# A COMPARATIVE ANALYSIS OF THE EFFICACY OF COW, CHICKEN AND PIG WASTES ON SPINACH (*SPINACIA OLERACEA*) AS ALTERNATIVES TO ARTIFICIAL FERTILIZERS.

**BY**

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**ABSTRACT**

Spinach (*Spinacia oleracea*) is a low growing fleshly leaved annual plant that can be used as a vegetable and or to treat a variety of diseases. This study aimed at comparing the effectiveness of cow, chicken and pig manure on the plant height, leaf number, leaf length as well as root length of spinach. An experiment was conducted in a greenhouse at Africa University between the months of June and July 2018. The experiment was a randomised complete block design (RCBD) with chicken manure, cow manure, pig manure, fertilizer and no treatment as the treatments. The no treatment was used as a negative control whilst fertilizer was used as the positive control. Spinach seeds were planted 2cm below the soil surface in pots 30cm apart from each other. Weeding, watering and pest control measures were done uniformly across the treatments, when and as required. Data was collected after thinning at weekly intervals for six weeks and the parameters included plant height and number of leaves. At maturity, leaf area as well as root length were recorded. The one-way analysis of variance displayed significant differences ($p<0.05$) between the treatments and the negative control. Chicken manure gave the highest leaf area, plant height and leaf number followed by cow manure, while pig manure gave the lowest. However, Tukey-Kramer multiple comparison analysis indicated that was no significant difference between chicken manure and the positive control ($p>0.05$). These results therefore show that chicken manure is more effective on spinach growth rate as compared to cow and pig manures.

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## DEDICATION

This project is dedicated to my beloved parents, Mr C. and Mrs B. Sauramba, my brother and sisters, the Sauramba family at large, who made completion of this project and my degree a success. I would like to thank you for your continuous support and encouragement. I appreciate the financial and emotional support you gave me throughout my four years in university.

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# CHAPTER ONE: INTRODUCTION

## 1.1 Background

The use of fertilizers as agricultural inputs is required for sustainable crop production. The use of inorganic fertilizers has drastically declined following the energy crisis, which has immensely affected most of the developing countries (Maerere *et al*, 2001). Zimbabwe, being one of the affected countries has since been facing food insecurity issues for small holder farmers.

About seventy-five years ago, animal waste was applied to crop and pasture lands as a plant nutrient source and occasionally as a means of disposal (Hanks, 2007). However, following the introduction of intensive confinement systems these wastes were then later on not considered an asset but a liability due to their low value and high cost to handle and transport (Freeman and Bennett, 1969). Irrespective of the enormous manure production potential, very little amount of the available animal manure is being utilised for crop production indicating serious underutilisation of such resources (Maerere *et al.*, 2001). This is largely due to lack of scientific basis for advising farmers on aspects such as appropriate application rates, storage techniques and application methods (Maerere *et al.*, 2001).

The primary uses of animal wastes are as sources of plant nutrients (fertilizer), that impact soil properties, such as soil nitrate, soil pH and organic matter (Hanks, 2007). In addition, there is need to compare different types of animal manures under similar field conditions so as to come up with indications on manure recommendations (Maerere *et al.*, 2001). They can also be used as feedstock for energy (methane) generation. Due to high fiber content and frequently high levels of non-protein nitrogen, dried poultry manure has been used as an animal feed for ruminants (Ghaly and Macdonald, 2012).

*Spinacia oleracea* commonly known as spinach is an edible flowering plant and a member of the Chenopodiaceae (Goosefoot family) (Guide, 2000). It is a cool weather vegetable that produces an excellent crop in the cool temperatures of spring but does poorly in the heat of the summer when plants bolt (send up flower spikes) with resulting deterioration of the leaves. Spinach has been found valuable for constipation, dyspepsia (chronic indigestion), anaemia, neuritis, nerve exhaustion, tumors, insomnia, arthritis, obesity, high blood pressure and bronchitis (Roshan *et* al, 2012).

The nutrition of spinach depends mainly upon the three most important elements which are nitrogen, phosphorus and potassium (Journal and Applied, 2016). Among the nutrients required by plants in a large amount, nitrogen is the most essential and at the same time, one of the most important growth factors in controlling yield and quality of most vegetable crops (Koike *et al*, 2008).

This study will analyze the effectiveness of chicken droppings, cow dung as well as pig droppings on spinach. The proper application of manure to farmlands and storage is an economical and environmentally sustainable mechanism for increasing crop production (Nova Scotia Department of Agriculture, 2006). Cattle manure is excellent in amending the soil as it increases soil quality and crop yields by providing required large inputs of nutrients and organic material (Manure, 1997). The use of chicken manure has overtaken the use of other animal manure (for example, pig and cow manure) due to its high content of nitrogen, phosphorus and potassium (Dikinya and Mufwanzala, 2010). In addition, chicken manure is the most preferred as compared to other animal manures because of its high concentration of macro-nutrients (Dikinya and Mufwanzala, 2010). However, due to chicken manure acidity, improper addition of chicken manure severely affects root growth and seed germination. Moreover, if applied correctly chicken manure acts as a good soil amendment and or fertilizer as it contains nitrogen, phosphorus and potassium (Dikinya and Mufwanzala, 2010).

## 1.2 Problem statement

In Zimbabwe, most households have an absurd belief that agricultural productivity can only be improved through increments in chemical fertiliser input, but instead this has robbed the soil of its fertility (Mugwendere, 2015). Agricultural production in rural Zimbabwe has suffered generally as a result of acute shortages of essential inputs such as seeds, fertilizer and fuel (Mugwendere, 2015). This then results in lower farm produce due to lack of inputs from the farmers. Following a case study by the author on an Irrigation Scheme in Marange, Mutare, farmers mainly rely on crop production and animal rearing for income but they, however, face problems on how to acquire some artificial fertilizers to be applied to their natural soils. The accumulation of these animal wastes, if not managed properly, causes unnecessary pollution on land and air, such as odours caused by the activity of anaerobic microorganisms in the manure (Ghaly and Macdonald, 2012). Through runoff, these wastes can be washed away into water bodies and cause eutrophication which then ruins aquatic life (Black and Eng, 1967).

## 1.3 Justification

Due to lack of capital, small holder farmers need to improve their farm produce by means of using the available resources they can acquire. Degraded soils tend to be common to smallscale farmers than medium and large scale farmers mainly because small scale farmers cannot afford fertilizers and lime resulting in infrequent application (Derpsch *et al*, 2015). Inputs such as inorganic fertilizers and pesticides become expensive for smallscale farmers who own less than three-hectare lands. Therefore, how to improve crop production and soil property become smallholder farmers concerns. They also want to reduce fertilizer cost, lower bulk density, improve soil fertility and learn some organic fertilizer production technologies so that they can increase income.

Many environmental problems of current arise due to high production and accumulation of animal wastes which are too great for the basic degradation processes inherent in nature

(Gómez-Brandón *et al*, 2013). Following adequate appropriate applications, animal manure constitutes a valuable resource of fertilizer with high content of nutrients required for plant growth (Gómez-Brandón *et al*., 2013). It also represents a low cost environmentally friendly alternative to inorganic fertilizers (Gómez-Brandón *et al.*, 2013). When manure is applied and managed properly according to the agronomic needs of crops, it will improve crop productivity and reduce the demand for commercial fertilizer. Manure is one resource that affects the quality of the environment if not managed properly thus, livestock and poultry producers, regardless of size, need to manage manure for better economic returns and environmental protection (Black and Eng, 1967).

Manure is commonly used as a fertilizer and as an amendment to improve the quality of the soil (Hanks, 2007). Large volumes of organic waste are generated nationwide in Zimbabwe every day hence animal waste is readily available for farmers in large quantities. It can be easily acquired and costs of transportation can be very little to none thus it is affordable. The spreading of slurry can cause several environmental problems such as the release of malodorous compounds and ammonia to the air, the production and entry to the upper atmosphere of nitrous oxide, the loss of slurry by surface run-off and the leaching of organic matter, nitrogen, phosphorus and potassium to drainage and ground waters (Black and Eng, 1967).

Spinach has not been produced greatly as compared to other vegetables (Koike *et al*., 2008). Its production in the United States has increased from the year 2004-2005 but, however, has been decreasing gradually from 2009-2014 (Koike *et al.*, 2008). The level of commercial spinach production is perceived to be low, and observed to be scarce and expensive in the local

Nigerian markets where they are available (Rahji and Omotesho, 2006). Fertilizers being a major input to realize the potential of high-yielding varieties showed a moderate growth in usage during the previous decade. In 2000-2001, fertilizer (in terms of NPK nutrients) use in most parts of Africa was about 90 kg/ha and it raised to 106 kg/ha in 2005-2006 (Venkatesh and Nithyashree, 2014). However, during the second half of the 2000s a notable change in fertilizer consumption was recorded. During the first half of 2000s, the consumption increased to the tune of 6 kg/ha, whereas in the latter half it decreased by 35 kg/ha (Venkatesh and Nithyashree, 2014). This has also resulted in a reduction in farm produce hence the need to try and use animal manure as an alternative to chemical fertilizers.

## 1.4 Objectives

### 1.4.1 Main objective:

- to determine the efficacy of different animal wastes on the growth rate (plant height, leaf number, leaf length and root length) of *Spinacia oleracea.*

### 1.4.2 Specific objectives:

*i.* to determine the effect of cow, chicken and pig wastes on the plant height of spinach, ii. to determine the effect of cow, chicken and pig wastes on the number of leaves of spinach, iii. to determine the effect of cow, chicken and pig wastes on the root length of spinach and iv. to determine the effect of cow, chicken and pig wastes on the leaf size of spinach.

## CHAPTER TWO: LITERATURE REVIEW

### 2.1 History of spinach (*Spinacia oleracea*) cultivation

Man in his effort to satisfy his hunger, discovered that domestication of animals and cultivation of crops are better ways to securing food for his family. Spinach originated in Persia where it was known as Aspanakh (Nutrition Facts, 2011)**.** It then made its way to China in the 7$^{th}$ century when the King of Nepal sent it as a gift and later on arrived in Europe in the 11$^{th}$ century (California *et al.*, 2011). North Americans began spinach cultivation in the early 19$^{th}$ century (Eat, 2002). It was first cultivated as medicinal plant but then was eaten by monks on feast days by 1551 AD (Production Agricultural Services, 2010). By 1806, about three varieties were grown (Sheet, 2017). These varieties are classified by leaf types. Savoy (wrinkled) and semi-savoy are used for fresh markets, while smooth (flat) types are used for baby spinach (Muhumed, 2017). It is now widely grown all year round in the temperate regions of the world (Production *et al*., 2010). In California, spinach is grown in four areas which are: the southern desert valleys, the southern and central coasts as well as the central San Joaquin Valley (Koike *et al.*, 2008).

For thousands of years, spinach has been consumed and it is believed that it made its way into Indian and Asian cooking through Arab traders who carried it from the Middle East (Sheet, 2017). By far, the world's leader in spinach production is China. In 2014, this country produced 22.1 million tonnes of spinach, which represents approximately 85% of the global supply. Spinach became a popular vegetable in countries such as Spain and later on diffused to Germany, England, Italy and France (Production *et al.*, 2010). Due to the sale of freshly packaged teen and baby spinach, there has been an increase in spinach consumption in the United States (Sheet, 2017).

Currently, spinach is a minor crop being delivered directly to wholesalers but, however, it has increased in popularity as a salad crop hence there seem to be potential for additional wholesale markets (Guide, 2000). It has many uses thus it can be eaten raw in a salad or sandwich as an alternative to lettuce, can be cooked as a side dish, or mixed with other foods as part of a main course (Center for Nutrition, Diet and Health, 2008).

The minimum temperature for seed germination is 2ºC with a maximum germination temperature of 30ºC and an optimum range of 7 to 20ºC. Young plants can withstand temperatures as low as -9ºC (Muhumed, 2017). Best crop growth occurs at 15 to 20ºC with a minimum temperature of 5ºC and a maximum of 30ºC. Spinach bolts rapidly when days are both long and hot. Bolting refers to the premature production of a seed stalk and renders the product unmarketable (Muhumed, 2017). To reduce bolting, the selection of resistant varieties to bolting would reduce the problem.

## 2.2 Importance of spinach

### 2.2.1 Nutritional value

Spinach is primarily used as a vegetable food source and is a relatively nutritious dietary supplement. It is a very nutritious vegetable which is rich both in core nutrients and phytochemicals (Zealand, 2007). Fresh spinach is a good source of antioxidant vitamins such as vitamin A and C as well as antioxidants such as beta-carotene and lutein. These play a healing role in aging and combating different diseases such as cancer and promote normal eyesight (Sheet, 2017) Major micronutrients that are available include vitamin A (from beta carotene), C, K and folates (Sheet, 2017). It also provides minerals such as calcium, potassium and fibre which is low in calories (Zealand, 2007).

### 2.2.2 Medicinal value

Medicinally spinach has been traditionally used as an anti-inflammatory, antifungal, analgesic, anticancer agent, to lower high blood pressure, cure of irregular monthly periods, treatment of anaemia, treat boils and to treat dysentery (Roshan, Naveen and Shruthi, 2012). It is also further revealed that the mucilaginous liquid from the leaves and stalks is used as remedy for headaches (Roshan *et al*, 2012).

Spinach leaves help in weight reduction as it is low in calories and fat. It is very nutritious and has a good quality of fat soluble dietary fibre. This fibre aids in digestion, prevents constipation, maintains low blood sugar and curbs overeating. Thus, this leafy vegetable is often recommended to dieters because in dieting, it is important to avoid repetitive eating.

A number of studies have shown that spinach contains strong antioxidant activity and high levels of antioxidant compounds such as phenolics and carotenoids (Zealand, 2007). These antioxidants protect living cells against harmful effects of free radicals and other reactive oxygen species (Bergquist, 2006). Many chronic diseases and health issues which are associated with ageing are believed to result from excessive oxidative stress thus antioxidant activity is very important (Zealand, 2007).

Epidemiological and laboratory studies have also shown that spinach, its extracts and compounds may delay or retard age related loss of brain function, reduce the extent of postischaemic stroke damage to the brain, and protect against cancer through various different mechanisms (Zealand, 2007). A high intake of vegetables such as spinach is well known to have positive effects on human health and it has been correlated to a decreased risk of most degenerative diseases and several forms of cancer (Bergquist, 2006). Other possible health benefits of consuming spinach include improving blood glucose levels in people with diabetes

(Bergquist, 2006).

### 2.2.3 Income generation

Spinach and other vegetables are the most constantly and extensively cultivated food and income generating crops in many parts of Africa (Orefi and Demenongo, 2011**)**. Spinach can give high yield per unit area of land, hence generate high income for the farmers (Mohammed, 2002). Poor dissemination of technological information has resulted in low farm income, weak financial position, and to poor funding of small- holder farmer's economic activities. Also, the level of commercial spinach production is perceived to be low, and observed to be scarce and expensive in the local Nigerian markets where they are available. Farmer's use of resources and information technologies efficiently is of importance in Nigeria agricultural production (Rahji and Omotesho, 2006). This will reduce the level of starvation, increase food production and cushion the effect of food security. Increasing quantity of spinach production, means increase in amount consumed and invariably reducing the amount of starchy food consumed.

## 2.3 History of manure as fertilizer

Addition of lime, fertilizers or manures to soil should be based on recommendations from a soil test (Center of Nutrition, Diet and Health, 2008). In mainland Tanzania, animal manure output is about 14 million tons per year. This is about four times the amount of nitrogenous fertilizers used in the country in 1980. Efficient use of animal manure could therefore alleviate the problem of declining land productivity in most parts of Tanzania. Irrespective of the enormous manure production potential, very little amount of the available animal manure is being utilised for crop production (Kimbi *et al*, 1992). It was observed that in extensive livestock grazing systems only about 1% of farmers apply animal manure on land, indicating serious underutilisation of such resources. This is largely due to lack of scientific basis for advising farmers on aspects such as appropriate application rates, storage techniques and application methods (Maerere *et al.,* 2001)

Fertilizers add only the chemical nutrients required by the crop. Its indiscrimate use leads to additional expense, environmental issues, deficiency in micronutrients, adverse effects in reproductive phase initiation or increased pest incidence (Maerere *et al.*, 2001). On the other hand, addition of animal manure is a holistic approach. It improves the physical and biological features of the soil as well which bears others additional benefits both to fertility as well as to the environment (Nova Scotia Department of Agriculture, 2006).

Manure has been used for centuries as a fertilizer for farming, as it is rich in nitrogen and other nutrients which facilitate the growth of plants (Nova Scotia Department of Agriculture, 2006). It is most commonly available non-chemical fertilisers on the market at low cost. It also contains smaller amounts of other important nutrients.

In an investigation to determine the effect of organic mulch on the growth and yield of spinach, it was observed that mulching improved the performance of the spinach plants in terms of plant growth and yield (Manyatsi and Simelane, 2017). Organic mulch used in this case was treated sewage and organic compost. Chicken manure has also been used in an attempt to increase the growth and crop yield of spinach (Dikinya and Mufwanzala, 2010). This has shown to have significant differences in the growth rate of spinach. While the use of organic wastes as manure has been in practice for centuries all over the world, (Dikinya and Mufwanzala, 2010) there still exists a need to assess which of the animal manures available for small scale farmers is more effective on spinach.

**2.4 Improvement of soil health**

Organic fertilizers have many benefits for the soil. Unlike chemical fertilizers, organic fertilizers reduce acidity in the soil and do not cause leaching. They do not kill beneficial microorganisms in the soil. They also help improve the structure of the soil including the circulation of air, which sustains beneficial microorganisms that help release nutrients to the soil (Koike *et al.*, 2008).

## 2.5 Factors affecting spinach production

### 2.5.1 Pests

The most frequent pests for spinach are the spinach leaf miner and aphids. Control can be done by destroying infected crop residue and weeds. Also the use registered pesticides can be of help. An integrated pest management programme can be followed by the use of management strategies for diseases and pests, including crop rotation and spraying with registered insecticide and fungicide (Production *et al.*, 2010).

### 2.5.2 Diseases

Diseases that affect spinach plants include downy mildew, furasium wilt, yellow rot, spinach blight and damping off. These can be controlled by treating the seeds with a registered chemical immediately before planting, by planting resistant cultivars, avoiding planting when the soil temperature is high, practising 3-year crop rotation and considering hot water treatment of the seed (Production *et al.*, 2010).

## CHAPTER THREE: MATERIALS AND METHODS

### 3.1 Study site

The study was carried out at Africa University farm located in Mutare, Manicaland from June to July 2018. The experiments were done in a greenhouse. The area receives an average annual rainfall between 800-1000 mm with most rain falling between December and February. The average summer temperature was 27ºC and the average winter temperature was about 7ºC (Mugwendere, 2015).

### 3.2 Sources of materials

The spinach seeds (fordhock giant) used in the study were purchased from Farm and City Centre in Mutare. These seeds were planted in respective pots containing soil obtained from the university farm and the desired treatments. The treatments used (cow, pig and chicken wastes) applied to the soil were obtained from the university farm.

### 3.3 Experimental design

The experimental design used in the experiment was Randomised complete block design (RCBD). These blocks were randomly assigned to the experimental units to block the effect of sunlight as well as temperature (Table 1). Homogeneity among treatment units was difficult to maintain due to the two confounding factors (temperature and sunlight) hence the choice of experimental design. There were five blocks and each block contained one of the five treatments. The experiment had a total of 25 Ford hock giant plants assigned at random.

Table 1: Arrangement of treatments in blocks in the greenhouse.

| BLOCK 1 | BLOCK 2 | BLOCK 3 | BLOCK 4 | BLOCK 5 |
|---|---|---|---|---|
| **5** | **3** | **4** | **3** | **5** |
| **1** | **2** | **1** | **1** | **3** |
| **3** | **5** | **3** | **5** | **1** |
| **2** | **1** | **2** | **4** | **2** |
| **4** | **4** | **5** | **2** | **4** |

**Key:**

1- Chicken manure

2- Cow manure

3- Pig manure

4- Compound D fertiliser (positive control)

5- No treatment (negative control)

## 3.4 Sample preparation

### 3.4.1 Soil sampling

Soil (vlei soil) used in the study was collected from the Africa University farm using a hoe at a depth of 0-20cm. The soil was air dried in the shade, ground into finer particles and was sieved using a 2mm sieve to remove stone particles, roots and other plant matter. It was made free from lumps manually using hands before it was used in the study. A sample of the soil was then taken for laboratory analysis to determine the nutrient composition as well as pH. The soil was then placed in pots at a depth of about 20cm.

### 3.4.2 Manure sampling

Animal manure (cow, chicken and pig) used was collected from the farm using a spade and each of the manures was packed in a 25kg pack. These were sun dried so as to kill any germs available or insects which could later hinder the growth of spinach crop. Each of the wastes was mixed with soil on a weight per weight (w/w) ratio according to the methods by Wong *et al.* (2001), at the rate of: 9:1 (that is, 90% soil, 10% manure). After homogenization, each sample was transferred into plant pots in 5 replicates for each application rate for the greenhouse pot experiment (Dikinya and Mufwanzala, 2010).

### 3.4.3 Preparation of sample plants

This study was carried out in a greenhouse with a sample size of twenty-five plants. The seeds were planted in plastic pots (20cm in diameter and 20cm in depth) filled with fine soil mixed with the appropriate treatments. Five seeds were planted per pot on 15 June 2018 and were placed about 2cm below the soil surface. The pots were spaced 30cm apart from each other. After emergence, the seedlings were thinned when they were about 5cm tall leaving behind one plantlet per pot. This was done to avoid competition for nutrients and to ensure maximum growth of plants.

### 3.4.4 Watering

Watering was done manually using a watering can to the sample plants about three times a week to field capacity until the end of the growth period. This was done to avoid moisture stress to the plants. The soil was made damp and not over flooded with the water.

### 3.4.5 Weed control

Weeds that emerged during the experimental period were removed manually by plucking them out using hands.

### 3.5 Data collection

#### 3.5.1 Measuring plant height

Plant height was measured at weekly intervals over a period of six weeks. Sampled plants were measured from the ground level to the tip of the plant using a ruler and a tape measure.

#### 3.5.2 Counting number of leaves

The number of leaves on each of the experimental units was determined at weekly intervals for six weeks manually by counting them. Dead and senescent leaves were disregarded in determinations of the number of leaves.

#### 3.5.3 Measuring leaf size

At day 60 (maturity) leaf sizes were determined by measuring the length and width of the largest leaf per plant. Measurements were done early in the morning when there was less direct solar radiation.

#### 3.5.4 Measuring root length

At maturity plants were uprooted and an assessment of root growth was done for each treatment by measuring taproot length. This was measured using a ruler and a tape measure.

## CHAPTER 4: RESULTS

The results indicated certain differences in terms of growth rate for the different treatments applied.

Table 2: Effect of different animal manures on the mean plant heights, number of leaves, leaf areas and root length of spinach.

| | **Mean change in plant height per day (cm)** | **Mean change in number of leaves per day** | **Mean leaf area ($cm^2$)** | **Mean root length (cm)** |
|---|---|---|---|---|
| **Chicken manure** | 0.193 | 0.133 | 255.3 | 6.1 ± 0.034 |
| **Cow manure** | 0.131 | 0.100 | 79.6 | 8 ± 0.014 |
| **Pig manure** | 0.136 | 0.085 | 74.7 | 10.1 ± 1.88 |
| **Fertilizer** | 0.178 | 0.100 | 185.8 | 6.3 ± 0.00 |
| **No treatment** | 0.076 | 0.076 | 48.2 | 18.2 ± 0.05 |

### 4.1 Effect of different animal wastes on change in plant height of *S. oleracea* per day.

The application of different animal manures on spinach had an effect on the change in plant height. There were significant differences (Anova: $p<0.05$) in data pertaining to plant height in relation to the treatments added.

After a multiple comparison test (Tukey-Kramer) was conducted, it was observed that chicken manure was not significantly different from either of cow, pig manures or fertilizer ($p>0.05$).

However, there were significant differences between chicken manure and the negative control ($p<0.05$). Also, cow and pig manures were not significantly different from each other ($p>0.05$)

(Appendix 1).

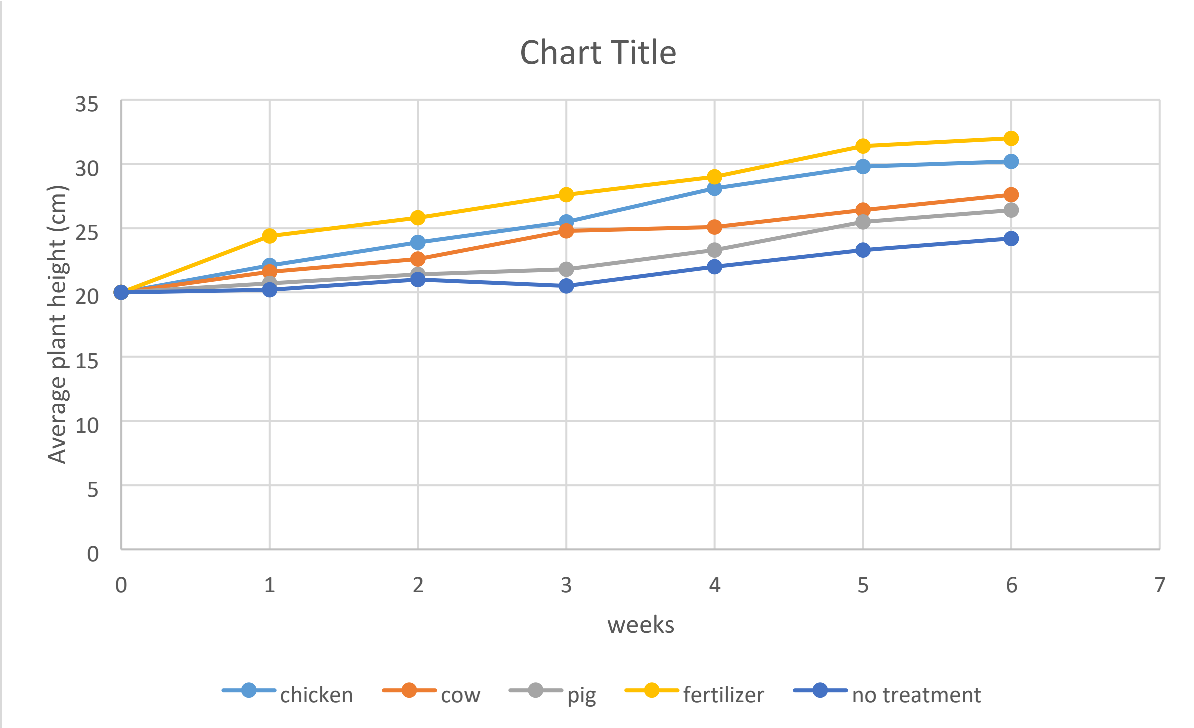


Figure 1: Effect of the different animal manures on plant height over the growing period.

The trend in plant height was chicken manure > cow manure > pig manure (Fig 1).

**4.2 Effect of different animal wastes on change in *S. oleracea* number of leaves per day.**

Data regarding cumulative number of leaves showed significant differences ($p<0.05$) for the different treatments added. Significant differences were observed between the groups: chicken manure and no treatment, chicken and cow manure, chicken and pig manures ($p<0.05$) (Fig 2). Pig manure and no treatment were not significantly different from each other but significantly different from cow, chicken manures and fertilizer (Appendix 2).

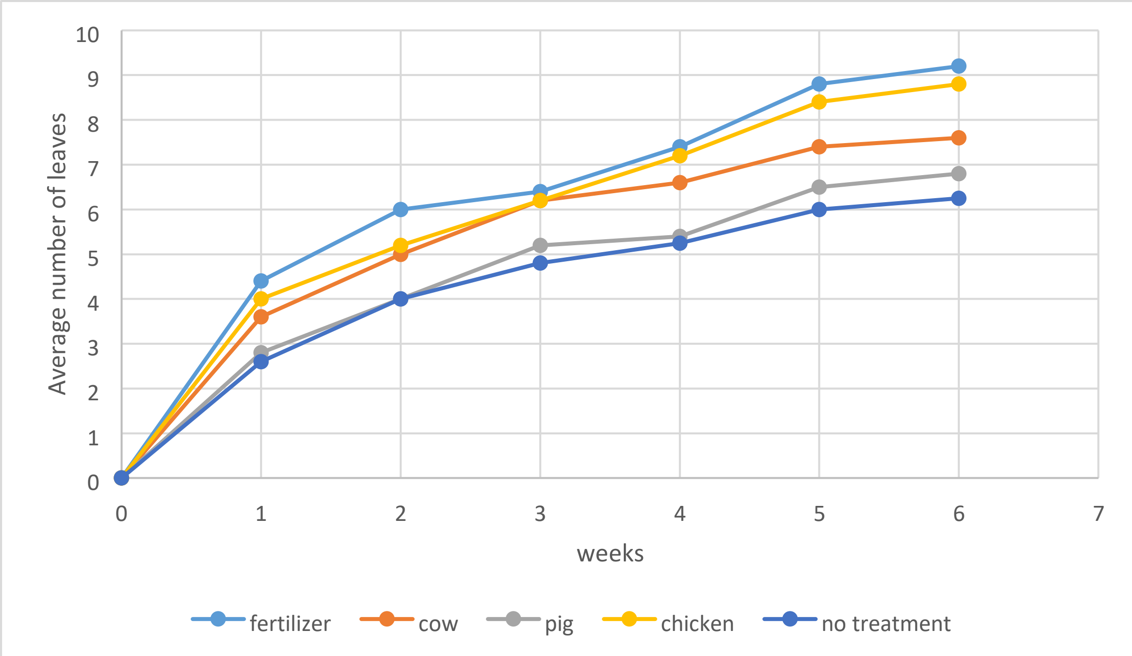


Figure 2: Effect of the different animal manures on number of leaves over the growing period.

**4.3 Effect of different animal wastes on *S. oleracea* tap root length.**

Tap root lengths of spinach were significantly influenced by the different types of manures added ($p<0.05$). The mean tap root lengths ranged from 6-18.2 cm for all the treatments (Table 2). Significant differences were observed among each of the four treatments (cow manure, chicken manure, pig manure and fertilizer) and no treatment group ($p<0.05$). In addition, all the treatment groups were significantly different from each other (Appendix 3).

**4.4 Effect of different animal wastes on change in number of leaves of *S. oleracea* per day.**

There were significant differences among the treatments on the change in leaf numbers of spinach ($p<0.05$). In Table 2, the change in number of leaves per day varied with the type of manure applied.

Tukey-Kramer multiple comparison analysis showed that there were significant differences among chicken manure, cow manure and no treatment ($p<0.05$). No significant differences were observed between chicken manure and fertilizer (Appendix 4).

## CHAPTER 5: DISCUSSION

### 5.1 Effect of different animal wastes on plant height and number of leaves of *S. oleracea*.

Manure is rich in nutrients, including trace elements necessary for crop growth (Ahmadi and Jafarpour, 2015). It is usually applied at higher rates, relative to inorganic fertilizers. When applied at higher rates, they give residual effects on the growth and yield of succeeding crops ( Gulshan *et al*, 2013). The application of different animal manures on spinach had an effect on the change in plant height. From the results of the investigation carried out, on the basis of change in plant height per day, it may be concluded that chicken manure produced significantly higher plant height, compared with other manure types used.

The nutrient content in plant tissue significantly increased with the application of animal manures as compared to the plants without animal manure or fertilizer. Chicken manure having more nutritional value as compared to other manures (Dikinya and Mufwanzala, 2010) resulted in plants with greater plant heights. The rate at which the plant heights increased was directly proportional to the rate of increase in number of leaves.

### 5.2 Effect of different animal wastes on *S. oleracea* tap root length.

When growing conditions are favourable and the soil is deep, the tap root can grow to a depth of about 150 cm or even more. However, the spinach plant can still grow a significant root system if it is left to grow for about 90 days (Roshan *et al*, 2012). With enough nutrients being available in the soil, the tap root of plants becomes short with a significant thickness.

This was observed in spinach plants grown under the treatments of fertilizer and chicken manure. Plants in pots without treatments had the longest tap root thus the plants deepened their tap roots in search of nutrients in-order to survive. Similar results were reported by

Wright *et al*. (1995), who observed that maximum root growth and rooting depth of barley crop were higher in treatments, which received animal manures relative to where manure was not applied. The results also revealed variations among the three manures and the trend was: poultry manure > cow manure > pig manure. These responses by the spinach plants to the manures could largely be due to the initial differences in total nitrogen, total phosphorus and organic carbon of the three manures (Maerere *et al*., 2001). Dikinya and Mufwanzala (2010) stated that chicken manure significantly increases the phosphorus of soil since it releases more phosphorus than nitrogen which in turn stimulates root development of plants.

### 5.3 Effect of different animal wastes on *S. oleracea* leaf area.

Leaf area is a crucial growth index determining the capacity of plant to trap solar energy for photosynthesis and has marked effect on growth and yield of plant (Detpiratmongkol *et al*, 2014). The influence on leaf area remained significant under different types of organic manure and application levels. The highest leaf area was obtained under chicken manure followed by cow manure and the least was recorded for pig manure which was statistically at par with no treatment. The application of manures and fertilizer increased the growth of the plants, which might have been due to the balance availability of nutrients to the plants that resulted in a favourable soil environment. These favourable conditions increased the nutrient availability and water holding capacity of the soil resulting in enhanced growth and yield (Rashid *et al*., 2013).

### 5.4 Conclusion

The greenhouse experiment study was undertaken to assess the effectiveness of chicken manure, cow manure and pig manure on the growth rate of spinach. The study revealed that chicken manure is a potential source of plant nutrients and chemical conditioner. From the results of the investigation, on the basis of plant growth of spinach, it can be concluded that chicken manure produced significantly higher plant height, more number of leaves and larger leaf sizes as compared with other manure types used.

### 5.5 Recommendations

This study recommends that in areas where there is low agricultural inputs in terms of vegetable production (mainly spinach), farmers cultivate crops fertilizing using chicken manure as it is a potential source of plant nutrients. In addition, farmers will have higher yield and will invest less in pesticide usage which may be harmful to the environment by the use of pest resistant varieties.

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## APPENDIX 1

1A: SPSS output for test between subject effects for change in plant height per day.

**Tests of Between-Subjects Effects**

Dependent Variable: changeinplantheightperday

| Source | Type III Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Corrected Model | .056[a] | 8 | .007 | 2.339 | .070 |
| Intercept | .510 | 1 | .510 | 170.154 | .000 |
| treatment | .042 | 4 | .011 | 3.510 | .031 |
| block | .014 | 4 | .003 | 1.169 | .361 |
| Error | .048 | 16 | .003 | | |
| Total | .613 | 25 | | | |
| Corrected Total | .104 | 24 | | | |

a. R Squared = .539 (Adjusted R Squared = .309)

## Homogeneous Subsets

**Changeinplantheightperday**

Tukey HSD[a,b]

| treatment | N | Subset | |
|---|---|---|---|
| | | 1 | 2 |
| no treatment | 5 | .07600 | |
| cow manure | 5 | .13120 | .13120 |
| pig manure | 5 | .13560 | .13560 |
| Fertilizer | 5 | .17800 | .17800 |
| chicken manure | 5 | | .19300 |
| Sig. | | .062 | .414 |

Means for groups in homogeneous subsets are displayed.

Based on observed means.

The error term is Mean Square(Error) = .003.

a. Uses Harmonic Mean Sample Size = 5.000.

b. Alpha = .05.

## Post Hoc Tests

**1B: Tukey Post Hoc multiple comparisons for change in plant height per day.**

**Multiple Comparisons**

Dependent Variable: changeinplantheightperday
Tukey HSD

| (I) treatment | (J) treatment | Mean Difference (I-J) | Std. Error | Sig. | 95% Confidence Interval | |
|---|---|---|---|---|---|---|
| | | | | | Lower Bound | Upper Bound |
| chicken manure | cow manure | .06180 | .034609 | .414 | -.04423 | .16783 |
| | pig manure | .05740 | .034609 | .484 | -.04863 | .16343 |
| | fertilizer | .01500 | .034609 | .992 | -.09103 | .12103 |
| | no treatment | .11700* | .034609 | .027 | .01097 | .22303 |
| cow manure | chicken manure | -.06180 | .034609 | .414 | -.16783 | .04423 |
| | pig manure | -.00440 | .034609 | 1.000 | -.11043 | .10163 |
| | fertilizer | -.04680 | .034609 | .665 | -.15283 | .05923 |
| | no treatment | .05520 | .034609 | .521 | -.05083 | .16123 |
| pig manure | chicken manure | -.05740 | .034609 | .484 | -.16343 | .04863 |
| | cow manure | .00440 | .034609 | 1.000 | -.10163 | .11043 |
| | fertilizer | -.04240 | .034609 | .738 | -.14843 | .06363 |
| | no treatment | .05960 | .034609 | .449 | -.04643 | .16563 |
| Fertilizer | chicken manure | -.01500 | .034609 | .992 | -.12103 | .09103 |
| | cow manure | .04680 | .034609 | .665 | -.05923 | .15283 |
| | pig manure | .04240 | .034609 | .738 | -.06363 | .14843 |
| | no treatment | .10200 | .034609 | .062 | -.00403 | .20803 |
| no treatment | chicken manure | -.11700* | .034609 | .027 | -.22303 | -.01097 |
| | cow manure | -.05520 | .034609 | .521 | -.16123 | .05083 |
| | pig manure | -.05960 | .034609 | .449 | -.16563 | .04643 |
| | fertilizer | -.10200 | .034609 | .062 | -.20803 | .00403 |

Based on observed means.

The error term is Mean Square(Error) = .003.

*. The mean difference is significant at the .05 level.

## APPENDIX 2

## 2A: SPSS output for test between subject effects for change in leaf number per day.

**Between-Subjects Factors**

| | | Value Label | N |
|---|---|---|---|
| treatment | 1 | chicken manure | 5 |
| | 2 | cow manure | 5 |
| | 3 | pig manure | 5 |
| | 4 | fertilizer | 5 |
| | 5 | no treatment | 5 |
| block | 1 | block 1 | 5 |
| | 2 | block 2 | 5 |
| | 3 | block 3 | 5 |
| | 4 | block 4 | 5 |
| | 5 | block 5 | 5 |

**Tests of Between-Subjects Effects**

Dependent Variable: changeinleafnumber

| Source | Type III Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Corrected Model | .011[a] | 8 | .001 | 2.964 | .031 |
| Intercept | .244 | 1 | .244 | 504.782 | .000 |
| Treatment | .010 | 4 | .002 | 4.929 | .009 |
| Block | .002 | 4 | .000 | 1.000 | .436 |
| Error | .008 | 16 | .000 | | |
| Total | .263 | 25 | | | |
| Corrected Total | .019 | 24 | | | |

a. R Squared = .597 (Adjusted R Squared = .396)

## Post Hoc Tests

## treatment

## 2B: Tukey Post Hoc multiple comparisons for change in leaf number per day

**Multiple Comparisons**

Dependent Variable: changeinleafnumber
Tukey HSD

| (I) treatment | (J) treatment | Mean Difference (I-J) | Std. Error | Sig. | 95% Confidence Interval | |
|---|---|---|---|---|---|---|
| | | | | | Lower Bound | Upper Bound |
| chicken manure | cow manure | .03360 | .013912 | .161 | -.00902 | .07622 |
| | pig manure | .04800* | .013912 | .024 | .00538 | .09062 |
| | fertilizer | .03360 | .013912 | .161 | -.00902 | .07622 |
| | no treatment | .05760* | .013912 | .006 | .01498 | .10022 |
| cow manure | chicken manure | -.03360 | .013912 | .161 | -.07622 | .00902 |
| | pig manure | .01440 | .013912 | .836 | -.02822 | .05702 |
| | fertilizer | .00000 | .013912 | 1.000 | -.04262 | .04262 |
| | no treatment | .02400 | .013912 | .447 | -.01862 | .06662 |
| pig manure | chicken manure | -.04800* | .013912 | .024 | -.09062 | -.00538 |
| | cow manure | -.01440 | .013912 | .836 | -.05702 | .02822 |
| | fertilizer | -.01440 | .013912 | .836 | -.05702 | .02822 |
| | no treatment | .00960 | .013912 | .956 | -.03302 | .05222 |
| Fertilizer | chicken manure | -.03360 | .013912 | .161 | -.07622 | .00902 |
| | cow manure | .00000 | .013912 | 1.000 | -.04262 | .04262 |
| | pig manure | .01440 | .013912 | .836 | -.02822 | .05702 |
| | no treatment | .02400 | .013912 | .447 | -.01862 | .06662 |
| no treatment | chicken manure | -.05760* | .013912 | .006 | -.10022 | -.01498 |
| | cow manure | -.02400 | .013912 | .447 | -.06662 | .01862 |
| | pig manure | -.00960 | .013912 | .956 | -.05222 | .03302 |
| | fertilizer | -.02400 | .013912 | .447 | -.06662 | .01862 |

Based on observed means.
The error term is Mean Square(Error) = .000.
*. The mean difference is significant at the .05 level.

## Homogeneous Subsets

**changeinleafnumber**

Tukey HSD[a,b]

| Treatment | N | Subset | |
|---|---|---|---|
| | | 1 | 2 |
| no treatment | 5 | .07580 | |
| pig manure | 5 | .08540 | |
| cow manure | 5 | .09980 | .09980 |
| Fertilizer | 5 | .09980 | .09980 |
| chicken manure | 5 | | .13340 |
| Sig. | | .447 | .161 |

Means for groups in homogeneous subsets are displayed.

Based on observed means. The error term is Mean Square(Error) = .000.

a. Uses Harmonic Mean Sample Size = 5.000.

b. Alpha = .05.

## APPENDIX 3

## 3A: SPSS output for test between subject effects for tap root length

**Between-Subjects Factors**

| | | Value Label | N |
|---|---|---|---|
| treatment | 1 | chicken manure | 5 |
| | 2 | cow manure | 5 |
| | 3 | pig manure | 5 |
| | 4 | fertilizer | 5 |
| | 5 | no treatment | 5 |
| block | 1 | block 1 | 5 |
| | 2 | block 2 | 5 |
| | 3 | block 3 | 5 |
| | 4 | block 4 | 5 |
| | 5 | block 5 | 5 |

**Tests of Between-Subjects Effects**

Dependent Variable: taprootlength

| Source | Type III Sum of Squares | Df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Corrected Model | 525.720[a] | 8 | 65.715 | 7.361 | .000 |
| Intercept | 2371.690 | 1 | 2371.690 | 265.661 | .000 |
| treatment | 499.060 | 4 | 124.765 | 13.975 | .000 |
| block | 26.660 | 4 | 6.665 | .747 | .574 |
| Error | 142.840 | 16 | 8.928 | | |
| Total | 3040.250 | 25 | | | |
| Corrected Total | 668.560 | 24 | | | |

a. R Squared = .786 (Adjusted R Squared = .680)

## 3B: Tukey Post Hoc multiple comparisons for tap root length treatment

**Multiple Comparisons**

Dependent Variable: taprootlength
Tukey HSD

| (I) treatment | (J) treatment | Mean Difference (I-J) | Std. Error | Sig. | 95% Confidence Interval | |
|---|---|---|---|---|---|---|
| | | | | | Lower Bound | Upper Bound |
| chicken manure | cow manure | -1.900 | 1.8897 | .849 | -7.689 | 3.889 |
| | pig manure | -4.000 | 1.8897 | .261 | -9.789 | 1.789 |
| | fertilizer | -.200 | 1.8897 | 1.000 | -5.989 | 5.589 |
| | no treatment | -12.100* | 1.8897 | .000 | -17.889 | -6.311 |
| cow manure | chicken manure | 1.900 | 1.8897 | .849 | -3.889 | 7.689 |
| | pig manure | -2.100 | 1.8897 | .798 | -7.889 | 3.689 |
| | fertilizer | 1.700 | 1.8897 | .893 | -4.089 | 7.489 |
| | no treatment | -10.200* | 1.8897 | .000 | -15.989 | -4.411 |
| pig manure | chicken manure | 4.000 | 1.8897 | .261 | -1.789 | 9.789 |
| | cow manure | 2.100 | 1.8897 | .798 | -3.689 | 7.889 |
| | fertilizer | 3.800 | 1.8897 | .305 | -1.989 | 9.589 |
| | no treatment | -8.100* | 1.8897 | .004 | -13.889 | -2.311 |
| fertilizer | chicken manure | .200 | 1.8897 | 1.000 | -5.589 | 5.989 |
| | cow manure | -1.700 | 1.8897 | .893 | -7.489 | 4.089 |
| | pig manure | -3.800 | 1.8897 | .305 | -9.589 | 1.989 |
| | no treatment | -11.900* | 1.8897 | .000 | -17.689 | -6.111 |
| no treatment | chicken manure | 12.100* | 1.8897 | .000 | 6.311 | 17.889 |
| | cow manure | 10.200* | 1.8897 | .000 | 4.411 | 15.989 |
| | pig manure | 8.100* | 1.8897 | .004 | 2.311 | 13.889 |
| | fertilizer | 11.900* | 1.8897 | .000 | 6.111 | 17.689 |

Based on observed means.

The error term is Mean Square(Error) = 8.928.

*. The mean difference is significant at the .05 level.

# APPENDIX 4

## 4A: SPSS output for test between subject effects for average leaf area

**Between-Subjects Factors**

| | | Value Label | N |
|---|---|---|---|
| treatment | 1 | chicken manure | 5 |
| | 2 | cow manure | 5 |
| | 3 | pig manure | 5 |
| | 4 | fertilizer | 5 |
| | 5 | no treatment | 5 |
| block | 1 | block 1 | 5 |
| | 2 | block 2 | 5 |
| | 3 | block 3 | 5 |
| | 4 | block 4 | 5 |
| | 5 | block 5 | 5 |

**Tests of Between-Subjects Effects**

Dependent Variable: averageleafarea

| Source | Type III Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Corrected Model | 183100.920[a] | 8 | 22887.615 | 5.656 | .002 |
| Intercept | 414156.603 | 1 | 414156.603 | 102.350 | .000 |
| treatment | 159910.160 | 4 | 39977.540 | 9.880 | .000 |
| block | 23190.760 | 4 | 5797.690 | 1.433 | .269 |
| Error | 64743.290 | 16 | 4046.456 | | |
| Total | 662000.813 | 25 | | | |
| Corrected Total | 247844.210 | 24 | | | |

a. R Squared = .739 (Adjusted R Squared = .608)

## 4B: Tukey Post Hoc multiple comparisons for average leaf area treatment

**Multiple Comparisons**

Dependent Variable: averageleafarea
Tukey HSD

| (I) treatment | (J) treatment | Mean Difference (I-J) | Std. Error | Sig. | 95% Confidence Interval | |
|---|---|---|---|---|---|---|
| | | | | | Lower Bound | Upper Bound |
| chicken manure | cow manure | 179.7000* | 40.23161 | .003 | 56.4435 | 302.9565 |
| | pig manure | 180.6500* | 40.23161 | .003 | 57.3935 | 303.9065 |
| | fertilizer | 65.5000 | 40.23161 | .502 | -57.7565 | 188.7565 |
| | no treatment | 207.1000* | 40.23161 | .001 | 83.8435 | 330.3565 |
| cow manure | chicken manure | -179.7000* | 40.23161 | .003 | -302.9565 | -56.4435 |
| | pig manure | .9500 | 40.23161 | 1.000 | -122.3065 | 124.2065 |
| | fertilizer | -114.2000 | 40.23161 | .076 | -237.4565 | 9.0565 |
| | no treatment | 27.4000 | 40.23161 | .958 | -95.8565 | 150.6565 |
| pig manure | chicken manure | -180.6500* | 40.23161 | .003 | -303.9065 | -57.3935 |
| | cow manure | -.9500 | 40.23161 | 1.000 | -124.2065 | 122.3065 |
| | fertilizer | -115.1500 | 40.23161 | .073 | -238.4065 | 8.1065 |
| | no treatment | 26.4500 | 40.23161 | .963 | -96.8065 | 149.7065 |
| fertilizer | chicken manure | -65.5000 | 40.23161 | .502 | -188.7565 | 57.7565 |
| | cow manure | 114.2000 | 40.23161 | .076 | -9.0565 | 237.4565 |
| | pig manure | 115.1500 | 40.23161 | .073 | -8.1065 | 238.4065 |
| | no treatment | 141.6000* | 40.23161 | .021 | 18.3435 | 264.8565 |
| no treatment | chicken manure | -207.1000* | 40.23161 | .001 | -330.3565 | -83.8435 |
| | cow manure | -27.4000 | 40.23161 | .958 | -150.6565 | 95.8565 |
| | pig manure | -26.4500 | 40.23161 | .963 | -149.7065 | 96.8065 |
| | fertilizer | -141.6000* | 40.23161 | .021 | -264.8565 | -18.3435 |

Based on observed means.

The error term is Mean Square(Error) = 4046.456.

*. The mean difference is significant at the .05 level.