BINDURA UNIVERSITY OF SCIENCE EDUCATION

DEPARTMENT OF CROP SCIENCE

Effects of different types of organic fertilizers on growth and yeild of tomatoes

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A DISSERTATION SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENTS OF THE BACHELOR OF AGRICULTURAL SCIENCE HONOURS DEGREE

(CROP SCIENCE)

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BINDURA UNIVERSITY OF SCIENCE EDUCATION

FUCULTY OF AGRICULTURE AND ENVIRONMENTAL SCIENCE

RESEACH PROJECT SUBMISSION APPROVAL FORM

This research project is the outcome of my original research work, and I'm submitting it to fulfill the requirements of the Bachelor of Agricultural Science Honors Degree in Crop Science. As far as I'm aware, the results presented in this project have not been submitted to any other institutions before, nor are they being currently submitted elsewhere.

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As the supervisor of the aforementioned student's research project, I can attest that the project is ready for submission.

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DECLARATION

I Panashe Kusikwenyu do hereby declare that this dissertation was the result of my own original efforts and investigation and such work has not been presented elsewhere for any degree or any university program. All other supplementary sources of information have been acknowledged by means of references.

Panashe Kusikwenyu

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Signature…………………………………

Date…………………………………………

CERTIFICATION OF THE DISSERTATION

Bindura University of Science Education

Department of Crop Science

The undersigned certify that they have read and recommend to the Bindura University to accept a dissertation entitled: **EFFECTS OF DIFFERENT TYPES OF ORGANIC FERTILIZERS ON**

GROWTH AND YEILD OF TOMATOES

Submitted by

Panashe Kusikwenyu

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In partial fulfillment of the requirements for the Bachelor of Science Honors Degree in Agriculture.

DATE…………………………………………………………………

DEDICATION

This research project is dedicated to my parents Mr P. Kusikwenyu and Mrs Z Kusikwenyu and all my family members.

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I'm thankful to the Almighty God for giving me strength, guidance and protection. Great appreciation goes to my supervisors Dr. T. Goche and Dr. J. Chikuvire for assisting me from the beginning of the research project to the end. I would also want to thank Mr and Mrs Hoko for providing me with land and some chemicals used during the project. Special thanks to Mr Tsuro for providing organic manures. Not forgetting my family and friends from Bindura University of Science Education. God bless you all.

ABSTRACT

In Zimbabwe, tomatoes are a highly valued crop, primarily sold fresh but also processed in large quantities. They are often used in salads, soups, stews, sauces, and other dishes. The productivity of tomato plants is heavily influenced by the nutritional quality of the soil. To investigate the impact of various organic fertilizers on tomato growth and yield, a study was conducted. The experimental field was divided into four blocks, each containing four beds with different treatments: (A) cow manure, (B) sheep manure, (C) poultry manure, and (D) control. The organic fertilizers were applied at a rate of 20 tons per hectare. Results indicated significant differences ($P<0.05$) in plant height, number of leaves, fresh and dry weight of shoots and roots, number of flowers, and fruits per plant based on the type of organic fertilizer used. Poultry manure was found to be the most effective compared to cow manure and sheep manure, suggesting that farmers can benefit from using poultry manure in tomato production.

Key words: Tomatoes, soil nutrition, cow manure, sheep manure, poultry manure

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CHAPTER 1

INTRODUCTION

1.1 BACKGROUND

The tomato, scientifically known as *Lycopersicon esculentum*, is a member of the solanaceae family and is a highly significant vegetable crop grown throughout the year in Zimbabwe, as well as in many other countries around the world. According to Peirce (1987), it is one of the most widely cultivated vegetables globally. Tomatoes are a crucial source of essential nutrients such as vitamins A, B, C, iron, and phosphorus, which are beneficial to human health (Varel *et al*., 2003; Naika *et al*., 2003). In Zimbabwe and other developing countries, tomatoes are essential for improving people's quality of life and economic well-being. In Zimbabwe, the highest tomato yield was recorded in 2015, where 25323 tonnes were harvested from 3508 hectares of land (FAOSTAT, 2020). Tomatoes are primarily grown for their fruits, which are used in many households on a daily basis, making them a staple food item.

The tomato plant is an annual herb that can vary in height and maturity depending on the specific variety. Its leaves are characterized by a large size, greenish color, and deep clefts with multiple leaflets. The shape of the tomato fruit can vary, with some being round, oval, or elongated, which is determined by the specific variety. When ripe, tomato fruits can be orange, yellow, or red and typically contain numerous small, hairy, light brown seeds that are kidney or pear-shaped (Tindall, 1993). In Zimbabwe, the most common tomato varieties are produced by Prime Seedco and Avanos, including Tengeru 97, Star 9009, Royal plus, Rodade, and Daisy F1.

Tomatoes are crops that thrive in warm weather, although they can withstand colder temperatures to some extent. However, they are not particularly tolerant of low temperatures. Tomato plants grow best when the temperature ranges between 26 and 29 ◦C, and wide variations in temperature can result in poor fruit quality and reduced yields. When humidity is high, it creates a favorable environment for various foliar diseases, while low relative humidity can cause issues with plant

infertility.

Zimbabwean horticultural plants typically need fertilizers, which can be natural or synthetic, as well as organic or inorganic. Organic fertilizers are derived from natural sources such as plants or animals, including compost, livestock manure, green manure, and crop residues. They enhance soil physical properties like water holding capacity, soil structure, soil aeration, and cation exchange capacity while preventing nutrient leaching. High temperatures promote the decomposition of organic matter in the soil (FAO, 2003), and adding organic fertilizers can help maintain long-term soil fertility levels. Additionally, organic fertilizers provide essential plant nutrients like nitrogen, potassium, and phosphorus, as well as some micronutrients. Low soil fertility due to insufficient organic matter is a significant issue in tomato production, but using organic manures has been shown to increase crop yield and soil quality, particularly soil organic matter content (Garg *et al*., 2005; Islam *et al*., 2010).

Inorganic fertilizers, also known as synthetic fertilizers, are obtained through the mining of mineral deposits such as lime and phosphate, or through industrial chemical processes, such as the production of urea. These fertilizers contain important nutrients like nitrogen, phosphorus, and sulfur, as well as some micronutrients, and they are readily available to plants for uptake. However, they can be overused or underused, which can negatively impact tomato production and affect smallholder farmers' yields. Inorganic fertilizers are also lost from the soil quickly, so crops need to be fertilized regularly to maintain optimal nutrient levels.

According to Yafan and Baker (2004), the inclusion of organic fertilizers from both compost and animal manures can enhance soil physical properties, including improved aggregation, increased soil aeration, lower bulk densities, and increased water retention. This also leads to an improvement in the supply of plant nutrients, thereby boosting tomato yield. Additionally, Baker and Bryson (2006) suggested that compost fertilization can promote plant growth effectively. Similarly, Gade (2007) reported that the application of farmland manure resulted in a significant increase in both the fresh and dry weights of tomato shoots and roots.

Yafan and Baker, Gad *et al*, Moez *et al* (2001) reported a positive response of tomatoes to organic manure showing an increase in yields as well as growth. This study shows if organic fertilizers at a rate of 20 tons per hectare improves tomato yield.

1.2 Problem statement

Tomato yields have decreased in Bindura due to lack of fertilizers leading to poor fruit quality, stunted growth and fewer fruits per plant. Most small scale tomato farmers are facing a problem of lack of inorganic fertilizers and knowledge of using organic fertilizers in production hence reduction in yield.

1.3 Justification

To address the issue of reduced tomato crop yield, the application of either organic or inorganic fertilizers is recommended. The use of organic fertilizers can lead to improved soil characteristics, including better aggregation, increased soil aeration and lower bulk density, reduced surface crust, and increased water retention. Additionally, organic fertilizers can supply essential plant nutrients, thereby promoting better tomato growth.

1.4 Main objective

To evaluate the effects of organic fertilizers on tomato production.

1.5 Specific objectives

i) To investigate the effects of different organic fertilizers on the growth rate of tomatoes.

ii) To determine the number of fruits per plant, number of flowers per plants grown using organic fertilizers.

1.6 Project hypotheses

i) Organic fertilizer has an effect on the growth rate of tomatoes ii) Organic fertilizer has an effect on the number of fruits per plant, number of flowers per plant and yield of tomatoes.

CHAPTER 2

LITERATURE REVIEW

2.1 Origin and plant characteristics

The center of origin of formation has been placed in the constrained area between Western South America's Pacific coast and the Andes mountain range (WWF and IUCN, 1997), and they were exported to Europe in the 1500s. Due to the presence of the deadly chemical tomatine in the foliage and portions of the plant's green tissues, they were thought to be poisonous (Peralta, 2007; Naika *et al*., 2005).

Based although the plant was brought to Mexico indirectly through commerce between preHispanic cultures, the tomato was also domesticated there. On how they grow, tomatoes can be divided into three groups. Determinate, semi-determinate, and indeterminate varieties make up these categories. Determinate plants typically reach heights of 1 to 1.5 meters (Richardson, 2013), such as rodade, and have a bushy growth style that reduces the need for support. Certain determinate cultivars have a spreading habit and are advised for hanging basket cultivation. The traits of semi-determinate varieties, like Tengeru, lie somewhere between those of determinate and indeterminate types. Indeterminate cultivars, including Trinity and Thomas F1, yield fruits continuously until they wither or die and have a maximum height of 3 meters.

2.2 Tomato growth requirements

2.2.1 Climatic requirements

When deciding on the best variety and planting dates, climate is among the most crucial considerations. Tomatoes are considered a warm-season crop, they need a high temperature. They require fairly stable temperature ranges with maximum and minimum temperatures that aren't too far apart because temperature changes could lead to poor fruit quality or diminish productivity. The ideal temperature for vegetative development is between 16 and 29°C (Stake Ayres, 2019). The temperature range for this growth is 10 to 34°C. Tomatoes grow best in environments with relative humidity levels between 65% and 85%, which is also crucial for pollination and pollen production. The negative effects of higher humidity include an increase in the incidence of blotchy ripening, a negative impact on pollen release and distribution on the stigma, and a favorable environment for the growth of numerous folia diseases. Low relative humidity may result in sterility because pollen on the stigma dries out before germination, producing undersized, malformed fruits.

2.22 Soil requirements

In order for tomato production to be profitable, it is crucial to have productive soil. The quality and nutrient content of the soil significantly affect the yield and quality of tomato fruits. While tomatoes can grow moderately on various soil types, certain factors must be considered, such as soil nutritional content, compaction, effective soil depth, pH, crop rotation, herbicide residues, and water holding capacity. Worley (1976) found that tomato yield was higher in soils with a pH between 6.5 and 6.9 than in acidic soils, despite the fact that tomatoes can tolerate a wide range of pH levels. However, fruit size tends to decrease on acidic soils or soils with high salinity (Doss, Evans, and Turner, 1977; Papadopoulos and Rendig, 1983).

2.2.3 Irrigation and water requirements

The vegetative stage of the tomato plant requires a lot of water for the plant's growth, cell elongation and enlargement, as well as the generation of sugars (Gilman *et al*, 2001). During the vegetative stage, a lot of water is needed in order to transform solar energy into energy for photosynthesis (Sinha, 2004). For tomato growing in well-drained soil, regular watering is essential. When the sun is at its strongest, mature tomatoes require at least one gallon of water. In order to assist the plant store the water it needs, water holding capacity is also crucial. It can be raised by adding manure to the soil, which will contain and keep a lot of water for plants. This promotes the usage of organic matter in the soil, which results in better soil structure, more productivity, and better-tasting tomatoes. Organic materials not only add moisture to the soil but also improve its nutritional value to plants. Radial and concentric fruit cracking can be brought on by irregular moisture levels (Peet and Willits, 1995). This severe physiological condition renders the tomatoes unmarketable and causes rapid degradation. The amount of moisture that a crop needs depends on its type, the local climate, and the properties of the soil. Tomato irrigation in Zimbabwe uses a wide range of irrigation methods. Sprinkler, drip, and flooding techniques are available to farmers to help meet the needs of the plant. Since soil-borne diseases were attracted by flooding and sprinkler use, which was once common, most small-scale and commercial farmers are now converting to drip irrigation for growing tomatoes. If properly managed, drip irrigation conserves water and provides the perfect amount of moisture to plants.

Plants may exhibit symptoms such as wilting, a reduction in the number of leaves, a yellowing or browning of the foliage, a reduction in the size of the leaves, and a drop in the number of leaves (Strange *et al*., 2000). In a similar vein, excessive irrigation can lead to floods, which removes nutrients from the root zone. Over application may also result in runoff and damping off, both of which are inefficient (Moore, 2012).

2.3 Influence of cow manure in tomato production

Cow dung is another name for cow excrement. Grass and, depending on the cattle's diet, grains, fruits, or vegetables make up the majority of what is digested. It contains remnants of the hay, straw, bedding, grains, and other organic materials used to feed the animals, so it's not just cow feces. Cow manure is full of nutrients and good for growing plants. It is nourishing for tomato production since it contains 3-2-1 NPK (3% nitrogen, 2% phosphorus, and 1% potassium) (Adejomo, 2016). Protein levels in plants are influenced by nitrogen, phosphorus affects the production of seeds, fruits, and flowers, and potassium affects water regulation and growth pace. Additionally, it provides the nutrients calcium, magnesium, and sulfur necessary for tomato development. Cow manure does include hazardous diseases and germs, such as E Coli, and is also high in ammonia. Therefore, before the manure reaches the field, aging or decomposition procedures is required to breakdown the organic content and remove the hazardous elements. There are benefits and drawbacks to using cow dung in tomato farming. The benefits include that it strengthens soil structure, aids in soil regeneration, and provides the nutrients necessary for the production of tomatoes. It is also organic, so plants may be produced without the use of chemical products, and it is environmentally beneficial. Its drawbacks include the requirement for significant volumes of fertilizer to meet crop nutrient demands and the high methane emissions from composting cow manure outside of biogas plants.

An investigation on the effects of cow dung manure was carried out in Nigeria at Mnamdi Azikiwe University (Egboka *et al*, 2020) and it showed that cow dung in the rate of 20kg/ha showed a significant increase in the growth and yield of tomato.

2.4 Influence of sheep manure on tomato production

Manure from goats and sheep is particularly nutrient-rich, warm, and dry. They exhibit high concentrations of potassium, phosphorus, and nitrogen, with corresponding values of 0.7, 0.3, and 0.9 (Egboka, 2016). They ought to be aged and decomposed before being added to the soil. Large amounts of organic matter found in sheep manure improve the soil's ability to hold onto nutrients and water. It also contributes to improving soil structure by raising the number of beneficial bacteria in the soil, which can help break down organic matter and enhance soil structure. The high levels of organic matter in sheep dung can aid in fostering the growth of beneficial insects, which in turn can aid in the management of pests and diseases. By building up a thick layer of organic matter on the soil's surface, it can also aid in the suppression of weeds by obstructing sunlight and halting the germination of weed seeds. Sheep manure's mild alkalinity aids in balancing the pH of acidic soil by neutralizing it. This is crucial for plants that like neutral or slightly alkaline soil because acidic soil might stunt their growth.

2.5 Influence of poultry manure on tomato production

Poultry manure is a particular kind of manure that is typically made from chicken. It is a very important resource and one of the best organic fertilizers on the market. It increases soil fertility, fosters the growth of the plant's root system and vitality, and lessens their susceptibility to pest and disease infestations (William Stiles, 2017). All 13 of the crucial plant nutrients that are required by plants are present in poultry manure. Among them are the elements nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), sulfur (S), manganese (Mn), copper (Cu), zinc (Zn), chlorine (Cl), boron (B), iron (Fe), and molybdenum (Mo). It is nutritive to plants since it includes 1.5-3% phosphorus, 1.5-3% potassium, and 3-5% nitrogen (Chastain *et al*., 2001). A study that examined the impact of applying various rates of poultry manure on tomato growth and yield was conducted. During the 2013 growing season, the study was conducted in the Department of

Agricultural Education's Teaching and Research Farm at Nwafor Orizu College of Education in Nsugbe, Anambra State. The results showed that plants grown in control plots fared the least well, while plants grown in 10 tonnes per hectare poultry dung outperformed the competition in both growth and yield parameters. Therefore, for the study area's best tomato development and productivity, it is advised to apply 10 tonnes per hectare of poultry manure (Chukwuma, 2013).

According to Yafan and Baker (2004), organic fertilizers boost soil physical qualities such aggregation, greater soil aeration, lower bulk densities, increased water retention, and feed plant nutrients, hence enhancing tomato output. This is true of both compost and animal manures. Compost fertilization, according to Baker and Bryson (2006), is advantageous for promoting plant growth. Farmland manure considerably boosted the fresh and dry weights of tomato shoots and roots (Gad *et al*, 2007).

Yafan and Baker, Gad *et al*, Moez *et al* (2001) reported a positive response of tomatoes to organic manure showing an increase in yields as well as growth. This study shows if organic fertilizers at a rate of 20 tonnes per hectare improves tomato yield. Most studies were not done in Africa specifically in Zimbabwe, Bindura hence this study will show the direct effects of organic

fertilizers in this study area.

CHAPTER 3

MATERIALS AND METHODS

3.1 The study site

This project was carried out in Mashonaland central in Bindura. Bindura is in natural region 11B and its rainfall received per annum ranges from 750 to 1000mm. It is fairly reliable falling from November to March/April hence the region is suitable for intensive cropping and livestock production.

3.2 Experimental design

3.2.1Field layout design

The experimental fields were divided into four beds measuring 1 meter by 2 meters. Each bed contains all treatments whereby there are four plants per treatment. All beds contained 4 plants being treated with cow manure, 4 plants with sheep manure, 4 plants with chicken manure and 4 plants being treated with inorganic fertilizers. Tomato spacing will be 0.7 meters in row and 0.3 meters inter row spacing. Each bed will contain 16 plants.

To analyze my data, used a Randomized Complete Block Design (RCBD) in which the field will be divided into units or blocks to account for any variations in the field. Treatments will be randomly assigned to the subjects within each block, with each treatment being applied four times per block. The experiment will consist of four blocks, or replications, with each bed containing only one treatment. The main goal of grouping experimental units into blocks is to ensure that the units within each block are as uniform as possible, so that any differences observed between treatments are mainly due to the "true" differences between the treatments. Therefore, the conditions within each block will be as homogeneous as possible, while large differences may exist between blocks. The treatments within a block will be compared under relatively homogeneous conditions.

Randomization is done separately for each block or replicate. Each treatment has the same probability of being assigned to a given experimental unit within a replicate. Different letters represent different treatments; A represents cow manure, B represents sheep manure, C represents poultry manure and D represents inorganic fertilizer. My design is to contain are 4 Beds (I-IV) and 4 treatments (A-D), hence my layout will be as follows

Block I

AAAA	BBBB
CCCC	DDDD

Block II

DDDD	AAAA
BBBB	CCCC

Block III

BBBB	DDDD
AAAA	CCCC

Block IV

CCCC	BBBB
AAAA	DDDD

3.2.2 The exact amounts of organic fertilizers

The experiment consisted of 4 treatments including Cow manure (CM), Sheep manure (SM), poultry manure (PM) and inorganic fertilizer as a control. The applications of organic fertilizers are based on the usual application by local farmers at a rate of 20 tons per hectare, three times per growing season. The tomato variety Rio grande will be planted and weeding is to be done regularly throughout the season. In organic fertilizers will be applied using the starkeayres formula where at 0 to 5 weeks, nitrogen will be applies at a rate of 180 kg/ha to 200 kg/ha, followed by potassium at 6 to 12 weeks at a rate of 60 kg/ha to 100 kg/ha and calcium, magnesium and phosphorus at 12 to 20 weeks at a rate of 250 kg/ha to300kg/ha, 50 to 60 kg/ha and 300 kg/ha to 400 kg/ha.

Land preparation was done using a pick, hoe and harrow. The pick ensured a deep plough was obtained and a hoe was used to break clods and make a fine tilth. Transplanting was done three weeks after planting. Flood irrigation was to be used throughout the season to ensure growth and minimum wilting at any point of growth. For the control of pest's acephate, emmamactin benzoate, and belt are being used and copper, mancozeb, metalaxyl and tubeconozole are also being used for early blight and late blight and also other fungal infections.

3.3.1 Plant height

Plant height was measured by a 30cm ruler 2 two weeks after transplanting. A mark was drawn on the stem with a red maker and the results were recorded on a piece of paper. The procedure was repeated after every two weeks. All the plants were measured and the mean was then the final result in cm. The plants had to remain upright for easy measuring and this was achieved by the use of trellising.

3.3.2 Number of leaves per plant

The number of leaves was counted and recorded two weeks after transplanting up to the eighth week.

3.3.3 Fresh and dry weight of shoots

3.3.3.1 Fresh weight

The plant was uprooted in the field and quickly moved to a shaded area. To get precise data excess water on the surface was removed and also the roots were cut off using a pair of scissors and the plant was weighed immediately. The process was done quickly to avoid the plant starting losing water.

3.3.3.2 Dry weight

The plant was blotted to remove free surface moisture. The shoot was taken and oven dried in an oven set to low heat 35 degrees celcious overnight. The shoots were left to cool in a dry area and weighed.

3.3.4 Fresh and dry weight of roots

3.3.4.1 Fresh weight

The field was watered the night before and the experiment was done the following day in the morning for easy uplifting of the plants without disturbing or cutting the roots. A small garden shovel was used to uplift the plant and the plants roots were placed on running water in order to remove the soil or the organic fertilizers. I waited for 15 minutes to remove surface moisture and then weighed the roots.

3.3.4.2 Dry weight

The roots were blotted to remove free surface moisture. . The roots were taken and oven dried in an oven set to low heat 35 ^{o}c overnight. The roots was left to cool in a dry area and weighed.

3.3.5 Number of flowers per plant

Number of flowers were counted were counted just after flower formation initiation until the end of the flowering process (4 weeks after transplanting) and the total was recorded.

3.3.6 Number of fruits per plant

Number of fruits per plant were counted and recorded.

3.4 Data analysis

One-way analysis of variance (ANOVA) using Genstat statistical package was used. Least Significant Difference (LSD) at p=0.05 was used to separate the means.

CHAPTER 4

RESULTS

4.1 Plant height

There is a significant difference between plant height of tomatoes at p<0.05 on different weeks as a result of different organic fertilizer (Table 4.1, 4.2, 4.3, 4.4).

Table 4.1 Plant height on tomatoes as affected by poultry manure, cow manure and sheep manure at week 2

Time (weeks)	Treatment	Mean height (cm)
	2Poultry manure	8.220^{T1}
	Cow manure	7.100^{T2}
	Sheep manure	7.150^{T3}
	Control	7.445^{T4}
P<0.001		
LSD 0.4244		

Table 4.2 Plant height on tomatoes as affected by poultry manure, cow manure and sheep manure at week 4

Time (weeks)	Treatment	Mean height (cm)

	4 Poultry manure	13.650^{T1}
	Cow manure	12.800^{T2}
	Sheep manure	12.855^{T3}
	Control	13.045^{T4}
P< 0.003		
LSD 0.3805		

Table 4.3 Plant height on tomatoes as affected by poultry manure, cow manure and sheep manure at week 6

Time (weeks)	Treatment	Mean height (cm)
6	Poultry manure	18.673^{T1}
	Cow manure	16.635^{T2}
	Sheep manure	17.220^{T3}
	Control	18.763^{T4}
P<0.01		
LSD 0.5802		

Table 4.4 Plant height on tomatoes as affected by poultry manure, cow manure and sheep manure at week 8

Time (weeks)	Treatment	Mean height (cm)

	8Poultry manure	39.11^{T1}
	Cow manure	26.67^{T2}
	Sheep manure	29.92^{T3}
	Control	36.00^{T4}
P<0.001		
LSD 2.579		

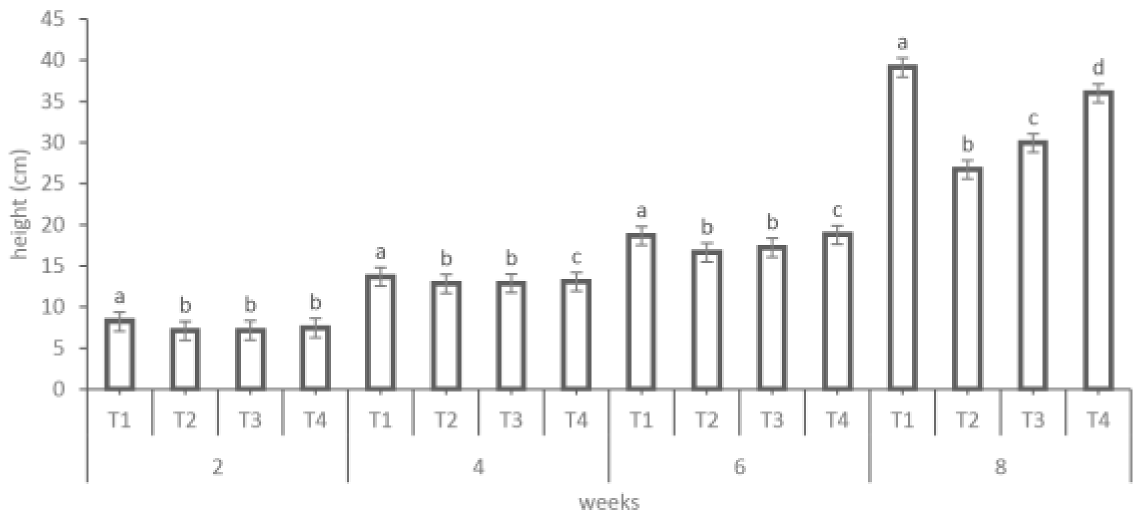

Figure 4.1 The height of tomatoes from week 2 to week 8 with T1 being poultry manure, T2 being cow manure, T3 sheep manure and T4 control. Error bars represents the least significance different of means (5% level). Bars with the same letters are not significantly different from one another.

T1 (poultry manure) had a significant effect on the plant height of tomato at week 8 as the plants had a mean height of 40cm (Table 4.4) The height between T2 and T3 was also significantly different with T3 having a mean height Toller than T2.

4.5 Number of leaves

Table 4.5 Number of leaves on tomatoes as affected by poultry manure, cow manure, sheep manure at week 2

Time (weeks)	Treatment	Number of leaves
2	Poultry manure	7.75^{T1}
	Cow manure	5.00^{T2}
	Sheep manure	6.50^{T3}

	Control	8.50^{T4}

P <0.001

LSD 1.366

Table 4.6 N umber of leaves on tomatoes as affected by poultry manure, cow manure, sheep manure at week 4

Time (weeks)	Treatment	Number of leaves
4	Poultry manure	22.25^{T1}
	Cow manure	14.50^{T2}
	Sheep manure	18.00^{T3}
	Control	20.50^{T4}

P <0.001

LSD 1.139

Table 4.7 Number of leaves on tomatoes as affected by poultry manure, cow manure, sheep manure at week 6

Time (weeks)	Treatment	Number of leaves
6	Poultry manure	40.25^{T1}
	Cow manure	24.25^{T2}

	Sheep manure	33.25^{T3}
	Control	37.50^{T4}

P < 0.001

LSD 2.996

Table 4.8 N umber of leaves on tomatoes as affected by poultry manure, cow manure, sheep manure at week 8

Time (weeks)	Treatment	Number of leaves
8	Poultry manure	59.00^{T1}
	Cow manure	35.00^{T2}
	Sheep manure	49.25^{T3}
	Control	54.25^{T4}

P < 0.001

LSD 2.996

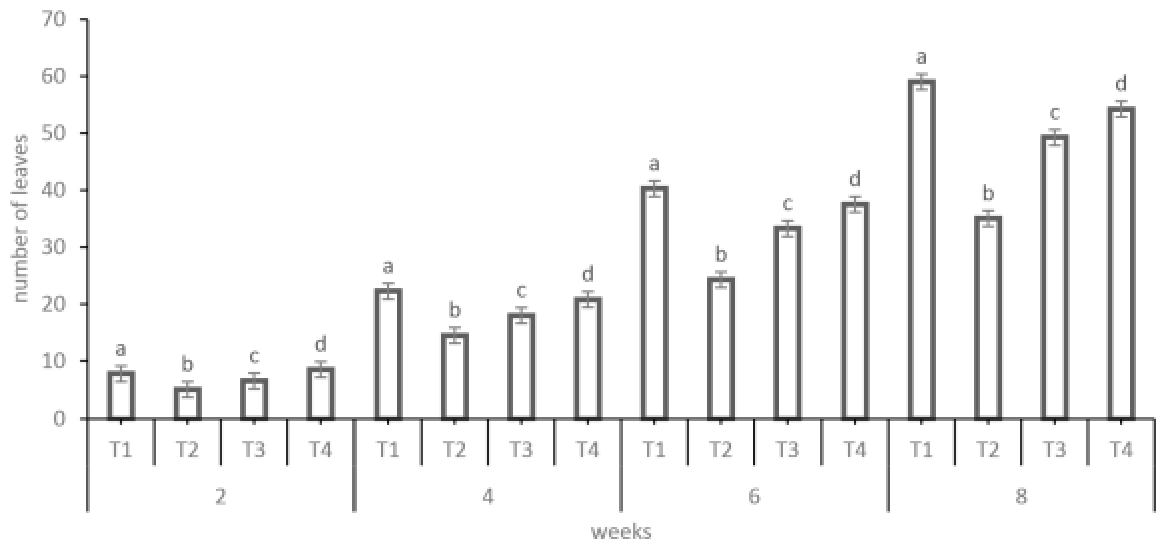

Fig 4.2 The number of leaves after 2, 4, 6, 8 weeks as affected by T1,T2,T3,T4 which are poultry manure, cow manure, sheep manure and control respectively. Bars represent the mean height of tomato plants. Error bars represent the mean +/- SE (n =16). Error bars represents the least significance different of means (5% level). Bars with the same letters are not significantly different from one another.

There is a significant difference in tomato number of leaves as T1 (poultry manure) was showing the highest number of leaves across all the treatments whilst there was statistically difference on other treatments at week 2 to week 6 (Table 4.8).

4.9 Fresh weight of shoots and roots

Table 4.9 Fresh weight of shoots and roots as affected by cow manure, sheep manure and poultry manure

Treatment	**Fresh weight (g)**	
	Shoot	**Root**
Poultry manure	187.55	64.43

Cow manure 175.90 53.05

Sheep manure 185.65 50.35 Control

116.85 57.45

p <0.001

LSD 1.782

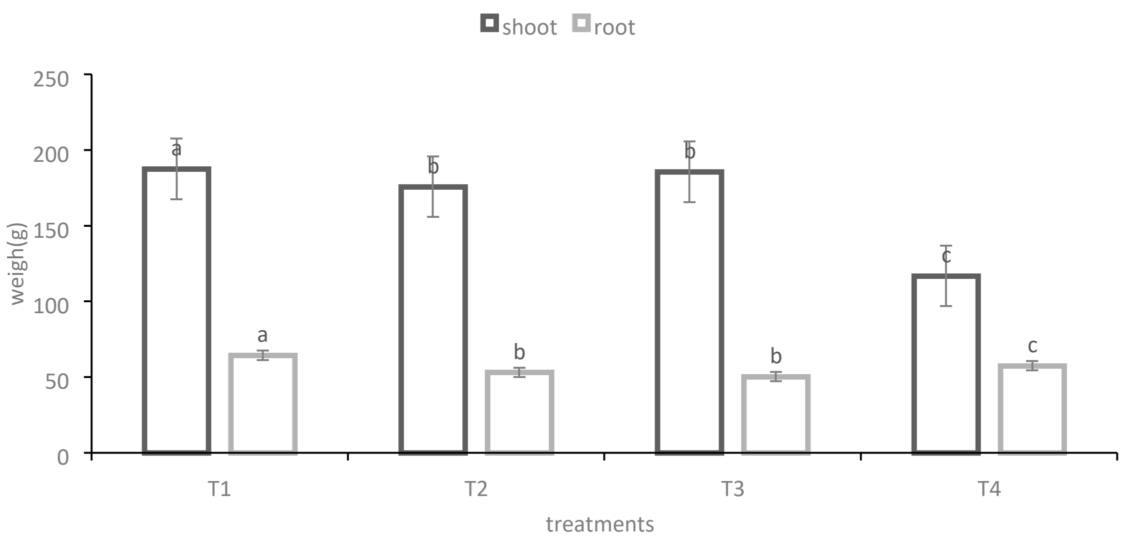

Fig 4.2 The fresh weight of shoot and roots as affected by poultry manure, cow manure, sheep manure and control T1, T2, T3, T4 respectively. Blue bars represent weight of shoots and the other weight of roots. Error bars represents the least significance different of means (5% level). Bars with the same letters are not significantly different from one another. Error bars represent the mean +/- SE (n =12) for shoots and +/- SE (n =12) for roots.

There is no significant difference of fresh weight of T1 (poultry manure) and T3 (sheep manure). There is a significant difference between T2 (cow manure) and T3 (control) although T3 showed the lowest fresh weight.

4.10 Dry weight of shoots and roots

Table 4.10 Dry weight of shoots and roots as affected by cow manure, sheep manure and poultry manure

Treatment	**Dry weight (g)**	
	Shoot	**Root**
Poultry manure	49.99	14.50
Cow manure	41.75	10.50
Sheep manure	41.70	9.075
Control	48.42	11.10
P< 0.001		
LSD 3.948		

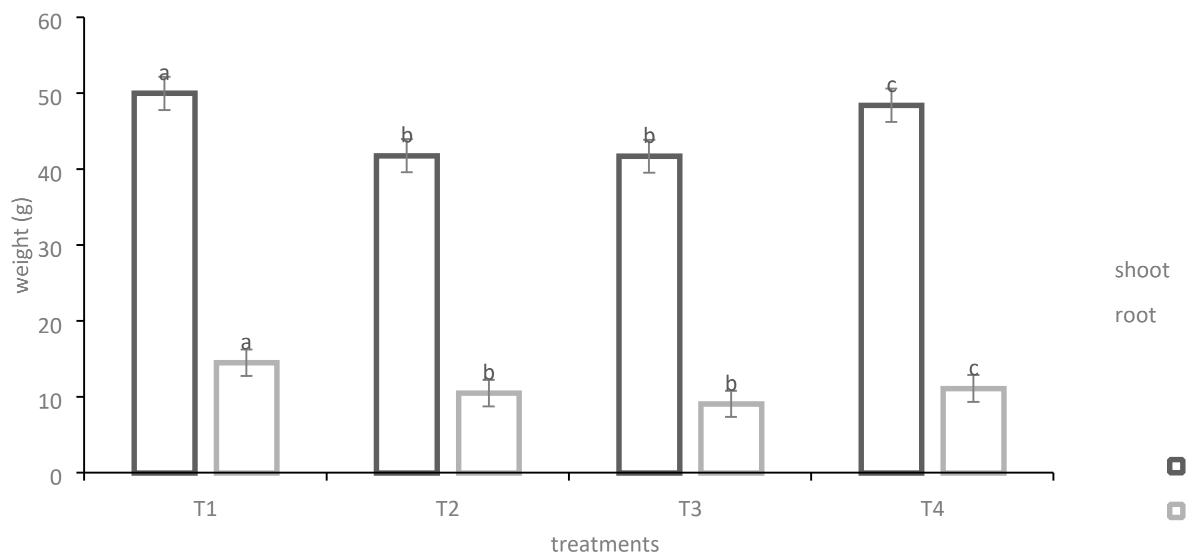

Fig 4.3.2 shows the dry weight of shoot and roots as affected by poultry manure, cow manure, sheep manure and control T1, T2, T3, T4 respectively. Blue bars represent weight of shoots and the other weight of roots. Error bars represent the mean +/- SE (n =12) for shoots and +/- SE (n =12) for roots. Error bars represents the least significance different of means (5% level). Bars with the same letters are not significantly different from one another.

There is a significant difference in dry weight of shoots and roots with T1 (poultry manure) showing the highest frequency that all other treatments. There is no significant difference between T2 (cow manure) and T3 (sheep manure) (Table 4.10)

4.11 Number of flowers

Table 4.11 Number of flowers per plant as affected by cow manure, sheep manure, poultry manure

Treatment	**Number of flowers per plant**
Poultry manure	102.00
Cow manure	93.00
Sheep manure	87.50
Control	104.50
P<0.001	
LSD 3.221	

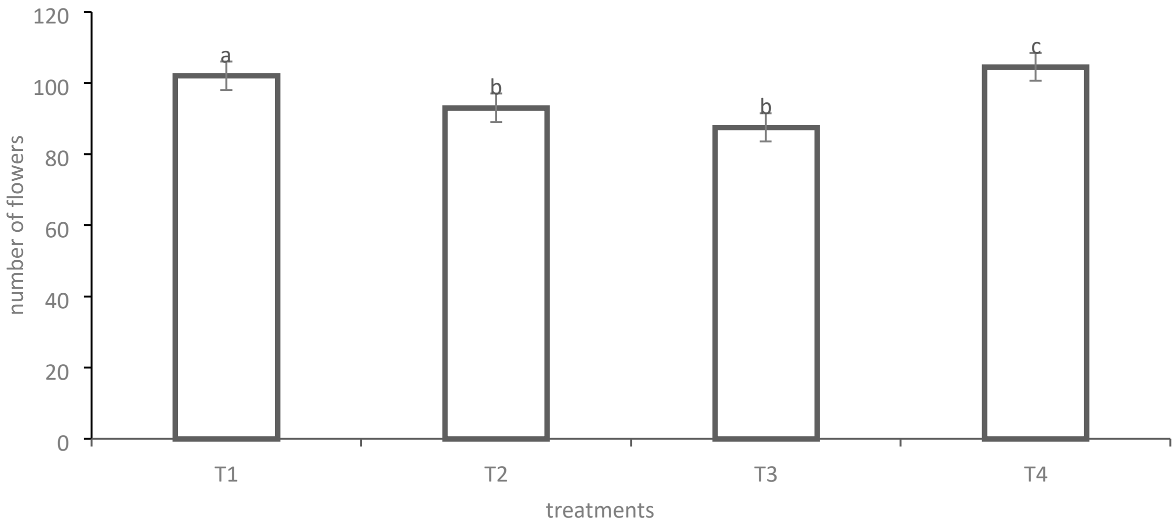

Fig 4.4 The number of flowers as affected by different organic manure with T1 being poultry manure, T2 being cow manure, T3 being sheep manure and T4 being the control. Error bars represent the mean +/- SE (n =16). Error bars represents the least significance different of means (5% level). Bars with the same letters are not significantly different from one another.

There is statistically difference in number of flowers in all treatments with T4 (control) showing the highest frequency and T3 (sheep manure) showing the least frequency (Table 4.11)

4.12 Number of fruits per plant

Table 4.12 Number of fruits per plant as affected by poultry manure, cow manure, sheep manure

Treatment	Number of fruits per plant

Poultry manure	98.25
Cow manure	89.75
Sheep manure	83.25
Control	101.00
P<0.001	
LSD 3.437	

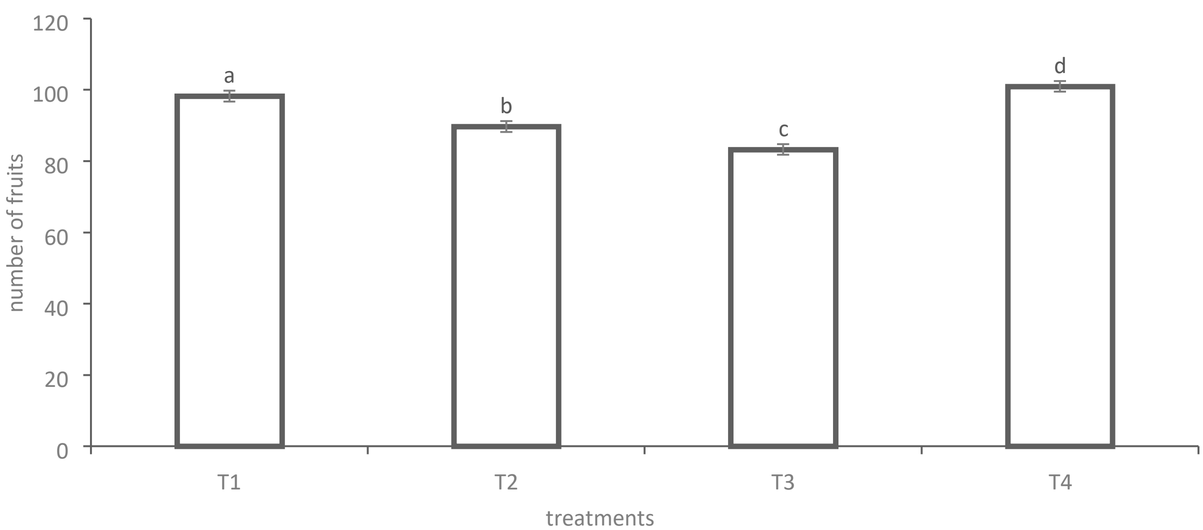

Fig 4.5 The number of fruits as affected by different organic manure with T1 being poultry manure, T2 being cow manure, T3 being sheep manure and T4 being the control. Error bars represent the mean +/- SE (n =16). Error bars represents the least significance different of means (5% level). Bars with the same letters are not significantly different from one another.

There is a significant difference number of fruits with T4 (control) showing the highest frequency whilst T3 (sheep manure) shows the least frequency (Table 4.12)

CHAPTER 5

DISCUSSION

5.1 Effects of poultry manure on tomato production

Poultry manure is rich in all 13 essential plant nutrients, including nitrogen, phosphorous, potassium, calcium, magnesium, sulfur, manganese, copper, zinc, chlorine, boron, iron, and molybdenum. These nutrients are absorbed by the animals through their feed, supplements, medications, and water, and are consequently present in their manure (Adejumo *et al* 2016).

Poultry manure as a soil amendment has a highly beneficial effect on tomato plant height. Significant differences were observed in plant height whereby poultry manure had the tallest plants 8.22 cm and others had no significant difference (Table 4.2). Poultry manure also has a big effect on the number of leaves, (Table 4.8) shows a highest number of leaves in plants treated with poultry manure. Poultry manure led to superior overall yield (Fig 4.5). Poultry manure had many flowers hence many fruits leading to a good yield. This finding aligns with previous studies conducted by Direkvandi *et al*. (2008) and Ayeni *et al*. (2010), which also reported significant improvements in plant height, number of branches and leaves as a result of poultry manure application. Due to its fast decomposition and mineralization rates, poultry manure undergoes rapid physical breakdown and biochemical transformation from complex organic molecules into simpler organic and inorganic molecules (Juma 1998). The rate of decomposition is influenced by various factors such as soil organisms, physical environment, and quality of organic matter.

During the decomposition process, different products are produced, including carbon dioxide, energy, water, plant nutrients, and resynthesized organic carbon compounds. Successive decomposition of dead material and modified organic matter results in the formation of a more complex organic matter called humus (Juma, 1998). Humus led to a high weight of fresh and dry weight in tomato plants (Table 4.9) because the roots could freely move in the soil. Humus affects soil properties and soil color, and as it decomposes, it darkens the soil. It increases soil aggregation and aggregate stability, soil CEC (the ability to attract and retain nutrients), and contributes to the availability of nitrogen, phosphorus, and other nutrients. Soil organisms use manure as food, and as they break down the manure, any excess nutrients are released, a process called mineralization. In poultry manure, organic nitrogen is quickly converted into NH_3 and later broken down to nitrate, which can be rapidly used by tomato plants. Nitrogen is important in plant processes such as photosynthesis, and a plant with sufficient nitrogen will experience high rates of photosynthesis and typically exhibit vigorous plant growth and development. Overall, incorporating poultry manure into soil can lead to improved soil quality and increased tomato yields, making it a valuable practice for tomato production.

5.2 Effects of cow manure on tomato production

According to Whalen *et al*. (2000), the addition of cattle manure to soil can raise soil pH to nearly neutral levels and enhance the availability of essential nutrients such as nitrogen, phosphorus, potassium, calcium, and magnesium. Ajayi and Adejumo (2016) observed that higher pH in soils was due to buffering from bicarbonates and organic acids present in cattle manure. Mineral nitrogen, available phosphorus, potassium, calcium, and magnesium levels increased immediately after manure application, and available phosphorus and potassium levels remained significantly higher. In this study, cattle manure was sourced from a cattle kraal and had undergone only two months of decomposition. In this project plants treated with cattle had no significant difference in height from sheep manure and control (Table 4.1) because of the slow releasing nutrient process.

Soil nitrogen and phosphorus are necessary for plant growth, and grazing animals such as cattle consume 30-50% of above-ground plant biomass, with some nitrogen and phosphorus returned to the soil in their excrement (Yoshitake *et al*., 2014). The deposition of animal waste influences soil carbon and nitrogen cycling in two ways: directly, by adding carbon and nitrogen to the soil, and indirectly, by altering the physical, chemical, and biological properties of the soil beneath it following deposition (Yoshitake *et al*., 2014). Proper application of animal manure and its subsequent decomposition yield highly plant-available nutrients that promote plant growth (Van der Waal *et al*., 2011). Cow manure is known to be one of the best fertilizers for promoting tomato plant growth, but it is important to avoid using it right away when it is fresh. In this study most of the nutrients were released at the flowering stage hence the plants had an average of 89.75 fruits (Fig 4.5). For optimal results, composting it for at least six months is recommended, as this allows time for the majority of weeds to die and all bacteria to be killed off (Yamaguchi, 2012). Fresh cow manure decomposes slowly and produces nutrients in small quantities at the soil active sites, resulting in lower yields compared to poultry manure.

5.3 Effects of sheep manure on tomato production

Research shows that sheep manure is beneficial for tomato production due to its high nutrient content, including nitrogen, phosphorus, and potassium, which are crucial for plant growth and development (Saeed *et al*., 2012). Moreover, sheep manure is an effective source of organic matter, which helps to enhance soil structure, water-holding capacity, and nutrient retention (Bhattacharyya *et al*., 2012).

The study revealed a significant difference in the number of flowers and fruits produced by tomato plants treated with sheep manure, poultry manure, and cattle manure, with sheep manure resulting in the least number of flowers (Table 4.11). Sheep manure decomposes slowly, and complete decomposition is necessary to release nutrients promptly hence its lowest number of leaves (Table 4.8) and in number of flowers (Table 4.11). Additionally, sheep manure has lower nitrogen levels, which may explain the lower yield results (Table 4.12). As a result, tomato plants treated with sheep manure required more watering than those treated with other types of manure.

However, it is important to apply sheep manure carefully to avoid over-fertilization, which can lead to nutrient imbalances and other issues. It is advisable to use sheep manure in combination with other organic materials such as compost and to monitor soil nutrient levels to ensure a proper balance of nutrients for the plants. Additionally, it is essential to compost sheep manure adequately before using it as a fertilizer to lessen the risk of crop contamination with harmful bacteria (Zhang *et al*., 2012).

CHAPTER 6

CONCLUSION AND RECOMANDATION

6.1 Conclusions

The research concludes that poultry manure at a rate of 20 tons per hectare can be used to boost tomato growth and yields. Due to a rapid increase in inorganic fertilizers in Zimbabwe farmers can adopt the use of manure to boost production. When using sheep manure or cow manure the farmer should consider the stage of decomposition of the manure and consider the type of feed that was used on the animals.

6.2 Recommendations

From the findings, the researcher recommends that:

i. The farmers in Bindura should use poultry manure in tomato in order to boost their harvest

ii. All manure to be used on tomatoes should go under the complete processes of decomposition for quick nutrient release.

REFERENCES

Adejumo, I.O., O.O. Adejumo, O.A. Oyekunle, and F.O. Olumide (2016). "Nutrient Composition of Poultry Manure and Its Potential as a Fertilizer." Journal of Agricultural Science, vol. 8, no. 2, pp. 187-195.

Ajayi, C.A., and I.O. Adejumo (2016). "Effect of Cow Dung Manure on the Growth and Yield of Tomato (Lycopersicon esculentum)." Journal of Applied Sciences and Environmental Management, vol. 20, no. 2, pp. 301-305.

Aghaalikhani, M., Modarres-Sanavy, S. A. M., Mokhtassi-Bidgoli, A., & Kashi, A. K. (2012). Effects of organic and chemical fertilizers on yield and yield components of tomato (Lycopersicon esculentum Mill). Journal of Agricultural Science and Technology, 14(4), 823-834.

Baker, J. T., & Bryson, C. T. (2006). Water use efficiency: a trait useful in developing drought resistant crops. Crop Science, 46(2), 947-949.

Bhattacharyya, P., Roy, K. S., Neogi, S., & Ghosh, B. (2012). Effect of vermicompost and composted farm yard manure on growth and yield of tomato. Journal of Environmental Biology, 33(5), 1025-1030.

Chukwuma, E.C., 2019. An Evaluation of Techniques of Tomato Production in Nigeria. Journal of Horticulture and Plant Research, 4(2), pp.1-8.

Doss, F., Evans, E.C., & Turner J.W(1997). Nitrogen and micronutrient fertilization and their effects on tomato production. Journal of Plant Nutrition, 1(3), 373-384

Egboka TP, C.O., Okafor, M,E .,Ofor, O.C., & Eze, C.N. (2020). Effects of organic manures on the growth and yield of tomato (*Solanum Lycopersicum L*) in Southen Nigeria. Agricultural

Journal Biology of North America, 11(2), 51-58

Environment, 58(1), 28-32

FAO. (2003). Plant nutrition for food security: A guide for integrated nutrient management. (No. 181).

FAOSTAT. (2020). Tomato production quantity: FAO statistics division.

Gad, H.A., EI-Amier, Y.A.,& Mohamed, S.M. (2007). Effects of organic and chemical fertilizers on growth, yield, quality of tomato, 10(4), 391-399

Gade, R. (2007). Effect of organic manure on growth and yield of tomato. Indian Journal of Horticulture, 64(4), 473-476.

Garg, V. K., Kaushik, P., & Singh, R. (2005). Evaluation of vermicompost and composts prepared from farm wastes and their effect on yield and uptake of macronutrients in wheat (Triticum aestivum L.). Bioresource Technology, 96(14), 1584-1591.

Gilman,C.K.,Lu,N., Turner, A.P., Dzantor, K.E., Johnson, J.B., & Fleisher, D.H. (2007). Effects of commercial fertilizer and organic amendments on fruit yield and quality in southern New

Jersey processing tomato. HortTechnology, 17(3), 390-398

Islum, R. Z. A., Mannan, M. A., Sultana, S., Mollah, M. A. R., & Rahman, M. M. (2010).

Effects of different types and levels of organic manure on the growth and yield of tomato. Journal of the Bangladesh Agricultural University, 8(1), 37-42.

Juma, N.G. (1998). The effects of different organic manures on the yield and nutrient uptake of

Moez, S., Soltani, M., Nemati, K., Shoukat-Fadaei, M. A., & Khorramdel, S. (2001). Effects of vermicompost and chemical fertilizers on some qualitative and quantitative properties of greenhouse cucumber. Journal of Practical Studies of Biosciences in Agriculture, 3(4), 1-7.

Moore, K.G.(2012). The effects of organic matter on soil physical properties. Plant Soil and

Nailq, N., Hussain, F., & Nisar, M. (2005). Effect of different manures on growth and yield of tomato (Lycopersicon esculentum Mill). International Journal of Agriculture and Biology, 7(6), 937-940.

Nakai, H., Hagio, M., & Sato, T. (2003). Effects of green manure crops and chicken manure on yield and quality of tomato (Lycopersicon esculentum Mill.). Soil Science and Plant Nutrition, 49(6), 865-871.

Peet, M., and Willits, D.H., 1989. Characterization of CO2 enrichment on tomato yield, photosynthesis and carbon balance in a closed system. Plant, Cell and Environment, 12(1), pp.31-38.

Peirce, L. C. (1987). The use of manures in vegetable production. Annual Review of Phytopathology, 25(1), 353-370.

Peralta, N. R. (2007). Organic farming and tomato production in the Philippines. In International Conference on Organic Agriculture and Agroecology in the Tropics and Subtropics (pp. 17-19).

properties in Mubi, Nigeria. Journal of Plant Nutrition, 27(9), 1595-1609.

Tindall, H. D. (1993). Vegetables in the tropics. Macmillan Education.
tomatoes. East African Agricultural and Forestry Journal, 63(4), 283-289

WWF IUCN. (1991). Agricultural value of hill forest. The Panda's Black Box: Opening up the Intelligent Use of Natural Resources, 16-21.

Yafam, M. G., & Baker, F. A. (2004). Effects of organic and inorganic fertilizers on tomato yield and soil

Rending, G., 2019. Effects of Organic Fertilizers on the Growth and Yield of Tomato (Solanum lycopersicum L.) in Ghana. International Journal of Agribusiness and Agricultural Economics, 6(4), pp.10-15.

Richardson, G.R., 1997. Multi-Crop Rotational Systems for Sustainable Tomato Production: Case Studies from Central and West Africa. In Proceedings of the Third International Symposium on Tropical Root and Tuber Crops, Lima, Peru, 25-30 November 1996 (pp. 33-39).

Stake Ayres, J., 2020. Tomato Production Guide for Beginners. [online] The Spruce. Available at: <https://www.thespruce.com/tomato-production-guide-for-beginners-4685267> [Accessed 2 December 2021].

Strange, R.N., Scott, P.R., and Gullino, M.L. (Eds.), 2008. Plant disease: a threat to global food security. Annu. Rev. Phytopathol., 46, pp.533-564.

Varel, V.H., Pashen, B.A., and Richardson, M.D., 1977. Influence of High Potassium Fertilizers on Tomato Production in Arkansas. HortScience, 12(5), pp.405-407.

Whalen, J.K., Chang, C., and Clayton, G.W., 2010. Microbial community structure and diversity in a Vertic soil profile. Canadian Journal of Soil Science, 90(4), pp.593-604.

William Stiles, E., 2018. Tomato Production in Greenhouses. [online] Penn State Extension. Available at: <https://extension.psu.edu/tomato-production-in-greenhouses> [Accessed 2 December 2021].

Worley, J.W., 1979. Potential World Tomato Production and Recent Uses of Modern Tomato Cultivars. In Genetic Resources of Tomato (pp. 11-24). Springer, Boston, MA.

Yamuguchi, J., 2019. Tomato Production and Market in Japan. [online] FreshPlaza. Available at: <https://www.freshplaza.com/article/9075957/tomato-production-and-market-in-japan/> [Accessed 2 December 2021].

APPENDICES

Appendix 1 ; Analysis of variance of plant height

Variate: Plant_height_week_2

Source of variation d.f. s.s. m.s. v.r. F pr.

block stratum 3 0.60947 0.20316 2.89

block.*Units* stratum

treatment 3 3.20847 1.06949 15.19 <.001

Residual 9 0.63363 0.07040

Total 15 4.45158

Information summary

All terms orthogonal, none aliased.

Tables of means

Variate: Plant_height_week_2

Grand mean 7.479

treatment	T1	T2	T3	T4
	8.220	7.100	7.150	7.445

Standard errors of means

Table	treatment
rep.	4
d.f.	9
e.s.e.	0.1327

Standard errors of differences of means

Table treatment

rep. 4 d.f. 9

s.e.d. 0.1876

Least significant differences of means (5% level)

Table treatment

rep. 4 d.f. 9

l.s.d. 0.4244

Stratum standard errors and coefficients of variation

Variate: Plant_height_week_2

Stratum d.f. s.e. cv% block 3 0.2254 3.0

block.*Units* 9 0.2653 3.5

Analysis of variance

Variate: Plant_height_week_4

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
block stratum	3	0.28625	0.09542	1.69	
block.*Units* stratum					
treatment	3	1.81970	0.60657	10.72	0.003
Residual	9	0.50935	0.05659		
Total	15	2.61530			

Information summary

All terms orthogonal, none aliased.

Message: the following units have large residuals.

block 4 *units* 1	-0.387	s.e.	0.178

Tables of means

Variate: Plant_height_week_4

Grand mean 13.088

treatment	T1	T2	T3	T4
	13.650	12.800	12.855	13.045

Standard errors of means

Table	treatment		
rep.	4	d.f.	9
e.s.e.	0.1189		

Standard errors of differences of means

Table treatment

rep. 4
d.f. 9

s.e.d. 0.1682

Least significant differences of means (5% level)

Table treatment

rep. 4 d.f. 9

l.s.d. 0.3805

Stratum standard errors and coefficients of variation

Variate: Plant_height_week_4

Stratum d.f. s.e. cv% block 3 0.1544 1.2

block.*Units* 9 0.2379 1.8 Analysis of variance

Variate: Plant_height_week_6

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
block stratum	3	0.8296	0.2765	2.10	
block.*Units* stratum					
treatment	3	13.5171	4.5057	34.25	<.001
Residual	9	1.1839	0.1315		
Total	15	15.5305			

Information summary

All terms orthogonal, none aliased.

Message: the following units have large residuals.

<

block 4 *units* 2 -0.550 s.e. 0.272

Tables of means

Variate: Plant_height_week_6

Grand mean 17.823

treatment	T1	T2	T3	T4
	18.673	16.635	17.220	18.763

Standard errors of means

Table	treatment		
rep.	4	d.f.	9
e.s.e.	0.1813		

Standard errors of differences of means

Table	treatment		
rep.	4	d.f.	9
s.e.d.	0.2565		

Least significant differences of means (5% level)

Table treatment

rep. 4 d.f. 9

l.s.d. 0.5802

Stratum standard errors and coefficients of variation

Variate: Plant_height_week_6

Stratum d.f. s.e. cv% block 3 0.2629 1.5

block.*Units* 9 0.3627 2.0 Analysis of variance

Variate: Plant_height_week_8

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
block stratum	3	17.552	5.851	2.25	
block.*Units* stratum					

treatment	3	383.276	127.759	49.15	<.001
Residual	9	23.394	2.599		
Total	15	424.222			

Information summary

All terms orthogonal, none aliased.

Message: the following units have large residuals.

block 3 *units* 4 -3.41 s.e. 1.21

Tables of means

Variate: Plant_height_week_8

Grand mean 32.93

treatment	T1	T2	T3	T4
	39.11	26.67	29.92	36.00

Standard errors of means

Table treatment

rep. 4 d.f. 9

e.s.e. 0.806

Standard errors of differences of means

Table treatment

rep. 4 d.f. 9

s.e.d. 1.140

Least significant differences of means (5% level)

Table treatment

rep. 4 d.f. 9

l.s.d. 2.579

Stratum standard errors and coefficients of variation

Variate: Plant_height_week_8

Stratum d.f. s.e. cv% block 3 1.209 3.7

block.*Units* 9 1.612 4.9 **Appendix 2; Analysis of leaf number**

Variate: Leaf_number_week_2

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
block stratum	3	0.1875	0.0625	0.09	
block.*Units* stratum					
treatment	3	28.1875	9.3958	12.89	0.001
Residual	9	6.5625	0.7292		
Total	15	34.9375			

Information summary

All terms orthogonal, none aliased.

Tables of means

Variate: Leaf_number_week_2

Grand mean 6.94

treatment	T1	T2	T3	T4
	7.75	5.00	6.50	8.50

Standard errors of means

Table	treatment		
rep.	4	d.f.	9
e.s.e.	0.427		

Standard errors of differences of means

Table   treatment

rep.   4   d.f.   9

s.e.d.   0.604

Least significant differences of means (5% level)

Table   treatment

rep.   4   d.f.   9

l.s.d.   1.366

Stratum standard errors and coefficients of variation

Variate: Leaf_number_week_2

Stratum d.f. s.e. cv% block 3 0.125 1.8

block.*Units* 9 0.854 12.3 Analysis of variance

Variate: Leaf_number_week_4

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
block stratum	3	2.1875	0.7292	1.44	
block.*Units* stratum					
treatment	3	135.6875	45.2292	89.22	<.001
Residual	9	4.5625	0.5069		
Total	15	142.4375			

Information summary

All terms orthogonal, none aliased.

Tables of means

Variate: Leaf_number_week_4

Grand mean 18.81

treatment	T1	T2	T3	T4
	22.25	14.50	18.00	20.50

Standard errors of means

Table treatment

rep. 4 d.f. 9

e.s.e. 0.356

Standard errors of differences of means

Table treatment

rep. 4 d.f. 9

s.e.d. 0.503

Least significant differences of means (5% level)

Table treatment

rep. 4 d.f. 9

l.s.d. 1.139

Stratum standard errors and coefficients of variation

Variate: Leaf_number_week_4

Stratum d.f. s.e. cv% block 3 0.427 2.3

block.*Units* 9 0.712 3.8 Analysis of variance

Variate: Leaf_number_week_6

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
block stratum	3	5.688	1.896	0.54	
block.*Units* stratum					
treatment	3	587.188	195.729	55.81	<.001

Residual	9	31.562	3.507
Total	15	624.438	

Information summary

All terms orthogonal, none aliased.

Tables of means

Variate: Leaf_number_week_6

Grand mean 33.81

treatment	T1	T2	T3	T4
	40.25	24.25	33.25	37.50

Standard errors of means

Table treatment

rep. 4 d.f. 9

e.s.e. 0.936

Standard errors of differences of means

Table treatment

rep. 4 d.f. 9

s.e.d. 1.324

Least significant differences of means (5% level)

Table treatment

rep. 4 d.f. 9

l.s.d. 2.996

Stratum standard errors and coefficients of variation

Variate: Leaf_number_week_6

Stratum d.f. s.e. cv% block 3 0.688 2.0

block.*Units* 9 1.873 5.5 Analysis of variance

Variate: Leaf_number_week_6

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
block stratum	3	5.688	1.896	0.54	
block.*Units* stratum					
treatment	3	587.188	195.729	55.81	<.001
Residual	9	31.562	3.507		
Total	15	624.438			

Information summary

All terms orthogonal, none aliased.

Tables of means

Variate: Leaf_number_week_6

Grand mean 33.81

treatment	T1	T2	T3	T4
	40.25	24.25	33.25	37.50

Standard errors of means

Table treatment

rep. 4 d.f. 9

e.s.e. 0.936

Standard errors of differences of means

Table treatment

rep. 4 d.f. 9

s.e.d. 1.324

Least significant differences of means (5% level)

Table treatment

rep. 4 d.f. 9

l.s.d. 2.996

Stratum standard errors and coefficients of variation

Variate: Leaf_number_week_6

Stratum d.f. s.e. cv% block 3 0.688 2.0

block.*Units* 9 1.873 5.5 Analysis of variance

Variate: Leaf_number_week_8

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.

block stratum	3	15.250	5.083	1.34	
block.*Units* stratum					
treatment	3	1292.250	430.750	113.19	<.001
Residual	9	34.250	3.806		
Total	15	1341.750			

Information summary

All terms orthogonal, none aliased.

Tables of means

Variate: Leaf_number_week_8

Grand mean 49.38

treatment	T1	T2	T3	T4
	59.00	35.00	49.25	54.25

Standard errors of means

Table treatment

rep. 4 d.f. 9

e.s.e. 0.975

Standard errors of differences of means

Table treatment

rep. 4 d.f. 9

s.e.d. 1.379

Least significant differences of means (5% level)

Table treatment

rep. 4 d.f. 9

l.s.d. 3.120

Stratum standard errors and coefficients of variation

Variate: Leaf_number_week_8

Stratum d.f. s.e. cv% block 3 1.127 2.3

block.*Units* 9 1.951 4.0 **Appendix 3; Analysis of variance of fresh weight of shoots**

Variate: Fresh_weight_of_shoots

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
block stratum	3	2.042	0.681	0.55	
block.*Units* stratum					
treatment	3	13449.397	4483.132	3613.61	<.001
Residual	9	11.166	1.241		

Total	15	13462.604

Information summary

All terms orthogonal, none aliased.

Message: the following units have large residuals.

block 3 *units* 4	-2.14	s.e. 0.84

Tables of means

Variate: Fresh_weight_of_shoots

Grand mean 166.48

treatment	T1	T2	T3	T4
	187.55	175.90	185.62	116.85

Standard errors of means

Table treatment

rep. 4 d.f. 9

e.s.e. 0.557

Standard errors of differences of means

Table treatment

rep. 4 d.f. 9

s.e.d. 0.788

Least significant differences of means (5% level)

Table treatment

rep. 4 d.f. 9

l.s.d. 1.782

Stratum standard errors and coefficients of variation

Variate: Fresh_weight_of_shoots

Stratum d.f. s.e. cv% block 3 0.412 0.2

block.*Units* 9 1.114 0.7 Analysis of variance

Variate: fresh_weight_of_roots

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
block stratum	3	1.6712	0.5571	2.25	
block.*Units* stratum					
treatment	3	453.5312	151.1771	610.24	<.001
Residual	9	2.2296	0.2477		
Total	15	457.4320			

Information summary

All terms orthogonal, none aliased.

Message: the following units have large residuals.

block 4 *units* 3 -0.91 s.e. 0.37

Tables of means

Variate: fresh_weight_of_roots

Grand mean 56.32

treatment	T1	T2	T3	T4
	64.43	53.05	50.35	57.45

Standard errors of means

Table treatment

rep. 4 d.f. 9

e.s.e. 0.249

Standard errors of differences of means

Table treatment

rep. 4 d.f. 9

s.e.d. 0.352

Least significant differences of means (5% level)

Table treatment

rep. 4 d.f. 9

l.s.d. 0.796

Stratum standard errors and coefficients of variation

Variate: fresh_weight_of_roots

Stratum d.f. s.e. cv% block 3 0.373 0.7

block.*Units* 9 0.498 0.9 **Appendix 4; analysis of variance of dry weight of shoots and roots**

Variate: dry_wight_of_shoots

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
block stratum	3	13.933	4.644	0.76	
block.*Units* stratum					
treatment	3	228.646	76.215	12.51	0.001
Residual	9	54.835	6.093		
Total	15	297.415			

Information summary

All terms orthogonal, none aliased.

Message: the following units have large residuals.

block 3 *units* 3 4.91 s.e. 1.85

Tables of means

Variate: dry_wight_of_shoots

Grand mean 45.46

treatment	T1	T2	T3	T4
	49.99	41.75	41.70	48.42

Standard errors of means

Table treatment

rep. 4 d.f. 9

e.s.e. 1.234

Standard errors of differences of means

Table treatment

rep. 4 d.f. 9

s.e.d. 1.745

Least significant differences of means (5% level)

Table treatment

rep. 4 d.f. 9

l.s.d. 3.948

Stratum standard errors and coefficients of variation

Variate: dry_wight_of_shoots

Stratum d.f. s.e. cv% block 3 1.078 2.4

block.*Units* 9 2.468 5.4 Analysis of variance

Variate: dry_weight_of_roots

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
block stratum	3	0.1191	0.0397	0.30	
block.*Units* stratum					
treatment	3	63.4819	21.1606	162.33	<.001
Residual	9	1.1732	0.1304		
Total	15	64.7742			

Information summary

All terms orthogonal, none aliased.

Tables of means

Variate: dry_weight_of_roots

Grand mean 11.294

treatment	T1	T2	T3	T4
	14.500	10.500	9.075	11.10

Standard errors of means

Table	treatment		
rep.	4	d.f.	9
e.s.e.	0.1805		

Standard errors of differences of means

Table	treatment		
rep.	4	d.f.	9
s.e.d.	0.2553		

Least significant differences of means (5% level)

Table treatment

rep. 4 d.f. 9

l.s.d. 0.5775

Stratum standard errors and coefficients of variation

Variate: dry_weight_of_roots

Stratum d.f. s.e. cv% block 3 0.0996 0.9

block.*Units* 9 0.3611 3.2 **Appendix 5; Analysis of variance of number of flowers**

Variate: Number_of_flowers

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
block stratum	3	1.500	0.500	0.12	
block.*Units* stratum					
treatment	3	749.000	249.667	61.56	<.001

Residual	9	36.500	4.056
Total	15	787.000	

Information summary

All terms orthogonal, none aliased.

Tables of means

Variate: Number_of_flowers

Grand mean 96.75

treatment	T1	T2	T3	T4
	102.00	93.00	87.50	104.50

Standard errors of means

Table treatment

rep. 4 d.f. 9

e.s.e. 1.007

Standard errors of differences of means

Table treatment

rep. 4 d.f. 9

s.e.d. 1.424

Least significant differences of means (5% level)

Table treatment

rep. 4 d.f. 9

l.s.d. 3.221

Stratum standard errors and coefficients of variation

Variate: Number_of_flowers

Stratum d.f. s.e. cv% block 3 0.354 0.4

block.*Units* 9 2.014 2.1 **Appendix 6; Analysis of variance of number of fruits**

Variate: number_of_fruits

Source of variation d.f. s.s. m.s. v.r. F pr.

block stratum 3 10.688 3.562 0.77

block.*Units* stratum

treatment 3 788.688 262.896 56.93 <.001

Residual 9 41.562 4.618

Total 15 840.938

Information summary

All terms orthogonal, none aliased.

Tables of means

Variate: number_of_fruits

Grand mean 93.06

treatment	T1	T2	T3	T4
	98.25	89.75	83.25	101.00

Standard errors of means

Table	treatment
rep.	4
d.f.	9
e.s.e.	1.074

Standard errors of differences of means

Table	treatment
rep.	4
d.f.	9
s.e.d.	1.520

Least significant differences of means (5% level)

Table treatment

rep. 4 d.f. 9

l.s.d. 3.437

Stratum standard errors and coefficients of variation

Variate: number_of_fruits

Stratum d.f. s.e. cv% block 3 0.944 1.0

block.*Units* 9 2.149 2.3