2	Week 8	Week 9
T_3	Week 12	Week 14
T_4	Week 13	Week 14

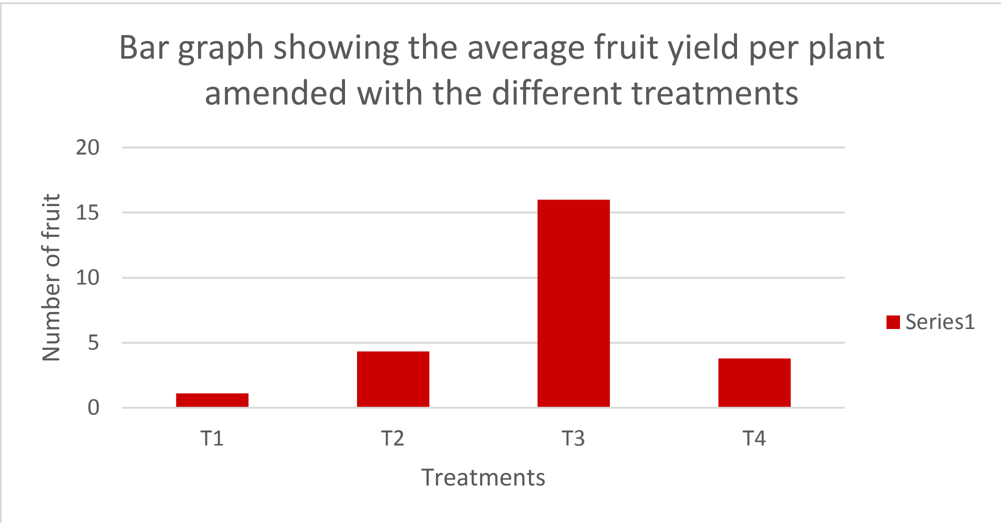

Fig. 9 (a)

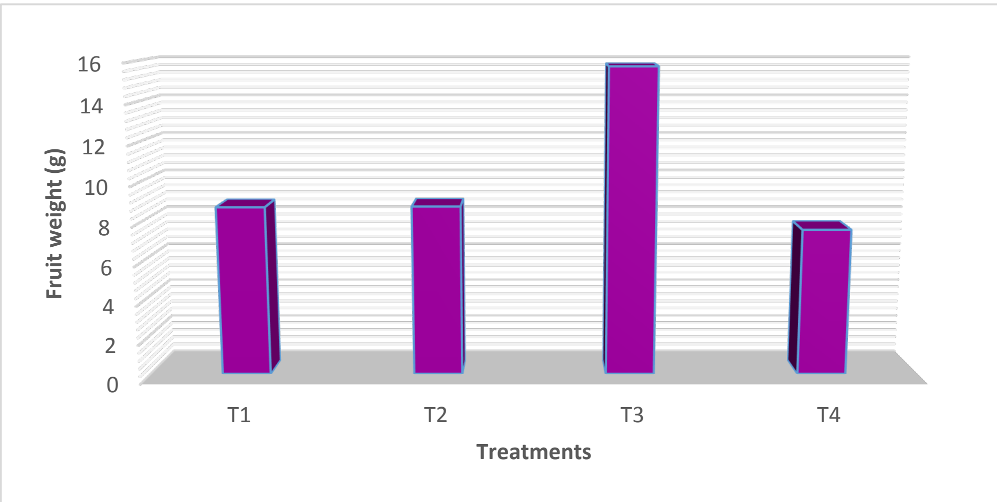

Fig. 9 (b)

Table 5 shows the fruiting and flowering period of pepper plants grown in the different treatment. Fig. 9 (a)-(b) show the fruit parameters of pepper after harvest. Plants amended with T_3 had the highest fruit yield, followed by T_2, T_4 and lastly T_1. In relation to fruit weight of pepper samples, T_3 had the highest average fruit weight followed by T_2, then T_1 which had only a slightly higher fruit weight than that of T_2 and lastly T_1 with the lowest average fruit weight of approximately 1 gram lighter than that of T_1. Chemical fertilizers have proven to have a better effect on fruit weight and fruit yield in this study.

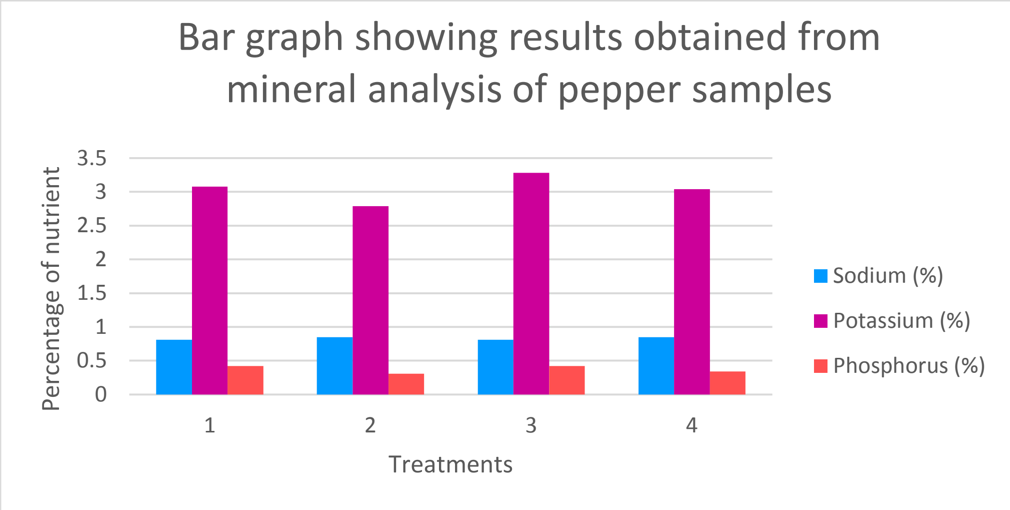

Fig.10

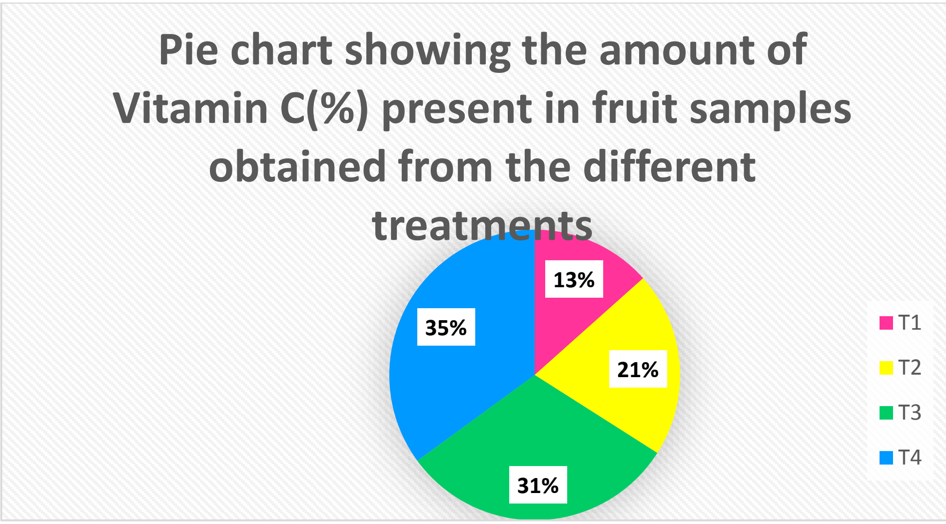

Fig.11

Fig. 10 shows results obtained from nutrient analysis of pepper samples grown in the different treatment. Fig. 11 shows the Vitamin C content in fruit samples obtained from different treatments. Pepper samples were analysed for their nutrient content.T_2 and T_4 had maximum amount of sodium, T_3 had the highest percentage of potassium, and T_3 and T_1 had the highest percentage of equal amounts of phosphorus. Vitamin C amount was highest in T4 which is a combination of organic and inorganic fertilizer. This combination have proven good results on the nutritional value of pepper. This was followed by T_3, T_2 and lastly T_1. Collectively, all results obtained have favored T_3 (chemical fertilizer). Plants response to T_3(chemical fertilizer) is better than any other planting medium for growing pepper plants since it is rich in nutrients and microbes which increases plant height, leaf numbers, and number of branches and stem diameter. It also increases the fruit yield and nutrient quality of fruits produce. However, despite these positive effect on pepper plants, there were presence of pest (whiteflies) and diseases on all pepper plants grown in T_3 .Neem extract were sprayed on all pepper plants since neem is known as a natural insect repellent. However, plants grown in chemical fertilizers were still susceptible to pest and diseases. Monroe, 2015, stated that chemical fertilizers increases plant diseases because they have a higher nitrogen content than slow-release organic fertilizers. With high abundance of nitrogen and phosphorus, plants are susceptible to mosaic infections. Lack of trace elements is also related to fungal and bacterial diseases in plants and vegetables .In addition, even though fruit yields and leaf numbers were high in T_3, there was massive leaf and fruit abscission occurring which may be due to the hormonal imbalance in plants grown on this treatment (Ashraf, et al, 2013). Early work by Kalmar and Lahav (1976), suggested that mineral nutrient applications could cause stimulation of vegetative growth during the period critical to fruit retention resulting in increased fruit drop and loss of yield (Lovatt, 1990).

T_2(vermicompost) was the second best treatment for growing pepper plants producing plants with significantly high amounts of chlorophyll as compare to the other treatments, good nutrient content and faster plant growth rate .Plants treated with T_2 had high growth rate when they were in potting media. However, after transplanting to the field, the rate of plant growth after a period decreases. The reason for this may be due to excessive application of vermicompost since too much vermicompost limits plant growth (Chamani *et al*, 2008). In contrast to T_3, there was no presence of pest and disease attack in this treatment. This is similar to result obtained from a study conducted by Mamta *et al*, 2012 where plants treated with vermicompost did not show any signs of pest and diseases which may be due to the pesticide action of vermicompost that aids in protecting crop plants against pest and diseases by suppressing, repelling or by inducing biological resistance in plants to fight them. The next treatment ,T_4, a mixture of T_2 and T_3 (organic and inorganic) was proven as the third best treatment for growing pepper plants with moderate plant growth rate, good fruit yield and good nutritional value. However, there was presence of whiteflies and diseases similar to that of T_3. Lastly, T_1 (promix), had little effect on the growth and productivity of pepper plants even though it had moderate amount of nutrients and there was small amount of diseases present. One reason for the limitation of plant growth in T_1 may be due to the pH level which was acidic having a negative effect on the microflora population in soil decreasing nutrient recycling and soil aeration.

4.0. CONCLUSION

The use of vermicompost for growing pepper plants did not have a greater effect on plant growth and productivity than other fertilizers. Chemical fertilizers (T_3) have proven to be the best medium for growing pepper plants producing plants with greater plant height, leaf number, number of branches and fruit yield. Not only does chemical fertilizers affect plant growth positively but also have negative impacts on pepper plants by causing pest and diseases on every plants grown in this treatment and premature dropping of fruits. Pepper plants also had a delay in flowering and fruiting period as compare to vermicompost and survival rate was negatively affected when compare to the other treatments. With presence of pest and diseases plants will require pesticide which in turn might leave residue in plants fruits and eventually cycle into our system upon consumption. T_2 was the second best medium for growing pepper plants producing plants with maximum chlorophyll content, faster germination rate and faster growth rate. This was followed by T4 the second best medium producing pepper with high amount of vitamin C and lastly the control which had relatively little effect on the growth rate of pepper plants.

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