BISHOP STUART UNIVERSITY

EFFECT OF DIFFERENT POULTRY MANURE TYPES ON THE PERFORMANCE OF TOMATOES *(Lycopersicon esculentum Mill)*

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18/BSU/MSC.A/002

A DISSERTATION SUBMITTED TO THE DIRECTORATE OF GRADUATE STUDIES, RESEARCH AND INNOVATIONS IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE AWARD OF A MASTER OF SCIENCE DEGREE IN AGRONOMY OF BISHOP STUART UNIVERSITY

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DECLARATION

I, Agaba Julius, do hereby declare that the work contained in this dissertation about "Effect of different poultry manure types on the performance of tomatoes" *(Solanum lycopersicum Mill)* is my original work and has never been submitted to any other university or institution for any award.

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APPROVAL

This dissertation about "Effect of different poultry manure types on the performance of tomatoes" *(Solanum lycopersicum Mill)* has been under our supervision and is now ready for submission with our approval.

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PROF. DAVID OSIRU

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(SUPERVISOR)

DEDICATION

This dissertation is dedicated to my wife Katushabe Abias who sacrificed all family pleasures and quality time for the sake of supporting my studies.

Her efforts towards the success of my studies portray the highest degree of love and care. May God through Jesus Christ reward her abundantly.

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LIST OF ACRONYMS

B	Broilers manure
L	Layer manure
C	Combination
CN	Control
RCBD	Randomized Complete Block Design
Cm	Centimeters
M	Meters
G	Grams
Kgs	kilograms
BSU	Bishop Stuart University
ANOVA	Analysis of variance
°C	Degrees centigrade
Ph.	Potential hydrogen
N	Nitrogen
P	Phosphorous
K	potassium
Ca	calcium
Mg	Magnesium
Cu	Copper
Fe	Iron
Mn	Manganese
Zn	Zinc
B	Boron
Ppm	Parts per million
Om	Organic matter
Ec	Cation exchange capacity
Lab	Laboratory
D.F	Degree of freedom
S.S	Sum of squares
M.S	Mean square
V.R	Variance ratio

F	value
t	tones

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ABSTRACT

Tomato *(Lycopersicon esculentum Mill)* is one of the most popular and versatile vegetables in the world, and organic production with high yields of desirable quality are a target of many producers. However, the yield of tomatoes in Uganda is low compared to other parts of the world. The reason is that most soils in Uganda are low in fertility. There is widespread soil degradation, due to massive soil erosion resulting into loss of organic matter, high soil acidity and nutrient imbalances hence low crop yields. This study aimed at establishing the effect of different poultry manure on the performance of tomatoes (Rio- Grande tomato variety).

The field trials were conducted during the years of 2020 and 2021 at Bishop Stuart University (BSU) farm Mbarara city, South Western Uganda. Four treatments which included Broiler, Layer, combination of Broiler and Layer chicken manure and the control were applied. The study was carried out in a randomized complete block design with four replicates. Measurements were made on number of leaves, number of flowers, plant height, fruit weight, fruit size, number of tomato fruits and yield per hectare. Broiler and layer manure blend increased the number of leaves, plant height, number of flowers, number of fruits, fruit weight and fruit size significantly.

The results indicate that poultry manure is very rich in nitrogen, phosphorus, potassium and micro nutrients making it a valuable source of plant nutrients. It is a useful remedy for soils that are depleted of nutrients.

Among the treatments, broiler and layer chicken manure gave the highest fruit yield of 13.8 and 13.4 tons per hectare (t/ha) respectively. A combination of the manure produced 12.8 t/ha and the control treatment gave the lowest yield of 8.1 tons per hectare (t/ha).

There was no significant difference between broiler and layer chicken manure. Both manure were equally good and enhanced yield. Therefore, farmers may opt for either of the two depending on the availability.

It is concluded that use of broiler or layer chicken manure will largely depend on availability and the cost of the manure.

It is therefore recommended that either broiler or layer chicken manure can be used for production of tomato in order to achieve high yields.

Keywords: Tomato, broiler manure and Layer manure, growth and yield, macro and micro nutrients.

CHAPTER ONE

INTRODUCTION

1.1 Background

According to (Foolad *et al.* 2018), tomato is the sixth most valuable crop in the world worth US$ 87.9 billion in 2016 and is grown in all soil types on a small scale for family use and commercial purposes.

Tomato belongs to the *solanaceae* family and the genus *Lycopersicon* which is a small genus within the large and diverse genera that consists approximately 90 genera and is one of the most consumed vegetables in the world (Singh *et al.* 2019). They can be eaten fresh or in processed forms such as source, ketchup, puree, paste, powder and soup. (Battistuzzi and Valenciano, 2012). Tomato is also a crop which is globally grown, some in the open field others in the green house. Indeterminate varieties are usually grown in greenhouses (Stoleru *et al.* 2020).

Tomato is a native crop to Peru, Galapagon Island and Ecuador; however evidence shows that the site of domestication was Mexico (Resende and Klee, 2020, Carrillo 2018). Tomatoes were introduced into the continent of Africa in the 16th century and currently it is the most widely grown vegetable crop. (Dhaliwal *et al.* 2011). The plant grows to the height of 1-3m and consists of weak stems that sprawl over the ground. For high yield, tomato requires support or staking. It is grown outdoor in temperate climate as an annual crop despite being a perennial in its native habit (Mohammed, 2017).

In Uganda, the crop is grown throughout the year. However higher profits are realized during the dry season since the demand is higher than supply. There is also low disease pressure during the dry season when the crop is grown under irrigation. Tomatoes play an important role in human diet because they are good source of minerals and vitamins a remedy for night blindness.

Tomatoes contain a high level of lycopene; substances that are used in some of the more pricy facial cleansers that are available for purchase (Wang, 2020).Tomatoes also help to prevent several types of cancer. Studies indicate that high levels of lycopene in tomatoes reduce the chances of developing prostate, colorectal and stomach cancer.

Lycopene is a natural antioxidant that works effectively to slow down the growth of cancerous cells (Bathla *et al*, 2019, Labrie and Marcelis, 2020).

Tomatoes help maintain strong bones. This is because they contain considerable amounts of calcium and Vitamin K. Both nutrients are essential in strengthening and performing minor repairs on the bones as well as the bone tissue (Amao, 2018).

There are many varieties of tomatoes that are grown in Uganda. These are Marglobe, Beauty, Roma, Heinz, Rio- Grande, DRD Hybrid, Asilla Hybrid, Eden Hybrid, Proster, Money maker (Bainomugisha, 2019). Among these, Rio Grande tomatoes are the most commonly grown.

The variety was used in the present study because it is the most commonly grown in Uganda, its seeds are cheap to buy and its fruits are easy to handle during harvesting and have long shelf life in the market. (Liamngee *et al*, 2019).

According to (El-Shafie, 2020), the most leading tomato producing countries in the world are China, India, USA and Turkey with a production of 56.4, 19.4, 12.6 and 12.2 million tons per year respectively.

Uganda produces 37,167 tons per year, (FAO 2020) with farmers harvesting 1.5 to 14 tons per hectare compared to the world average of 33.6 million tons per year. Egypt has a total annual production of 8.625 million tons and is the highest producer in Africa while Nigeria is the second producer with a total annual production of 1.560 million tones, (FAO, 2014).

Li, B. (2018), reports that tomato is a high yielding vegetable that requires a lot of fertilizers for its proper establishment, growth and yield. They are heavy feeders of macro-nutrient elements such as nitrogen, potassium, phosphorous, calcium and some micro-nutrients like iron, manganese and zinc. Inadequate supply of potassium and calcium makes tomato susceptible to physiological disorders such as blossom end-rot and plants fail to accumulate soluble solid sugars. (White *et al,* 2020). Smaller amounts of elements such as nitrogen, magnesium, phosphorous, Boron ad copper when applied together play a big role in dry matter partitioning and fruit setting of tomato plant. (Pandey, 2018). Chemical fertilizers have been reported as the most important contributor to increased agricultural yields over the past years (Anwar *et al*, 2018). However negative effects of chemical fertilizers on the soils and environment have been recognized as one of the limiting factors in sustainable agricultural production (Chen and Ruan, 2018). Most farmers do not apply fertilizers due to high costs and unreliable availability of inorganic fertilizers. In addition, few farmers who use chemical fertilizers have adequate knowledge on the recommended rates (Dalokom *et al*, 2016) leading to application of high amounts of chemical fertilizers, hence causing soil nutrient imbalances.

According to Birungi and Ngabirano, (2020), one of the most limiting factors to agriculture production and productivity in Uganda apart from pests and diseases, is low and declining soil fertility. This is partly in agreement with (Harris *et al,* 2018) who reported that Ugandan soils are no longer fertile and therefore, they need both organic manure and mineral fertilizers to regain fertility and produce enough food to feed its growing population.

Research comparing soil management using organic manure and chemical fertilizers has shown that soil organic matter and total nitrogen are high in soils where organic manure was applied (Ojeniyi *et al*, 2010).

Organic materials such as poultry manure are recognized as suitable organic fertilizer. Poultry manure if well-handled is the most cherished of all animal manures (Vasilev *et al*, 2017). The use of poultry manure for soil fertility maintenance, growth and yield of tomatoes has been reported by Olorode *et al,* (2020).

According to (Alonso *et al*, 2012), poultry manure exists in different forms, deep litter manure, broiler manure, cage manure and deep pit manure. Deep litter manure is produced by the Layer birds during the laying period and Broiler manure is produced by meat producing birds during fattening period.

According to Ashworth *et al,* (2020), the amounts of nutrients in poultry manure may differ due to different factors like breed of the birds, litter used, and moisture content of the manure and deity of the birds. Considerable research has been conducted to evaluate the effect of poultry manure on the growth and yield of a tomato crop. However; it is not yet clear whether response of the crop to Layers and Broiler manure may differ.

1.2 Statement of the Problem

Tomato productivity in Uganda is rated very low at 1.5 to 14 tons per hectare compared to world average of 56 tons per hectare (FAO, 2014).

The most common limiting factors to tomato productivity are pests and diseases, drought, soil erosion and low declining soil fertility across Uganda, (Birungi and Ngabirano, 2020).

It has been reported that low soil fertility is one of the leading constraint to production of tomato in Africa (Ogbomo, 2011). In Uganda, most soils are poor in fertility due to degradation and this has been a very challenging factor working against Ugandans' agricultural production due to the fact that most farmers rarely use fertilizers.

Therefore, this calls for the adoption of both inorganic and organic fertilizers to increase crop production. However, over dependence on inorganic fertilizers for crop production has negative effects on the soils and environment hence, limiting sustainable agricultural production. (Chen and Ruan, 2018). Moreover, inorganic fertilizers are expensive and largely out of reach by the small scale farmers in Uganda. Therefore it is pertinent to explore the use of organic fertilizers to increase crop production. Organic manure such as cow, goat, pig as well as compost are very good alternative to mineral fertilizer. Research conducted by Azeez *et al,* (2017) shows that poultry manure if well-handled is the most cherished of all animal manures since it contains all the essential plant nutrients such as phosphorous, nitrogen, potassium, zinc, iron, calcium, magnesium, boron, copper, molybdenum and sulphur which are responsible for the fertilisation of the soils This makes it the most appropriate organic manure for tomato production.

Therefore, this study was done to evaluate the effect of layer and broiler chicken manure on the performance of Rio-Grande tomato (*Lycopersicon esculentum Mill).*

1.3 Objectives of the study

1.3.1 Main Objective

The main objective of the study is to evaluate the effect of different poultry manure on the performance of Rio-Grande tomato variety (*Lycopersicon esculentum Mill).*

1.3.2 Specific objectives

(i) To determine tomato growth and development under layer and broiler manure.

(ii) To assess the composition of macro and micro nutrients in layer and broiler manure.

(iii) To determine the effect of layer and broiler manure on tomato fruit production and yield.

1.4 Research Hypotheses

1. There are variations in growth and yield parameter of tomatoes under layer and broiler manure.

2. There are significant differences between macro and micro nutrients under layer and broiler manure.

3. There are variations in fruit production of tomatoes under layer and broiler manure

1.6 Significance of the study

The study will provide farmers with choice of organic manure for the production of tomatoes. This research is also going to help to reduce the overdependence on inorganic fertilizers by farmers. Inorganic fertilizers are expensive and pollute the environment.

Results of the study will contribute to improvement in production and distribution of high-quality tomato in Uganda.

CHAPTER TWO

LITERATURE REVIEW

2.1 Description of tomato *Lycopersicon esculentum*

Tomato belongs to *solanaceae* family. It's an annual, climbing plant. The plant leaves are covered with shiny hairs which are usually prostrate, only the tips being erect. The leaves are large and deeply cleft, with many leaflets. The leaves are arranged alternately along the stems. Both the leaves and stems have strong smell. Clusters of four to six flowers sometimes more, form on the stems between the leaves. (Zeist *et al,* 2017).

The flowers are about one centimeter in diameter (Wan *et al*, 2020).Tomato fruits exists in many shapes appearing large and round oval or elongated, depending on the variety (Sinha *et al*, 2020)

The fruits may be orange, yellow or red when ripe, usually with numerous kidney or peer-shaped, hairy, light brown seeds (Bruno *et al,* 2018).

2.2 Review of the tomato production methods.

Land preparation is the first activity in the production of tomato. It involves activities such as bush clearing, uprooting tree stumps, removal of stones among other thing. The main field is ploughed 3 or 4 times and leveled properly using a hand hoe.

Tomatoes are a warm temperature crop requiring well-drained, fertile soils with good moisture capacity and a high level of organic matter (Adetunji *et al,* 2020).

Tomatoes do not thrive in cold weather and will not set fruits at temperatures below 14^0C and above 850F. Tomatoes need to be grown where they will receive at least six hours of direct sunlight per day (Shanmugapriya *et al,* 2018).

According to (Kumar *et al*, 2020), soils slightly acidic with pH of 5.8-6.8 are considered suitable. He also stated that low soil temperatures retard the growth of seedlings and absorption of minerals may be affected. On the other hand, high temperatures above 27 ^{0}C are likely to induce pollen sterility and high night temperatures adversely affect flower initiations'.

Excessive rainfall and high relative humidity can be harmful to the tomato crop, particularly if it is unstated, due to proliferation of the leaf diseases during humid conditions.

Fruits rarely ripen fully during wet periods and production is generally higher during the dry season, with irrigation, then during extended periods of rainfall (Coyago *et al*, 2018)

(Hartman and kester, 2002) states that elevation of up to 2000m are suitable for tomato cultivation and yields are generally higher at elevations over 1000m. However for successful growth and production, most cultivars, prefer low elevations due to the lack of adequate range of diurnal temperature variations.

2.3 Nursery bed preparation and management

Seeds are sown in containers or in a seedbed, preferably of fertilized soil. About 300-350g of seeds are required to plant one hectare. Raised beds are prepared. It should be avoided using same place for nursery preparation for every year. The nursery bed has to be properly leveled and nursery beds of any length and 1meter width are prepared (Angole, 2010).

Across the beds, lines are drawn at a spacing of 2.5 cm. The seeds are then sown sparsely along the lines of 0.5 cm depth and then covered by a thin layer of straw or dried grass. The beds are then watered using a rose can.

Germination occurs within 7-8 days after which the straw covers are removed and the beds irrigated directly. When seedlings become crowded, they are thinned to avoid competition for resources. However, plants must be hardened as they approach planting time. This is done by exposing the seedlings to open weather or by withholding irrigation regularly; thereafter the seedlings are then ready for transplanting (Angole, 2010).

2.4 Transplanting

Transplanting is suitable when the seedlings are at a height of 7.5 cm to 10 cm to the well prepared fields. It is always done during the late afternoon. This is so to ensure that the plant gains ample moisture for the survival during spring-summer period a spacing of 75x45 cm is recommended. The seedlings are then staked using sticks of about 2 m long.

Plants may also be raised from cuttings but difficulty is often encountered in obtaining virus-free material for propagation (Ranawaka *et al,* 2020).

2.6 Irrigation

The crop has a high water requirement throughout the growing period, until fruiting occurs. (Vanino *et al,* 2018).

During dry periods irrigation is very essential since rainfall is unreliable at such a time. It was done twice a week.

Uneven levels of water application, combined with lack of calcium or potassium in the soil water, may lead to a physiological disorder of the fruits known as blossom end rot (Hagassou *et al,* 2019) and (Hartman and kester, 2002).

2.7 Weed control

Tomatoes require clean weeding. However, mulched tomatoes do not require much weeding since the mulch sometimes suppressed weed growth. During weeding, soil was heaped on the root zones to encourage development of more side roots. These extra roots in turn enhanced nutrient uptake by the plant and consequently improved on the yield as part of plant growth. However, weeds could come up as the crops establish. Herbicides should be used along with proper cultural weed control techniques to obtain effective, economical weed control. Tomato plants require frequent shallow cultivation, especially during their first 4 weeks in the field (Angole, 2010). The surface of soil loosens by hand hoeing as soon as it is dry enough after every irrigation or shower.

2.8 Staking

Stakes of about 2 m long were firmly set at the planting site before transplanting. This avoided damage to the root stocks which would allow the entry of bacterial wilt diseases and other fungal infections.

Staking of plants was proved to be beneficial in the cultivation of tomatoes staking also prevent fruits form coming into contact with the soil, the preventing rotting of fruits.

2.9 Pruning

Pruning tomatoes encourages the growth of larger fruits but reduces the number of fruits per plant (Keter *et al*, 2020).

Many branches that developed were removed maintaining only four. Also older leaves were removed.

2.10 Growth period and harvesting.

Tomato fruits can normally be harvested after 75-85 days from the time of seed sowing (Bazgaou *et al,* 2021)

Pruned plants may have their fruits ready for harvest two weeks earlier than un-pruned plants

Harvesting is majorly done by hand picking so as to achieve selective harvesting and also minimize damage on the plant and fruits as well (Abera *et al,* 2020).

Harvesting is done at various stages that is, developed but are green and suitable sending to distant markets.

Pink stage, some of the portion of the fruit is red or pink but the fruit is not fully ripe. It is the most suitable for local markets.

Ripe stage; the major portion of the fruit is red and softening begins. It may be picked up for home use.

2.11 Comparison of Layer and broiler manures

Accounts of maggot production from chicken manure have rarely differentiated between broiler and layer manures. In a study by (Ofor and Aluzie, 2012) showed that maggot population level was significantly higher in broiler than in layer manures. Similarly population was significantly higher in layer than in broiler manure. Significantly higher quantity of maggot was harvested from broiler manure than layer.

Floor litter from one-year-old laying hens (LHM) and from eight-week-old broiler chickens (BCM) were incorporated in the soil of two fields and evaluated as nitrogen (N) sources for cabbage production on a non-nutrient-depleted soil (Jenkins, 2018). LHM had 3.4% moisture, 3.84% N and 3.41% phosphorus (P). BCM had 2.3% moisture, 4.46% N and 2.19% P. Field 1 received 2.4 t/ha BCM, 3.0 t/ha LHM, whereas Field 2 received 4.8 t/ha BCM and 6.1 t/ha LHM.

2.12 The composition of poultry manure in terms of macro and micro nutrients

Poultry farming has effects on increased utilization of organic wastes. Organic wastes contain varying amounts of water, mineral nutrients, and organic matter (Ismael *et al*, 2012). While the use of poultry manure has been in practice for centuries world-wide and in the recent times.

Furthermore, chicken manure is preferred amongst other animal wastes because of its high concentration of macro and micro nutrients (Dikinya *et al*, 2010). Increase in nitrogen levels from 40 - 60% and 17 - 38% with respect to control for Norfolk sandy soils and Cecil sandy loam soils, respectively following application of manure.

Application of chicken manure to soil enhances concentration of water soluble salts in soil. Plants absorb plant nutrients in the form of soluble salts, but excessive accumulation of soluble salts (or soil salinity) suppresses plant growth (Dikinya *et al*, 2010). The pH of dry poultry manure pellets was found to be 7.9, with most of the nutrients available in this environment while a decrease in the soil pH affects the availability of nutrients to plants.

The acidity due to poultry manure addition severely affects root growth and seed germination (Tiamiyu *et al*, 2012). Moreover, if applied correctly chicken manure acts as a good soil amendment and/or fertilizer (e.g. provides N, P and K) and can also increase the soil and leaf N, P, K Ca, and Mg concentrations. Soil chemical properties provide information on the chemical reactions, processes controlling availability of nutrients and ways of replenishing them in soils.

2.13 The effect of poultry manure on the growth rate of tomatoes.

In a study by (Adekiya *et al,* (2017) to obtain maximum economic value of plant nutrients in poultry manure and increase in tomato yield, field experiments were conducted at Owo, southwest Nigeria, during 2012 and 2013 early cropping seasons to study the effect of two application methods (broadcasting on the soil surface and the incorporated) and four times (3 weeks before transplanting), 0 week at transplanting, 3 weeks after transplanting, and 6 weeks after transplanting of poultry manure (PM)) applications on soil chemical properties, leaf nutrient concentrations, growth and yield of tomato.

Poultry manure significantly affected all the parameters measured except plant height (Hasanuzzaman *et al,* 2010). All the parameter measured were increased in Roma VF than in UC82-B except the number of flowers, days to first flowering, fruit length, fruit diameter, shoot fresh weight, fruit dry weight and shoot dry weight where the two varieties were similar. Application of 5 and 10 t ha-1 poultry manure were similar and significantly increased fruit fresh weight above the control and 15 t ha-1. However, the highest yield was obtained from 5 t ha-1 poultry manure with either Roman VF or UC82B which were significantly at par.

In a study by (Ewulo *et al,* (2016) to study the effect of poultry manure (PM), NPK 15-15-15 fertilizer and NPK 15-15-15 fertilizer + poultry manure on the growth and yield of tomato. The findings Showed that all levels of poultry manure and NPK 15-15-15 fertilizer + poultry manure increased leaf N, P, K, Ca and Mg levels. The soil chemical properties except pH increased with amount of poultry manure. NPK 15-15-15 fertilizer alone did not increase the soil and leaf Ca andMg. All levels of poultry manure, NPK 15-15-15 fertilizer alone and NPK 15-15-15 fertilizer +poultry manure increased the number of leaves, plant height, leaf area, number of fruits and fruit weight significantly. Among poultry manure levels, 30 t ha-1poultry manure gave the highest fruit yield. Among the seven treatments, NPK 15-15-15 fertilizer + poultry manure gave the highest yield.

In a study by (Isitekhale *et al*, 2013) showed that poultry manure is a suitable source of nutrients for tomato especially if applied at 30 t ha-1in the forest-savanna transition zone of southwest Nigeria. The combined use of NPK 15-15-15 fertilizer and poultry manure increased tomato yield compared to the application of NPK 15-15-15 fertilizer or poultry manure alone and is therefore recommended for sustainable production. In addition, lesser quantities of poultry manure and NPK 15-15-15 fertilizer would be required, therefore, reducing the amount of money spent on chemical fertilizer

2.14 The effect of poultry manure on the yield of tomatoes.

The poultry manure was rich in plant nutrients and the acidity was near neutral (Gaind *et al*, 2010). The results revealed that there were significant increase in number of branches and plant height. Significant differences were observed among the different rates of poultry manure applied all through the period. Plants sown on plot treated with 10 t ha^{-1} rate of poultry manure application had statistically the highest values of 88.49 cm and 7.03 as plant height and number of branches, respectively. In comparison with the control, poultry manure treated plots had significantly higher increase than the control plots.

The non-treated plots (control) significantly resulted in shorter plants and few numbers of branches suggesting that fertilization enhances the growth of tomato (Smitha *et al*, 2019). The significant increase of number of branches in the treated plots suggest more number of fruits and invariably more tomato yield which is the ultimate goal of the farmer. This agreed with the work of (Ayeni *et al*. 2010) who reported significant increase in plant height, number of branches and number of leaves as a result of application of poultry manure.

The result obtained on number of trusses, flowers and fruits of tomato plant indicated that there were significant differences among the different rates of poultry manure throughout the period (Agbo *et al*, 2012). Plants sown on plots treated with 10 t ha^{-1} poultry manure had the highest number of trusses, flowers and fruits per plant with the values of 23.18, 101.20 and 18.08, respectively. This may be attributed to the sufficient release of nutrients particularly N.P.K contained in the poultry manure applied, as these nutrients improve the growth and yield of crops. The number of fruits and leaves of crop significantly increased with increase in the concentration of poultry droppings. In comparison with the control, poultry manure treated plots had significantly higher number of trusses, flowers and fruits per plants than the control plots. The result on tomato fruit and seed yield indicated that significant differences were observed among the different rates of poultry manure used in the study by Demir, (2010). The application of 10 t ha^{-1} rate of poultry manure resulted in highest fruit and seed yield values of 8570.66 and 18.13 kg hg^{-1}, respectively. Tomato fruit weight increased with increasing manure source. In comparison with the control, poultry manure treated plots had significantly higher yield than the control. Fruit and fruit quality is improved as a result of application of poultry manure.

CHAPTER THREE

MATERIALS AND METHODS

3.1 Experimental site

The experiment was carried out at Bishop Stuart University farm Kakoba division, Mbarara district in Western Uganda. Mbarara is located at longitude 30.6582˚E and latitude 0.6132˚S. (United Nations Human Settlements Programme, 2012), Ntale *et al*, (2014).

The district receives an average annual rainfall of 1,200 millimeters with temperatures ranging between 17 °C and 30 °C. (Peden, D. 2016).

It has a bimodal rainfall pattern with the first season commencing from March and ending in about mid-June. There is usually a short dry spell in June or July before the second rain season begins in August and ends in November to December.

The experiments were carried out during the second rainy season of 2019 and the first rainy season of 2020.

The soil of the experimental field was medium black with good drainage and uniform texture with medium NPK status. The experiment followed a two year fallow. Summary of the chemical analysis of soil is given in table1.

3.2 Experimental treatments and Design

There were four treatments as follows; Broilers manure (B), Layer manure (L), a combination of Broiler and Layer manure (C) and Control (CN) in which no manure was applied. These treatments were examined in a Randomized Complete Block Design (RCBD) and were replicated four times. Details of the experimental layout are given in figure1.

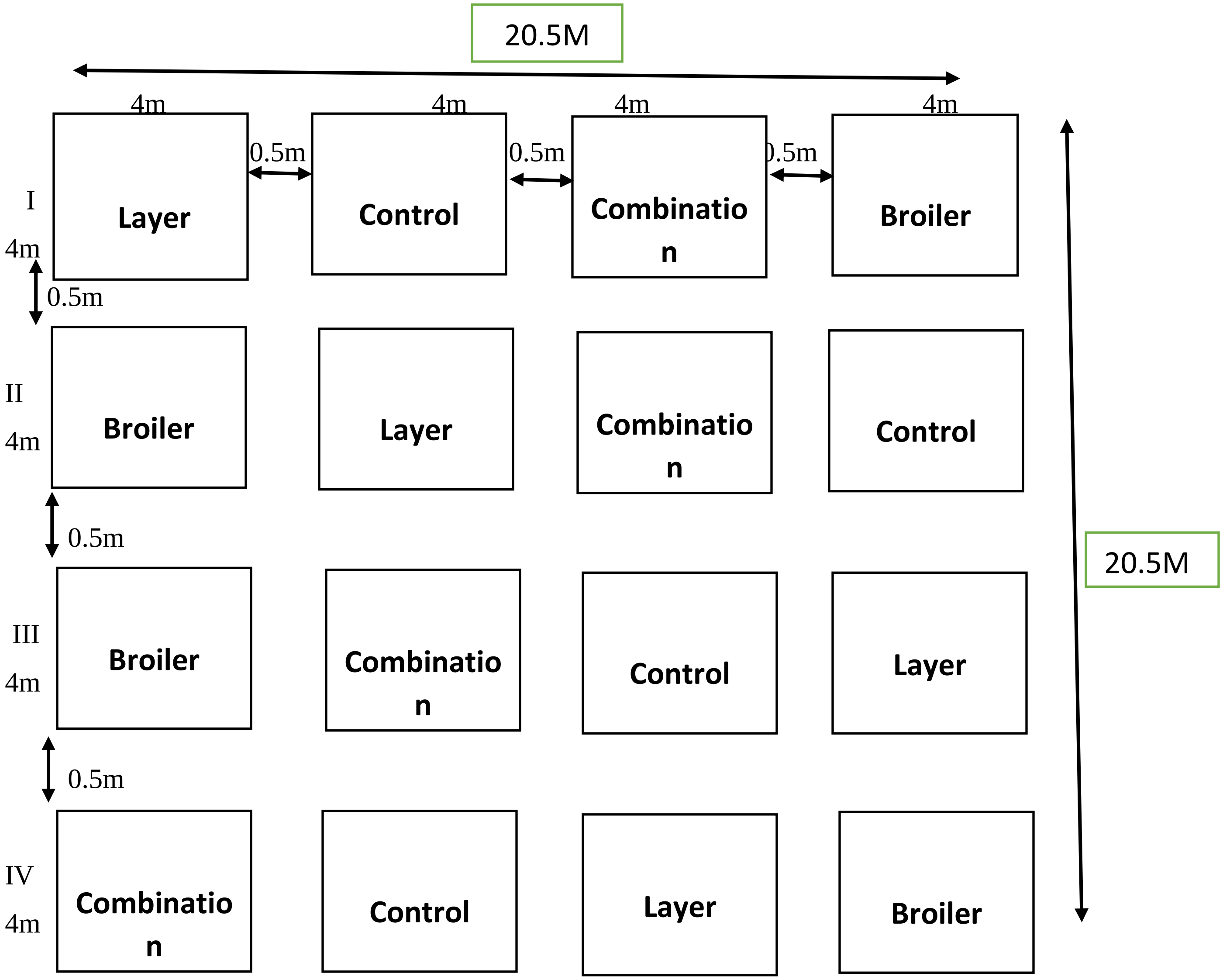
Plot sizes were 4 m by 4 m separated by 0.3 m. Crop spacing was 75 cm between the rows and 45 cm within the rows. Each plot contained twelve (12) tomato plants but only three (3) tomato plants were randomly selected and used to collect data. Seeds were planted in the nursery bed and the seedlings were transplanted after three weeks.

Rio Grande tomato variety was used because it is the most popular variety in Uganda.

Different poultry manure types were applied to the planting holes one month before transplanting as suggested by (Adekiya et al, 2019)

Each tomato plant received 340g of poultry manure which translates to 10t/ha of manure. Plants were kept weed free by regular weeding, disease infection and pest attack were controlled by the use of mancozeb, cypermethrine and Dimethoate fungicides and pesticides, respectively. Spraying was done at an interval of two weeks.

Fig. 1: Experimental lay out



3.4 Agronomic management

3.4.1 Preparation of nursery bed

After selection of the site, the nursery bed was prepared using a hand hoe and the soil was crushed up to get a fine tilth. All the grass, stones and roots were removed from the site. The beds were prepared and finally leveled. One wheelbarrow full of chicken manure which is equivalent to 10 kg was added into each bed. Beds of (3 m X 1 m) were prepared. After getting the bed of fine tilth, seeds of Rio Grande tomato were sown in beds uniformly at a depth of 2-3 inch and light irrigation was given immediately. All the beds were covered with grass to conserve moisture and hasten germination. The grass was removed after germination.

3.4.2 Preparation of the main field

In order to get good tilth of the soil for transplanting, first cultivation was done by using a hoe and followed by second cultivation which was done using both a hoe and a forked hoe and there after the field was marked as plots as shown in figure1 before transplanting.

3.3.3 Manure application

A well composted layer and broiler manure was applied to the each planting hole. Each planting hole received 340 g of layer, broiler or a combination of layer and broiler manure except for the control treatment. Combination treatment was achieved by mixing equal amounts of layer and broiler manure. This was done one month before transplanting. Laboratory analysis of nutrients from the manure was done to determine the nutrient composition of the manure and the results of analysis are given in Table 2.

3.4.4 Transplanting

Seedlings of Rio Grande tomato of uniform growth were selected for transplanting. Seedlings in the nursery bed were irrigated before removal for transplanting in order to prevent or reduce seedling root damage during transplanting. Transplanting was done on 10th September 2019 and 3rd March 2020 and the field was irrigated regularly after transplanting until the onset of rains.

3.5 Experimental measurements.

Data collection started two weeks after transplanting by which time the plants were well established and nearly 5 cm tall.

The following measurements were made;

3.5.1 Plant height and number of leaves per plant.

From each treatment, a random sample of three plants was selected. Data was taken from the three plants throughout the season. Plant height was measured for each plant from the soil surface to the top of the plant using a tape measure. Measurement of plant height commenced three weeks after transplanting and continued at two week interval until the 8^{th} week. In addition, the numbers of green leaves were counted.

The number of leaves was recorded from the same three plants after every two weeks.

3.5.2 Number of flowers per plant

The numbers of flowers per plant were counted from same plants as used above to determine the number of flowers per treatment. The numbers of flowers were determined when 50% flowering had occurred.

3.5.3 Number of fruits per plant

The number of fruits harvested from four randomly selected plants in each treatment was collected during each harvest, counted and summed up together and average numbers of fruits per plant were calculated.

3.5.4 Fruit total weight

The weight of five fruits was recorded separately using weighing balance and average weight was worked out for each treatment.

3.5.5 Fruit size

All the tomatoes fully formed from each plant were considered. For each treatment, sample of 5 tomato fruits from each treatment were cut in the middle and fruit diameter was measured using a ruler.

3.5.6 Yield per plot and per hectare

Fruits harvested from all the plants in each plot were weighted at each harvest. The total yield per plot was calculated after final harvest. This was then converted to t/ha based on the area harvested.

3.6 Analysis of variance

For growth and yield parameters, analysis of variance (ANOVA) table was generated using Gen Stat 11 statistical software. The confidential interval was set at 95% ($p \leq 0.05$).

CHAPTER FOUR

RESULTS

The physical- chemical properties of the soil from experimental site for the two seasons

The physical and chemical properties of the soils from the experimental site for season one and season two are given in Table 1. The physical and chemical properties of the soils were reasonably similar for the two seasons. For example pH was 5.6 in both seasons, EC was 77.1 and 71.4 in season 1 and 2, respectively; However, average phosphorous in season two was more than 15 times the average amount of phosphorous in season one.

The average amount of phosphorous required in the soils for proper root growth and establishment is 15 ppm. Therefore, this shows that in season one the soils had low phosphorous whereas season two soils had relatively higher amount of phosphorous in the soil.

The soil ph within the top 30 cm was slightly acidic for both seasons. This favors availability of micro-organisms and soil nutrients to be in a solution form for plant up take since most crops grow well in a ph between 5.5-6.8.

The amount of nitrogen and organic matter in the soil were significantly low for both seasons. The required amount of nitrogen and organic matter in the soil is 0.3% and 3% respectively. The amount of calcium, potassium and magnesium were high in the soils. The required amounts for proper crop growth are 1.75, 0.34 and 0.6 cmoles/kg, respectively. Calcium and magnesium moderates soil ph or acts as a good liming material, hence increases soil ph which is the reason why optimum ph of 5.6 the soil is required for crop growth.

The soil texture was sandy loam which enhances drainage. The micronutrients of the soil are moderate due to moderate soil Ph hence better conditions for crop growth.

Table 1: physical- chemical properties of the experimental site for the two seasons.

Sample Details	Lab	PH	EC	OM	N	Av.P	K	Na	Ca	Mg	%Sand	%Clay	%Silt	Cu	Zn	Fe	Mn
	No.		µS/cm	%age		ppm	cmoles/kg				Texture			mg/kg(ppm)			
Season one	A	5.6	77.1	1.71	0.15	4.00	0.50	0.12	3.8	1.32	42.0	17.0	41.0	1.11	21.3	212.2	42.2
Season two	B	5.6	71.4	1.51	0.13	54.1	0.44	0.21	3.5	1.02	44.0	15.0	41.0	0.99	16.9	198.3	34.2

The Composition of macro and micro nutrients in broiler and layer manure.

The chemical composition of the manure types used are given in Table 2. It is interesting to note that for both manure types the ph was very high (7.8-8.2). This is in contrast to ph recorded for the experimental site for both seasons (Table 1). The implication is that these manure types can be used to moderate ph for crop growth.

The results also indicate that poultry manure had less phosphorus and magnesium and rich in nitrogen, potassium, calcium and micro nutrients, thus providing a good source of plant nutrients and confirming earlier idea that both broiler and layer manure contain adequate quantities of macro and micro nutrients for plant growth. The normal amount of soil nitrogen, phosphorous, potassium, calcium and magnesium required for proper crop growth are 0.2%, 15ppm, 0.34 cmoles/kg 1.75 cmoles/kg and 0.6 cmoles, respectively. This suggests that, poultry manure is a useful remedy for soils that are depleted of nutrients either through over use or degradation processes.

***Table 2*: Composition of macro and micro nutrients in broiler and layer manure.**

Sample Ref:	pH	N	P	K	Ca	Mg	S	Cu	Fe	Mn	Zn	B
		g/100g (%age)						ppm (mg/kg)				
Broiler 1	8.2	2.3	0.91	2.11	0.56	0.21	0.68	6.54	452	85.5	46.5	9.2
Broiler 2	8.0	3.2	0.89	1.96	0.65	0.22	0.78	4.25	362	65.2	39.5	5.3
Broiler 3	7.9	3.3	1.02	2.02	0.58	0.31	0.66	5.32	390	89.3	45.4	3.3
Broiler 4	7.8	3.0	0.78	1.68	0.55	0.19	0.68	5.61	465	69.6	65.7	6.6
Broiler 5	8.1	2.2	0.77	1.32	0.65	0.21	0.65	4.94	568	78.9	54.8	4.9
Layer 1	7.9	2.0	1.22	1.26	0.96	0.32	0.44	3.85	541	120.	59.9	5.8
Layer 2	7.8	1.9	1.35	1.22	1.02	0.45	0.56	4.56	623	98.8	58.5	3.5
Layer 3	7.8	2.0	1.22	1.24	0.86	0.44	0.66	2.23	596	112.5	66.6	6.4
Layer 4	7.9	2.8	1.32	1.35	0.88	0.39	0.56	3.12	588	98.2	71.2	9.2
Layer 5	7.9	2.9	1.09	1.64	0.98	0.41	0.68	2.5.	612	102.1	69.3	8.1

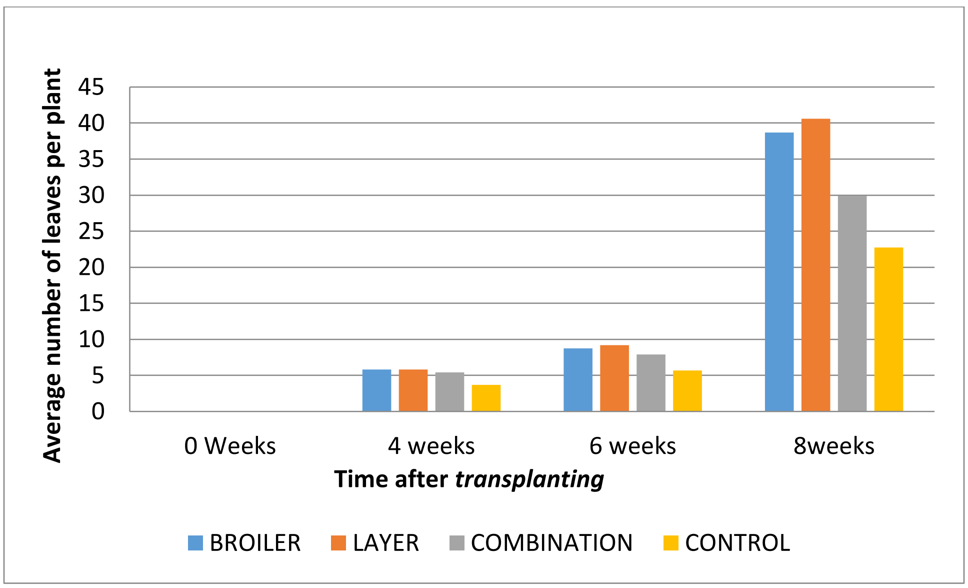
Effect of broiler and layer manure on selected growth parameters of tomato

4.1. The number of leaves per plant

The effects of manure types on the number of leaves per plant are given in figure 2a and 2b for season one and two respectively.

The results from season one show that at four weeks after transplanting, there was no significant difference between the treatments (Figure. 2a). This is probably because plants were still getting established. At six weeks after transplanting, differences between treatments were beginning to emerge. Application of manure types produced slightly higher number of leaves per plant than the control though the differences were not significantly different ($p < 0.05$). At the 8th week after planting, average number of leaves was highest in treatments with layer and broiler manure giving an average of 31 and 29 leaves per plant, respectively followed by the treatment with combination of manure. The control treatment produced significantly lower number of leaves in season one.

Similar patterns of results were recorded in season two (Figure. 2b). At four weeks after transplanting, there was no significant difference between the treatments ($p < 0.05$) At six weeks after transplanting, differences between treatments were beginning to emerge. At the 8th week after planting, average number of leaves were also considerably higher in treatments with layer and broiler manure giving an average of 41 and 39 leaves per plant, respectively followed by the treatment with combination of manure as in season one. The control treatment again produced significantly lower number of leaves as in season one. (Figure. 2a)



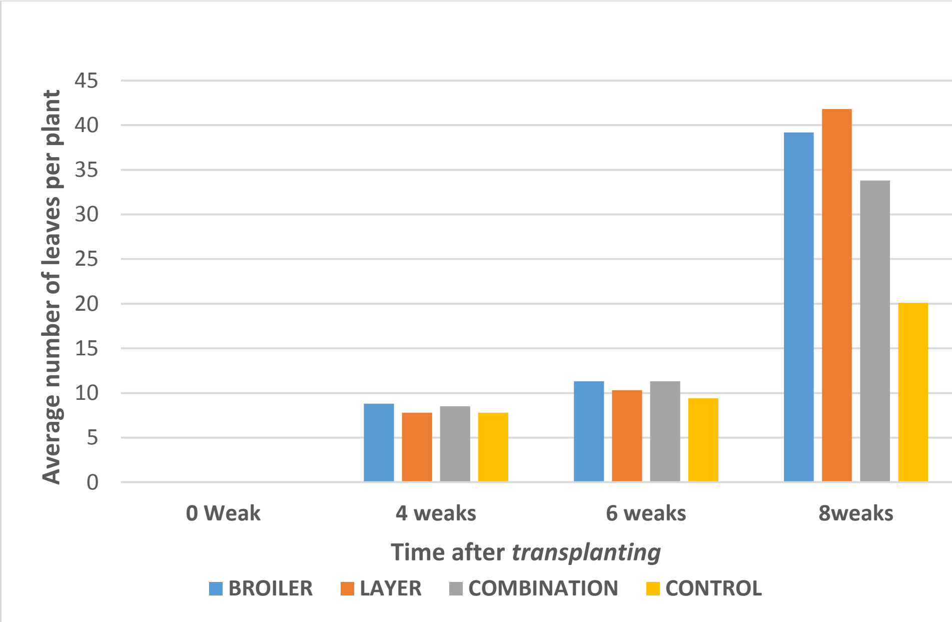


Figure 1: Effect of layer and broiler manure on the number of leaves per plant; 2a for season one and 2b for season two.

4.2. The plant heights

The effects of manure types on plant heights are given in figure 3a and 3b for season one and two, respectively.

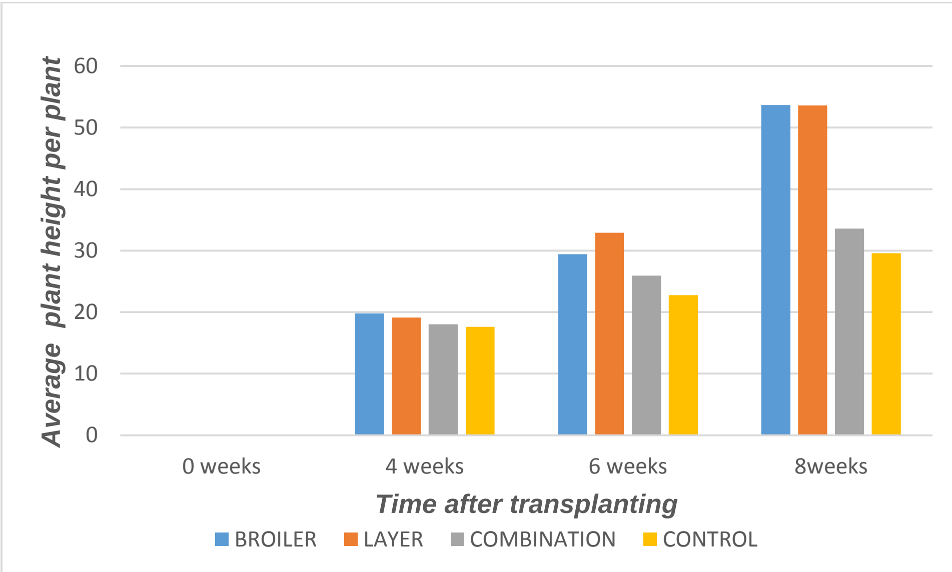
The results on plant heights followed similar pattern as the number of leaves per plant.

At four weeks after transplanting, there was no significant difference between treatments. All the treatments had average height of about 5cm, most likely because plants were still young and getting established. At six weeks after transplanting, all the treatments were better than control though not significantly different ($p < 0.05$. The average plant height was slightly greater in plots with layer manure and broiler manure giving an average of 9.1 cm and 8.7 cm respectively.

At the 8th week after transplanting, average plant height was greater in treatments with layer and broiler manure giving an average of 53 cm per plant followed by the treatment with a combination of manure. The control produced the shortest plants.

As with the number of leaves, similar, pattern of results were recorded in season two (Figure 3b)

The results on plant heights followed similar pattern as in season one however at 8 weeks after planting, broiler manure had slightly taller plants (61cm) than layer manure (59 cm) unlike in season one where average plant heights was the same.



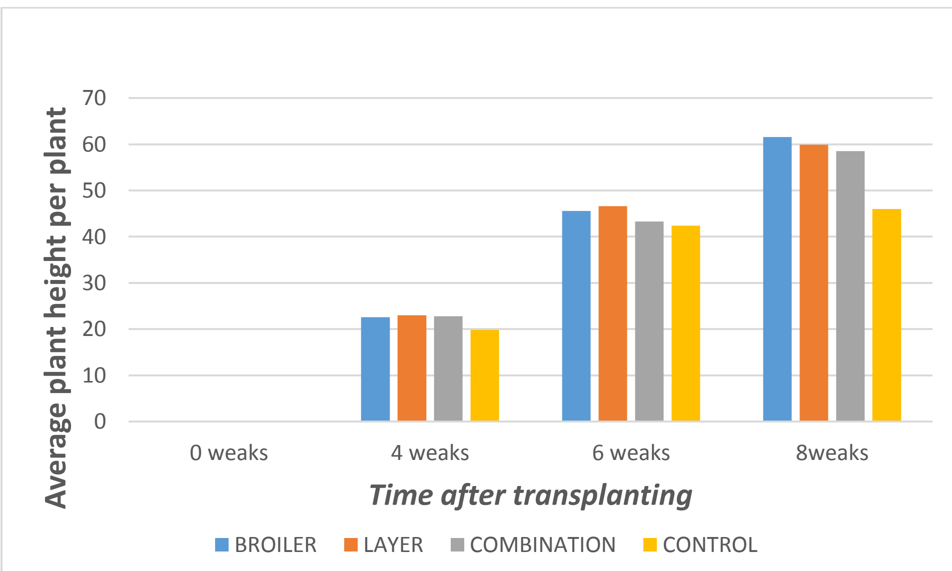


***Figure 2*: Effect of layer and broiler manure on the plant height; 3a for season one and 3b for season two.**

4.3. The number of flowers per plant

The effects of manure types on the number of flowers per plant are given in figure 4a and 4b for season one and two, respectively.

The results indicated that plants started producing flowers at 6 weeks after transplanting. As expected, the number of flowers increased with time from an average of 3 flowers per plant at 6 weeks after planting to about 10 flowers per plant at 8 weeks after transplanting. By the 10th week, the number of flowers had increased to an average of 12 flowers per plant. Broiler treatment produced significantly more flowers per plant than the rest at 10 weeks after transplanting ($p < 0.05$). The control treatment had the least number of flowers per plant by the end of 10th week after planting.

Similar results were recorded in the second season. Flowers started to develop at 6 weeks after planting. Plants under Broiler treatment produced significantly more flowers than the rest of the treatments ($p < 0.05$). There was no significant difference between the rest of the treatments and the control at six weeks after planting ($p > 0.05$). The number of flowers increased from an average of 8 per plant to about 12 flowers per plant at 8 weeks after transplanting. By the 10th week, the number of flowers had increased to an average of 14 flowers per plant. The control treatment had the least number of flowers by the end of 10th week after transplanting.

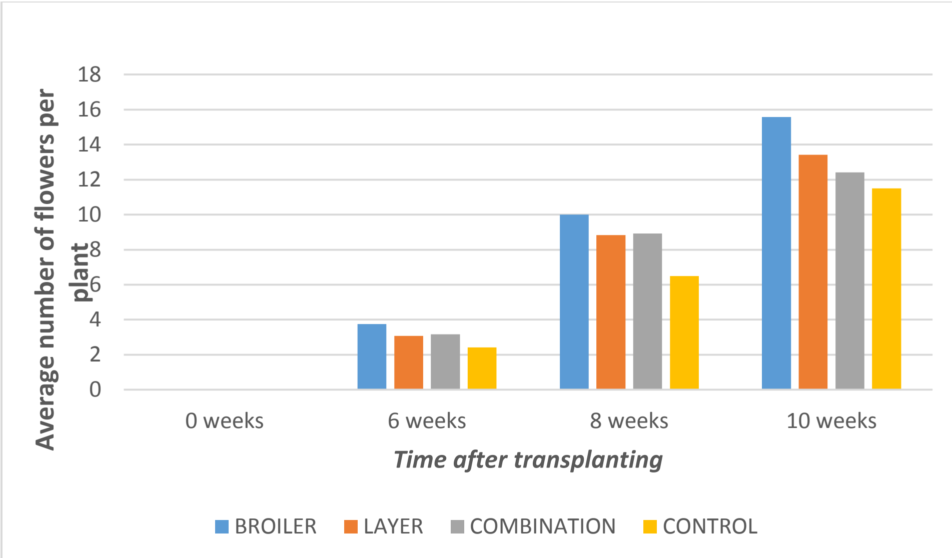


Figure 3a.

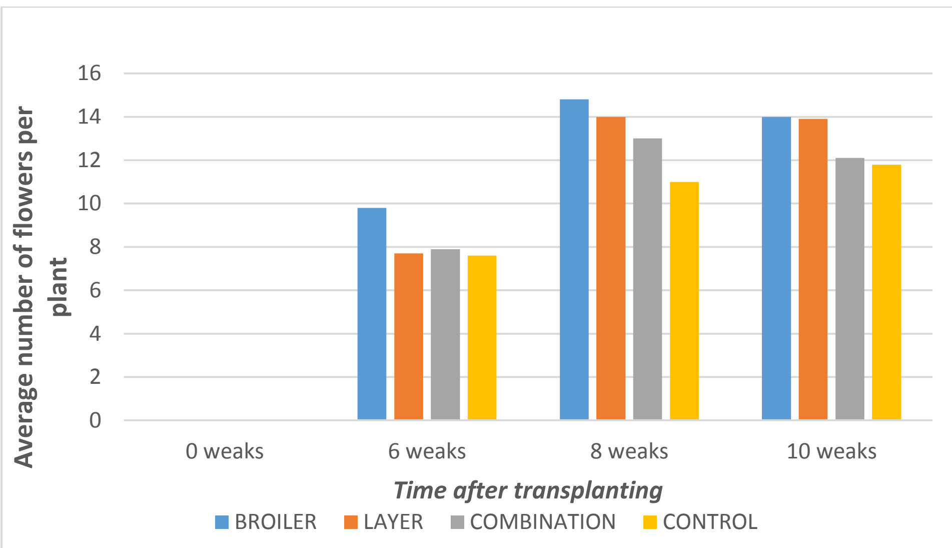


***Figure 3*: Effect of layer and broiler manure on the number of flowers; 4a for season one and 4b for season two.**

4.4. The number of fruits per plant

The mean effect of manure types on the number of fruits per plant is given in Table 3. In season one, all treatments were significantly better than the control. The highest number of fruits per plant (43.2) was achieved from broiler manure treatment though this was not significantly different from the results of layer manure or combination of broiler and layer manure ($p > 0.05$).

Season two, results followed similar pattern although the highest number of fruits per plant (42.7) was achieved from broiler treatment. This was however not significantly different from those from layer manure treatment or combination of broiler and layer manure ($p > 0.05$).

***Table 3*: Mean effect of manure types on the number of fruits per plant**

Season	Treatments	B	L	C	CN	LSD
1		43.2	36.8	35.9	18.7	7.54
2		42.7	33.7	36.8	22.5	9.92

B, CN, C, L and LSD stands for Broiler, Control, combination, Layer and Least significant different respectively.

4.5. The fruit diameter

The mean effect of manure types on the fruit diameter is given in Table 4. In season one, the fruit diameter under noon soil amendment was significantly lower than those under different manure applications ($p < 0.05$). The largest fruit diameter (4.975) was a achieved from the combination manure treatment though this was not significantly different from the results from layer or broiler manure treatment ($p > 0.05$). As with other parameters, the control treatment had the smallest fruit diameter.

In season two, results followed similar pattern although the highest number of fruits per plant (4.879) was achieved from broiler treatment. This was not significantly different from those from layer manure treatment or combination of broiler and layer manure ($p > 0.05$).

***Table 4*: Mean effect of manure types on the fruit diameter (cm)**

Season	Treatments	B	L	C	CN	LSD
	1	4.904	4.801	4.975	3.396	0.22
	2	4.879	4.617	4.517	3.121	1.12

4.6. Fruit weight per plant

The mean effect of manure types on fruit weight per plant is given in Table 5. In season one; all treatments had fruit weight per plant significantly higher than the control. The highest fruit weight (346.3) was achieved from the results from combination manure. Mean weights from Broiler manure and combination manure were significantly higher than results from layer manure.

In season two, results followed similar pattern and the highest fruit weight per plant (317) was achieved from layer treatment. This was not significantly different from those from broiler manure treatment or combination of broiler and layer manure ($p > 0.05$).

***Table 5*: Mean effect of manure types on fruit weight per plant**

Season	treatments	B	C N	C	L	LSD
1		335.7	181.5	346.3	295.2	42.85
2		305.2	282.6	308.1	317.0	12.32

4.7. Tomato fruit yields (tones/hectare)

The mean effect of manure types on tomato yield per hectare are given in Table 6. In season one fruit yields from manure amended soils were significantly higher than the control ($p<0.05$). The highest yield per hectare (13.67) was achieved from broiler manure. Tomato yields from Broiler manure and layer manure were significantly higher than those from combination of manures.

In season two, results followed similar pattern and the highest yield per hectare (14.08) was achieved from broiler treatment. Mean fruit yields from Broiler manure and layer manure were significantly higher than those from manure combination ($p<0.05$).

***Table 6*: Mean effect of manure types on yield (tones/ hectare)**

Season	Treatments	B	L	C	CN	LSD
1		13.67	13.44	12.83	8.10	2.56
2		14.08	13.19	11.49	7.83	2.14

CHAPTER FIVE

DISCUSSION

Influence of manure types on growth parameters.

The overall objective of the study was to evaluate the effect of manure types on the performance of tomato. One of the major constraints to tomato production is the declining soil fertility (Ogbomo, 2011). The use of chemical fertilizers has been claimed to be the best way to improve agricultural productivity, the negative effects of chemical fertilizers on the soils and environment appear to out way the benefits. Research comparing soils management using organic manure and chemical fertilizers has shown that soil organic matter and total nitrogen are high in soils where organic manure was applied (Ojeniyi, 2010). Organic materials such as poultry manure are recognized as suitable organic fertilizer. Poultry manure if well-handled is the most cherished of all animal manures (Vasilev, 2017). The use of poultry manure for soil fertility maintenance, increased growth and yield of tomatoes has been reported by Olorode, (2020). This in line with the results obtained from the study conducted as discussed below.

On the number of leaves, the results showed no significant difference between broiler and layer manure in the two seasons. The number of leaves was slightly higher for the layer treatment compared to the broiler and combination treatments. Layer and broiler treated plants recorded the highest average number of leaves (31 and 29) per plant than combination and control treatments respectively. This was because the manure applied contained adequate nitrogen which supported vigorous growth. The vigorous growth was reflected in more number of leaves and taller plants.

This observation was in agreement with the results of Direkvandi *et al*, 2008) who reported significant increase in plant height, number of branches and number of leaves. He attributed the increase to high nitrogen levels in the manure. The control treatment produced the least average number of leaves (9.5) and was significantly different from chicken manure treatments ($p<0.05$). This finding was also in line with the findings of Singh, (2020) and Agbede *et al*. (2008) who found out that application of poultry manure led to an increase in the number of tomato leaves.

On plant height, Broiler and layer manure application had no significant difference at four weeks after planting in both seasons (p.0.05). This is probably because the plants were still getting established. Broiler and layer manure treatments produced taller plants with the tallest plants being about the same (53.67 cm) and (53.58 cm), respectively. This is was most probably because the soils had adequate amount of nutrients for vigorous growth. The nutrient analysis showed that both manure types had high levels of nitrogen. This could have led to vigorous growth achieved within the applied treatments. This observation was in agreement with the results of (Oyewole *et al*, 2012) who reported that chicken manure applied at a rate of 150 kg/ha and 300 kg/ha produced taller plants compared to the control. Similarly the study by Ayeni, (2010) and Direkvandi, (2008) also showed significant increases in plant height, number of branches and leaves are as a result of poultry manure application. They explained that this was due to high nitrogen content in both layer and broiler manure. High amount of nitrogen ensures growth of tomato and stimulates early flowering.

The control treatment had significantly shorter plants (29.58 cm) compared to those that received manure. Shorter plants produced few numbers of tomato fruits than taller plants. This was largely because they had fewer sites for flower production. Improvement in the number of leaves and plant height though small can improve the leaf area index and consequently the light interception pattern of the crop.

Effect of manure on the number of flowers and number of fruits per plant.

The number of flowers represents the reproductive structure in tomatoes because they represent the number of fruits that are likely to develop and consequently the amount of yield to be achieved.

In the broiler treatment, the number of flowers increased from 3.7 per plant at six weeks after planting to 15 flowers per plant at 10 weeks after transplanting. Increased numbers of flowers in chicken manure treatments were as a result of high levels of nitrogen and potassium which were supplied through the application of chicken manure. Potassium ensures vigorous growth of tomato, stimulates early flowering and setting of fruits, thereby increasing the number of fruits per plant and the overall production. As seen earlier, the high levels of nitrogen and potassium in both broiler and layer manure might have led to improved production of flowers.

The results obtained are in agreement with those of Singh *et al,* (2020), Adekiya *et al*, (2017) and Agbede *et al.* (2008) who reported that application of of poultry manure gave the highest number of flowers per plant. The control plots had the least average number of flowers (9.5) which was significantly different from chicken manure treatments($p<0.05$).

On the number of fruits per plant, they were significantly higher in all manure treatments than the control ($p<0.05$). The significant difference between the manure treatments and the control was largely because of the high amounts of nutrients in poultry manure. Both layer and broiler manure had higher amounts of nitrogen and potassium. As explained earlier, sufficient nutrients in poultry manure ensures vigorous growth of tomato and stimulates early flowering and setting of fruits. (Adekiya, 2017)

Similar results were explained by Abou El-Magd *et al,* (2005) who found that application of poultry manure increased yield largely through improved soil physical and biological properties and through availability of macro nutrients like nitrogen, phosphorous and potassium to the plants. The micro nutrients such as boron and zinc are also responsible for flowering, fruiting and ripening of the fruit (Singh *et al,* 2020).

Effect of manure on yield and yield parameters

The study revealed that all manure treatments had significantly larger fruit diameter than the control ($p<0.05$). This is because poultry manure contains high levels of nitrogen and potassium responsible for fruit formation and establishment (Abou El-Magd *et al,* 2005). This might be the reason for improved size of tomatoes as explained earlier. Potassium ensures vigorous growth of tomato and stimulation of early flowering and setting of fruits. Nitrogen is also responsible for increased production interms of number of fruits, fruit size, storage quality, color, and taste of tomato.The results are in line with the results of (Qiu *et al,* 2020) who revealed that broiler and layer manure has similar nutrient concentrations (N, P, K, Mg, S and micro nutrients. Therefore fruit size increased as a result of application of chicken manure. (Fawzy, 2005).

The study findings also showed that broiler, layers and combination manure treatments gave highly significant fruit weight per plant compared to the control.

Difference in fruit weight may be due to the presence of Potassium and Nitrogen, which are responsible for regulating plant growth. This was also in agreement with the findings of Adekiya *et al,* (2017) and Ghorbani *et al,* (2008) who reported that tomato fruit weight increased with the application of poultry manure. He attributed this to nitrogen and potassium available in poultry manure which was applied. Tomato yield per hectare followed similar trend where by the manure treatments produced significantly higher yield than the control ($p<0.05$). Application of poultry manure produced the highest fruit yield of 13.8 t/ha by broiler 13.4 t/ha by layer and 12.8 t/ha by their combination. The lowest fruit yield (8.1 t/ha) was obtained from the control (no poultry manure) treatment.

The highest yield per unit area achieved from manure application was largely due to the high number of fruits per plant and bigger fruit size. This was due to chicken manure treatments that produced significantly higher yield than the control because of high levels of Nitrogen, Phosphorous and potassium which are present in chicken manure. Nitrogen is responsible for increased production of number of fruits, fruit size, storage quality, color, and taste of tomato.as described by Adekiya *et al,* (2017)

The implication of these results is that the soils at the site of the experiment were low in fertility and this explains why the control plots achieved low yield (8t/ha).

The physical- chemical analysis of soils at the experimental site indicated that nitrogen was only 0.15% and 0.13% for season one and two respectively. This was below the critical value of nitrogen 0.2% of nitrogen, below which the crop is negatively affected.

CHAPTER SIX

CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusion

The results showed that the application of chicken manure significantly enhanced high growth and yield of rio-grande tomato compared to the control treatment.

Application of layer and broiler manure enhances tomato growth and development. None of the poultry manure was superior to each other in the growth performance of tomato.

Nutrient compositions of layer and broiler manure or their blends are similar and enhance tomato productivity.

Tomato growth and yields responded similarly to layer and broiler manures, giving an option to farmers to use either of them.

Therefore it is recommended that farmers can use either layer or broiler manure to enhance tomato productivity.

The pH of both poultry manure is high and therefore can be used in acidic soils to raise soil Ph.

Broiler and layer manure are a good source of plant nutrients for tomato production and therefore, can be used as a bio-fertilizer.

6.3 Areas for further research

Same study should be repeated on farm to assess performance of poultry manure on tomato growth and yields under farmer's conditions.

There is need to carry out the same study using wood shavings instead of coffee husks which were used as litter in the experiment to assess performance of tomato growth and yields.

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APPENDEX

ANOVA tables showing growth and yield performance of tomatoes under interaction of applied soil treatments with season

ANOVA for number of fruits per plant

Source of variation	D.F.	S.S.	M.S.	V.R.	F pr.
Season	1	21.3	21.3	0.06	0.805
Treatments	3	12778.0	4259.3	12.15	<.001
Season. Treatments	3	389.8	129.9	0.37	0.774
Residual	184	64481.8	350.4		
Total	191	77671.0			

ANOVA for fruit size per plant

Source of variation	D.F.	S.S.	M.S.	V.R.	F pr.
Season	1	1.3838	1.3838	4.70	0.031
Treatments	3	81.2189	27.0730	91.93	<.001
Season. Treatments	3	2.1272	0.7091	2.41	0.069
Residual	184	54.1863	0.2945		
Total	191	138.9162			

ANOVA for fruit weight per plant

Source of variation	D.F.	S.S.	M.S.	V.R.	F pr.
Season	1	137.	137.	0.01	0.913
Treatments	3	476430.	158810.	14.03	<.001
Season. Treatments	3	74739.	24913.	2.20	0.090
Residual	184	2082984.	11321.		
Total	191	2634290.			

ANOVA for yield per hectare

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Treatments	3	34.450	11.483	4.16	0.031
Residual	12	33.116	2.760		
Total	15	67.566			