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DEPARTMENT OF CROPSCIENCE

Evaluation of cow dung as organic media and vermiculite as inorganic media in establishing Rodade plus tomato seedlings

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DEDICATION

This dissertation is dedicated to Sariwe Danga my mother, Misheck Hodzi my father and Hellen Hodzi my sister, I am proud of you all my family members.

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ABSTRACT

The cultivation of tomatoes in Zimbabwe is a vital agricultural practice that supports local food security and economic development.There are many problems incurred in the production of tomatoes in Zimbabwe. These problems are mostly incurred at nursery level and these include the death of tomatoes at seedling stage, disease and pest incidence, reduction of yields due to reduction in leaf area index. Most of these problems incurred at seedling stages are caused by the poor choice in the selection of growing media in the production of tomato nurseries. This research investigates the comparative effects of cow-dung and vermiculite based growing media on tomato seedlings by measuring growth metrics such as seedling stem-height, leaf count, and survival rate. Controlled experiments were conducted to assess the performance of cow dung and vermiculite. Data collected included seedling vigor, seedling stem-thickness, seedling stem-height, seedling survival rate, leaf area index and resilience to environmental stresses. Data analysis were done using the GenStart Data Analyzing tool and where there were significant differences the means were separated using the least significant differences at 0,05 probability level. The results showed that there was no significance difference on pest incidents and disease incidence across all the growing mediums. However the growing mediums had a significant effect on stem thickness, stem height, leaf area index and survival rate across all the growing mediums. The thesis unveil the potential of cow dung in enhancing stem thickness, stem height and leaf area index due to its rich nutrient and organic content. Vermiculite provided a support for high leaf number, survival rate, pest incidence, disease incidences as well as excellent moisture retention and aeration. Loam had the poorest performance in supporting all the growth parameters. Based on the results and information given by the study, cow dung and vermiculite support different growth parameter of tomato seedlings. Growing medium which contain cow dung strongly support stem thickness, stem height and leaf area index to tomato seedlings. On the other hand, vermiculite facilitate an increase in leaf number, survival rate, pest and disease incidence, therefore farmers should use a ratio of 1:1 mix of cow dung and vermiculite to have a balance in the robustness of the tomato seedling. Conclusively, the mixture of cow dung and vermiculite in proportionality improve the health of the tomato seedlings which fosters the production of tomato in large scale which aid to poverty alleviation and curbing malnutrition diseases like kwashiorkor.

Key words: Nursery, Organic, Inorganic, Photosynthesis, Cow dung, Vermiculite, Seedlings, Mixture, Alleviation

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ACRONYMS AND SYMBOLS

RCBD……………….......................Randomized Complete Design

CD…………………………………..Cow dung

CDL...…...Cow dung and Loam

L………………………………..…Loam

V…………………….....................Vermiculite

VL…………………………………Vermiculite and Loam

GM………………………………...Growth Medium

FAO………………………………..Food and Agricultural organization

NPK………………………………...Nitrogen: Phosphorus: Potassium

CEC………………………………Cat ion Exchange Capacity

CBD………………………………..Central Business District

UNIT OF MEASUREMENTS

cm………………………………………………….. Centimeters

cm^2…………………………………………………. Square centimeters cm^3

………………………………………………… Cubic centimeters

%...Percentage

g/plant……………………………………………….. Grams per plant

kg……………………………………………………. Kilograms ml

………………………………………………….. Milliliters l

…………………………………………………….. Liters

CHAPTER 1

1.1 INTRODUCTION

Tomatoes (*Solanum Iycopersicum*) is very important in the economy and food security in Zimbabwe. Tomatoes can be eaten raw and are usually used in abundance in the kitchen to make relish on a daily base. Tomatoes are an excellent source of essential nutrients, including vitamin, Lycopene and potassium, making them an important component of a healthy diet (ACIAR, 2005). Its nutritive value has played an important role in making tomatoes a cash crop for smallholder and commercial farmers in Zimbabwe. The production and selling of tomatoes also provide employment and cash inflows for millions of people in Zimbabwe and worldwide. This contributes to a significant rural development and poverty alleviation (Yamauchi, 2008). Global tomato production has been steadily increasing over the past years, driven by a drastic increase and growing demand from emerging markets, urbanization and changing in consumer preferences. Food and Agriculture Organization (FAO, 2017), states that the global production of tomatoes has grown from approximately one hundred million metric tons in 1990 to over one hundred and eighty million metric tons in 2020.This growth has been accompanied by the advances in tomato breeding, cultivation and post-harvest handling, which has also improved yield quality and shelf life (Nyoni, 2023).

Generally, in Zimbabwe tomatoes are grown in various regions, but it is grown the best in regions that have mild climate, well distributed rain-fall as well as suitable soil conditions.The soils should be fertile loamy soils with a ph. of 6.0-6.8 (Rukazenda 2015). The best regions for the production of tomatoes in Zimbabwe includes the Mashonaland East Province which have an average temperature which ranges from 20-28 degrees Celsius (Chikowo, *et al* 2019). Mashonaland West and Manicaland Province has got the same climatic conditions with Mashonaland East which makes them to be suitable for the successful production of tomatoes. However, establishing a robust tomato nursery is still a challenge, hence resulting in low production of tomatoes in Zimbabwe. The choice of growing media in the establishment of a robust tomato seedling is one of the important factors influencing seedling establishment and development (Chakanda, 2019). An ideal growing media should support good aeration, water retention and drainage while providing essential nutrients for healthy root and shoot growth. The two media which can be used are organic and inorganic media. This study aims to evaluate and compare the effectiveness of cow dung, an organic media versus vermiculite, an inorganic media in raising tomato seedlings of a variety *Rodade plus*. One way of improving productivity is by raising healthy seedlings in controlled nursery conditions before transplanting them to main field. The choice of growing media remains an important factor in establishing robust tomato seedlings.

Specifically, cow dung is widely used in Zimbabwean agriculture, known for improving soil healthy and fertility when applied to the field. It contains essential nutrients like nitrogen, phosphorous and magnesium (NPK) in amounts readily available for uptake by plant roots (Moyo, 2016). Cow dung also houses various beneficial microbes that aid nutrient cycling and disease suppression in the soil. Its high-water holding capacity helps to retain moisture for longer periods. Cow dung is cost-effective as it is readily available and inexpensive organic growing medium (Kabasa, 2022). These properties make cow dung a potential candidate for organic growing media in raising tomato seedlings. On the other hand, vermiculite is a commonly used inorganic growth media used in nurseries and greenhouses. Vermiculite has a high-water holding capacity. It can retain up to 400% of its weight in water and this make it an excellent growing media for horticultural crops like tomatoes (*Solanum Iycopersicum*) which requires consistent moisture levels (Nyandoro, 2020). This property also make vermiculite useful in seed starting and propagation as it helps to maintain a constant moisture level around developing roots. Vermiculite has high cat ion exchange capacity (CEC)/. CEC refers to the ability of the media to exchange positively charge ions (cations) with the surrounding solution. Its high CEC allows it to retain and exchange essential nutrients such as potassium, calcium and magnesium. Vermiculite has a low bulk density which make it easy to transport and handle. Vermiculite is also sterile, which makes it free from weed seeds, fungi and other microorganisms that are detrimental to plant growth (Chikanda, 2019). It is also durable, long-lasting media, resistant to decomposition and can be reused multiple times without losing its physical and biological properties. This property makes vermiculite a cost-effective and sustainable option for growers who are looking to a reliable and consistent growing medium. Since cow dung has been used in soil amendments, its effectiveness is still a need to investigate as a media that can provide valuable insights for commercial nursery practices. This study will therefore compare the performance of cow dung versus vermiculite in establishing tomato seedling of new hybrid variety *Rodade plus.*

A controlled greenhouse experiment will be set up with seeds grown in eighteen different trays with each containing two hundred holes. Tray A will be containing cow dung, Tray B will be containing a mixture of cow dung and loam soil and it will be compared versus Tray C containing vermiculite, Tray D will be containing a mixture of vermiculite and loam soil and tray E will be contain soil as a control for both cow dung as well as vermiculite. Each tray will be replicated three times. It is important to note that cow dung is not sterile, therefore it will be sterilized using hot water (Moyo, 2016). Standardized protocols will be followed for sowing, watering, lighting, temperature and general care of the seedlings. Regular observations and measurements will be recorded from sowing till seedlings are ready for field transplanting. Statistical analysis will be done to determine any significant difference between six treatments. It is hypothesized that treatments with cow dung only will support faster germination, higher seedling establishment and better overall growth followed with the treatment with a mixture of loam soil and cow dung compared to the treatments with vermiculite (Nyandoro, 2020). The results of this study will help to understand the suitability of cow dung as a sustainable organic media over its counterpart vermiculite for commercial horticulture applications. This Knowledge can help the extension services and nursery operators to recommend suitable growing media for raising robust tomato seedlings. The outcome will also help to generate important insights towards selecting suitable organic and inorganic growing media based on their abilities to raise tomato seedlings.

1.2 Problem statement

Tomato crop is a vital horticultural crop which produce tomato fruit which is needed in abundance in making relish both in rural and urban household (Beard, 1973). Its cultivation is hindered by failing to choose an appropriate growing medium which ultimately lead to failing in the establishment of robust tomato seedlings (Nair, 2010). Tomato production can be increased by establishing healthy tomato seedlings. Due to climate change, cow dung has become scarce and water has become scarce. The scarcity of water is causing a slow release of essential nutrients to ensure robustness in tomato seedlings. Cow dung has the capacity to contain pathogens such as *E.coli* and Salmonella which can be detrimental to growth and healthy of tomato seedlings (Praad, 2015). This has risen the need to purchase chemicals to cure pathogens and weed which might harbor diseases, henceforth high costs of production. High cost of production encountered when establishing tomato seedlings using cow dung has given a chance for vermiculite which has a good water holding capacity and is sterile. Apart from its sterility, vermiculite can be used again and again without losing its biological structure, therefore this study serves to compare the performance of cow dung versus vermiculite in establishing robust tomato seedlings of a new hybrid variety *Rodade Plus*

1.3 Justification of the study

This research aims to compare the performance of cow dung, an organic media versus vermiculite as an inorganic material, as growing media for tomato seedlings. There are several reasons as to why such a study is important and worthy undertaking. Furthermore contributions to sciences, selecting appropriate growth media is a key aspect of raising healthy tomato seedlings (Srinivasan, *et al* 2020). Some studies have compared organic and inorganic materials individually, limited resource exists comparing a locally available organic amendments like cow dung directly with vermiculite. Conducting a controlled experimental study under standardized conditions will generate scientifically robust data on the growth media types. The results will add to the existing knowledge pool regarding selection of optimum media for raising tomato nursery plants.

Benefits to horticultural practices; Nursery practices followed by both large-scale commercial producers and stallholder farmers will benefit significantly from the insights gained. Understanding the benefits of utilizing inexpensive organic amendments like cow dung versus vermiculite will aid informed decision-making regarding media composition and management (Sharma & Gupta., 2022). If shown to be effective, utilizing locally available cow dung at tomato nurseries can reduce dependence on expensive imported media. Overall, the outcome will help to optimize nursery protocols for sustainable tomato cultivation systems. Contribution to policy making; government and agricultural extension services design policies and guidelines around best field practices. Demonstrating the advantages of cow dung, a local organic waste material, can promote to its wide adoption as a valued agricultural input (Srinivasan, *et al* 2020). This study’s findings can support policies encouraging utilization of on-farm residues for nutrient recycling and media production. With proper recommendations, smallholder farmers stand to gain through locally sourced quality seedling production and improved livelihood options.

Socio-economic Benefits; Utilizing cow dung, a waste by product, constructively as nursery media presents distinct socio-economic advantages. It provides an avenue for farmers to add value to their cattle waste. When adopted at large scale, it can boost rural economies through the increased fodder and manure sales supplemented by media sales or contract nursery services. Overall, community development is fostered by establishing sustainable value chains around agricultural waste. Improved crop productivity; raising robust, healthy seedlings is the foundation for achieving higher field yields (Kumar, *et al* 2021). Significant yield improvements are projected when adopting improved nursery practices. The study's outcome may support increased tomato production per hectare, income gains for farmers and greater food security at local levels. This will indirectly benefit consumers through a stable vegetable supply at reasonable prices (Griffiths, *et al* 2021).

Environmental sustainability; Current global priorities advocate building circular bio-economy models. Reusing organic wastes as input in nursery media represents such a sustainable approach. It prevents environmental pollution from uncontrolled manure dumping while supporting agricultural intensification through optimized nutrient recycling (Hoffman, *et al* 2022). Overall, the study makes a case for promoting regenerative practices, benefiting both smallholder livelihoods and the climate. To summarize, comparing an inexpensive organic amendment cow-dung versus vermiculite has implications spanning diverse domain from science and farm practices to policy planning, socio-economic and the environment. By adding the knowledge based on optimized media selection, this study presents significant contributions and tangible benefits. It warrants undertaking to foster informed decision making, uplifting community development and support national priorities of sustainable intensification and climate action.

1.4 Objectives of the study

1.4.1 Specific objectives

-To analyze plant growth parameters like stem thickness, stem height, Leaf area index and number leaves recorded at a three weeks intervals in seedling grown in cow dung and vermiculite.

- To determine the survival rate of tomato seedlings across in treatments containing cow dung versus treatments containing vermiculite

-To examine incidence of common diseases and pests in tomato seedlings grown in cow dung versus and vermiculite media at three weeks interval throughout the nursery period.

1.5 Hypothesis

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There is a significant difference in stem thickness, stem height, leaf area index, number of leaves as well as pest and disease accumulation in tomato seedlings raised in cow dung versus vermiculite**.**

CHAPTER TWO

2.0 Literature Review

2.1 Tomato ecology and uses

Tomato origins were traced back to the Andean region of South America, specifically in the modern day Peru and Ecuador. Scientific studies suggested that the wild ancestors of the tomato were being cultivated by the indigenous people as early as 500BC (Smith, 2001). The early varieties were smaller, bitter and yellow. They were starkly different from the plumb red fruits we are familiar with today. The indigenous people initially used these wild tomatoes for various purposes, including culinary and medicinal applications (Mauro, *et al* 2024).The domestication of these tomato began with the Mexicans, who recognize the value of the fruit and began to cultivate them in their field and gardens. The commenced the introduction of tomatoes in their diet, using it in various dishes and as a staple food source (Cohen, 1999).

The tomato popularity continue to spread throughout Europe and beyond during eighteenth and nineteenth century. The introduction of hybrid varieties enhanced the fruit's appeal, making it larger, juicier and even more flavorful (Mauro, 2014). As global trade routes expanded, tomato found its way to Africa where they were embraced by diverse cultures and were incorporated into various culinary traditions. Tomato is now a popular fruit all over the world even in African countries like Zimbabwe, with countless variety for different purposes. The adaptability of tomatoes to various climate (Smith, 2001).Tomatoes (Solanum lycopersicum) require consistent and adequate moisture throughout their growing season. According to Kemble, 2020 ,tomatoes need approximately 25 to 35mm of water per week either from irrigation or rainfall. The supply of water which is uneven or insufficient will result in blossom end rot, cracking, and reduced fruit size (Heuvelink, 2018).

Tomatoes also thrive in soils which well drained and less acidic with the pH which ranges from 6.0 to 6.8 (Kemble, *et al* 2023).High organic content should be in the soil for the provision of the nutrients which are necessary for plant growth and fruit production (Heuvelink, 2018).Tomatoes are very sensitive to temperature fluctuation and they require a specific temperature range for the optimum growth and fruit production. Kemble, 2023 states that ideal temperature for the growth of tomatoes ranges from 18 to 29 degrees celceous.Temperature above 35 degrees celceous will severely impacts the plant growth, flowering and fruit development (Heuvelink, 2018). Prolonged exposure to cold temperature will ultimately lead to chilling injury while high temperatures cause flower abortion and fruit drop (Sato et al, 2006) Tomatoes are also sun loving crop and require enough sunlight for the growth and development of tomato plant. Tomatoes needs a minimum of 6 hours of direct sunlight per day, with an ideal range of 8 to 10 hours (Kemble, *et al* 2023).Enough sunlight is necessary for plant's photosynthetic processes, which drive the production of carbohydrates (Heuvelinkk, 2018)The moderate humidity needed for tomatoes ranges from 60% to 80% (Kemble, *et al* 2023).High humidity levels increase the risk of fungal diseases such as Botrytis and alternaria , while low humidity lead to increased transpiration which result in water stress and reduced fruit quality.

2.2 The tomato seedling morphology.

The tomato plant (*Solanum lycopersicum*) has a fibrous root system. The rooting system is relatively shallow and this allows the plant to efficiently absorb water as well as nutrients from the upper layer of the soil (Sato, *et al* 2006). The roots can spread out which helps in anchoring the plant and this also increase the surface area for the absorption of water and nutrients, mostly in well drained soils. The tomato plant also have the herbaceous stem that is green in color .It grows upright or sprawling, depending on their varieties. The stem of the tomato is hallow and has nodes and internodes. Nodes are the point where leaves and branches merge whilst internodes are the segments between these nodes. The stem structure of the tomato plant make it possible for the transportation of nutrients between roots and leaves. The leaves of a tomato plant are compound and pinnate, meaning that they are divided into multiple leaflets (Smith, 2018). The leaves have separate margins and are arranged along the stem. The leaf structure is important for the photosynthetic processes. The presence of trichomes on the leaves helps to reduce water loss and deter herbivores. The tomato plant are classified into two main growth habits which are determinant and indeterminate .Determinant varieties grows to a certain height and then stop. They then produce their fruits at once. Indeterminate variety continues to grow and produce the fruits throughout the growing the season.

2.3 Tomato nursery management

The tomato nursery management is an area of concern when it comes to tomato cultivation, focusing on the successful propagation of tomato plant seeds to seedlings ready for transplanting. The effective nursery management ensures healthy plant growth minimize disease incidence and maximize yield potential (Smith, 2018). Selection of the right seed is very important for the success nursery management. High quality seeds that are disease resistant and suited to the local climate should be selected. Prior to sowing, tomato seeds are treated with fungicides to prevent seed borne disease. In addition, soaking seeds in water for some few hours enhance germination and emergency rate. The choice of growing medium is crucial for seedling health. A well-draining, sterile medium is recommended to prevent diseases. The pH of the growing medium should be well maintained between 6.0 to 6.8 for optimum nutrient uptake (Raiola, *et al* 2014). The tomato seeds are typically sown in seed trays filled with prepared growing medium. The sowing depth should be about 0.5 to 1 inch. After sowing, the trays should be kept in a warm environment to promote germination. Maintaining adequate moisture is needed to be done during this phase (Cohen, 1999). A lot of care should be offered to avoid over watering which leads to the development of dump-off diseases. Once the seedling emerges, watering should be done in a constant manner. Water applications should be optimal to avoid waterlogging. Fertilizer should be applied when the seedlings develop their first leaves. Pest and diseases monitoring is also an important management practice. Common issues include fungi diseases like dump off and pest such as aphids and whitefly (Sato, *et al* 2006). Implementation of integrated pest management (IPM)strategies like the use of insects and organic pesticides helps to control these threats .Regular sanitation such as cleaning the tools used on a daily bases is also an important thing to do to prevent diseases. Before transplanting the seedlings into the field, the seedling undergoes the process called hardening (Cohen, 1999). This involves a gradual acclimatization of seedlings to outdoor conditions by exposing them to sunlight, wind and varying temperatures. This process helps to reduce transplant shocks and increase the survival rates of seedlings once transplanted.

2.4 History of the use of Cow dung as a growing medium in tomato seedlings.

Cow dung has been a pillar in horticultural practices for years in the past, especially for the establishment of nursery for various crops which included tomatoes. The Historic importance of cow dung is in its role as a natural fertilizer and soil conditioner. This has been recognized across different cultures and agricultural systems (Sharma, 2005).In the ancient days, cow dung was applied in fields to enhance soil structure and fertility. This belief is routed that cow dung does not only nourish the soil, but also promote a beneficial micro-organisms. In many rural farming practices, cow dung is mixed with other organic materials to create compost which is later applied in the fields prior to production of a crop. The organic matter in cow dung is believed to improve soil aeration and water retention which are very critical for the successful germination and growth of seedlings (Gupta, 2013) with an increase in new discoveries in horticultural production, cow dung has been used to produce horticultural seedlings like cabbages, onions as well as tomatoes. When establishing tomato nursery, cow dung should be applied because tomatoes need a nutrient rich medium in order to be so much robust. These nutrient include phosphorous, nitrogen and potassium and these nutrients are needed by tomato strong seedlings, which are crucial for a successful harvest (Jain, 2010).Horticultural farmers usually prefer to mix cow dung and soil to create fertile and conducive planting medium for tomato seeds. Apart from supplying nutrients, the mixture also enhance the microbial activities in the soil which aids in nutrient absorption by the plants. Moreover, the use of cow-dung in tomato nursery as a growing medium align with sustainable agricultural practices. It also reduce the reliance on chemical fertilizers, promoting organic approach to farming (Singh, 2018). This has a greater importance in increasing awareness about environmental sustainability and health benefit of eating organically grown produce. The historic use of cow dung in horticulture, especially in the establishment of tomato nurseries, underscore its importance as a natural resource. By the useful and important task of enriching the soil and give essential nutrients, cow dung promote the production of healthy seedlings. As horticultural practices continue to evolve, the integration of traditional methods with modern techniques proves cow dung to remain a valuable asset in sustainable horticulture.

2.4 History of the use of vermiculite as a growing medium in tomato nursery

Vermiculite, a naturally occurring mineral that expands when heated, has been utilized in horticulture since the mid-20th century. Its unique properties, including lightweight structure and excellent moisture retention, make it an ideal growing medium for various plants, particularly in nursery settings for seedlings like tomatoes. The adoption of vermiculite in tomato nurseries began to gain momentum in the 1960s and 1970s. During this period, researchers and horticulturists started to recognize the advantages of using vermiculite as a growing medium. Studies indicated that vermiculite provided superior aeration and drainage, which are essential for healthy root development in tomato plants (Smith, 2010). This was particularly important in nursery environments where seedlings are sensitive to waterlogged conditions.

By the 1980s, the use of vermiculite became more widespread in commercial tomato production. Growers appreciated its ability to retain moisture while simultaneously preventing root rot, a common issue faced by tomato seedlings (Jones, 2015). This characteristic allowed for more efficient water management, which is crucial in nurseries where maintaining consistent moisture levels is vital for seedling health. Extensive research throughout the 1990s further confirmed the benefits of vermiculite, especially when used in combination with other growing media such as peat moss and perlite. This combination not only improved seedling vigor but also enhanced nutrient availability, leading to healthier and more robust tomato plants (Brown & Green, 2018).

In recent years, vermiculite has continued to be a popular choice in tomato nurseries, particularly in soilless growing systems. Its role in promoting sustainable agricultural practices is increasingly recognized, as it can help reduce the reliance on chemical fertilizers and improve overall soil health (Taylor, 2020). Overall, the history of vermiculite as a growing medium in tomato nurseries illustrates its evolution from a novel material to a fundamental component in horticultural practices, driven by its beneficial properties and the ongoing pursuit of sustainable growing solutions.

CHAPTER THREE

3.0 Materials and Methodology.

3.1Description of the trial site

The experiment was conducted at Bindura University of Science Education farm. The farm is situated 16.3 km from Bindura CBD along Bindura Shamva road in Mashonaland Central Province. It GPS coordinates are 17.3085551° S latitude 31.5655424° E longitude And is at an altitude of 1131 meter above the sea level. It lies in the agro- ecological region 11B. The minimum and the maximum temperatures for the area are 23°C and 32°C respectively and an average rainfall of 750mm-1000mm per year. Soils are black loam with moderate low water holding capacity with pH ranging from 5.0-6.8 on the calcium chloride scale.

3.2Experimental design

The trial was set in a Randomized Complete Block Design (RCBD) with a single factor. There were five treatments which were, cow dung (CD), cow dung and loam (CDL), Loam (L).Vermiculite (V), Vermiculite, vermiculite and loam (VL), which were replicated three times.

3.3 Land preparation

The land was cleared using a hole because the weeds were at an early vegetative stage. The ground was leveled using, a tape measure and a spirit level to ensure that the ground is level.

A sheet of polythen plastic was spread on the ground to sterilize the ground. The float trays were laid on top of the plastic. Each tray had a measurement of 244 ×91cm.According to Thompson (2011) pathways should be 45cm-50cm, however pathways of 60cm were left between the trays to lower the chances of compromising of the outcomes from different trays. The trays were randomly named using the lotto system .The Randomized order of blocks was as follows: Cow dung and Loam (CDL), Vermiculite (V), Cow dung (CD), Loam (L), Vermiculite and Loam (VL), and they were replicated three times in that manner. Filling the trays with different growing media was done and then planting thereafter. Each tray was carrying a total of 144 plants per tray. The experiment constituted of 3 trays in three blocks. The blocking factor was sunlight orientation. Each block had three trays representing each treatment. The pathways left between the trays was 60 cm.

3.4 Nutrient Content Analysis of Medias

Cow dung is a natural, organic material that have been used in agriculture many years ago. According to Laboratory researches, cow dung is rich in major nutrients such as nitrogen, phosphorous and potassium. This makes it an excellent fertilizer for seedlings. In addition, cow dung has beneficial microorganisms that helps in the breaking down of organic matter, thus making nutrient available for the plants. The micro-organisms found in cow dung also help in improving soil structure because they exudes substances which brings soil particles together.

This make cow dung an ideal material for establishing seedlings.

On the other hand, vermiculite is an inorganic material that is derived from mineral vermiculite. Vermiculite is a lightweight, porous material that is mostly used as soil amendment to improve drainage and Aeration. Science also states that vermiculite is a good source of potassium and other micronutrients like zinc and boron. However, it lacks the beneficial micro-organisms and nutrients present in cow-dung. Theoretical conclusions always bring that cow dung appears to be a better growing media for the establishment of a newly hybrid Rodade plus. This study saves to be a practical comparison of how the two growing media cow dong and vermiculite are going to perform in the establishment of tomato nursery. It is important to note that vermiculite is very sterile and the steps to sterilize cow dong is going to be given below.

a) Taking a 20kg of sun dried cow dung and put it in a big washing dish

b) Heating water up to a boiling point.

c) Pour the boiling water into the contain wit cow dung.

d) Leave for 20 minutes to allow all the bacteria and pathogens to die.

e) Remove the water after 20 minutes.

f) Allow the cow dung to be sundried to allow the remaining pathogens to die.

Then the cow dung was put in to trays and some were also mixed with loam at the ratio of 3 cups of cow dung as to 3 cups of loam soil, same applies to the vermiculite.

3.5 Planting procedure

Soon after putting the growing Medias into the trays, *Rodade plus* tomato seeds were put, one seed per hole. *Rodade plus* tomato variety is a newly grown hybrid tomato which is also a late maturing tomato variety. The seeds were placed at the depth of 2 cm in each planting hole. The planting was done on 20 March 2025. Watering was immediately done using a watering cane to ensure efficacy in soil miniaturization and infiltration and was supplemented by rain moistures.

3.6 Fertilizer application

The recommended rate of basal fertilizer per hectare of 1000kgs of compound S (7:21:8) was applied at a rate of 0.05kg per tray for basal dressing one day after planting. This gave a total of 0.9kg of compound S per 15 trays of *Rodade plus* tomato seeds. Compound S was applied using the broadcasting method across all the trays. Compound C was also applied at 0,05kg per tray. Split application of compound C was done with the same application rate 0.05kg per tray. The first application was done at three weeks after planting, with the second which was done at the sixth week after planting.

3.7 Water management

Morrison et al 2007 alluded that inability to supply sufficient water will ultimately lead to crop failure. Tomato nursery was established in rain season, so watering was done during the dry spells. Watering was done almost on a daily bases with a watering cane to ensure efficacy in terms of water penetration .It was ensured that the soil was always wet throughout the research period.

3.8 Weed management

Weeds were hand pulled from the trays. This was so because the roots of tomato seedlings are so shallow .Weeding was done at two weeks interval and the weeds which were prevalent was *Bidens pilosa* (Blackjack).It was complicated to remove those weeds because at early stages, *Biden pilosa* is very similar to tomato seedlings. Weeding was done to reduce crop weed competition for Nutrients, water, sunlight, space and the weeds may harbor pests.

3.9 Pest control

At planting, Karate zeon was used at 60ml/16l Knapsack to prevent cutworms that might be present in all the Medias. Young tomato seedlings are very fragile and very sensitive to pests and diseases infections, therefore it is of great importance to provide an intensive care so as to avoid losses at tender ages. Three weeks after planting, Acetamiprid was used at 80ml/ 16l 0f water to prevent and fight thrips. At fifth week, Demiothate was also used at 50ml/16l of water to fight against *Tuta absoluta*. This was done after scouting and two trays showed signs of *thrips* and *Tuta absoluta* respectively.

3.10Data collection

Data were collected manually by taking measurements fro few randomly selected plants and measured. Nutrient uptake and biomass accumulation were calculated using the tissue analysis which can also be called the harvesting method.

3.10.1 Growth measurement

Stem thickness: A point was chosen which was some few centimeters above the ground for consistency purposes. A string was placed around the stem of the few randomly selected seedlings. The string was then stretched on a meter rule and readings were taken at three weeks interval until the nineth week in centimeters (cm)

Height of the seedlings: Seedlings were randomly selected from different trays and they were made to stand upright. A string and a meter rule was used to measure at least ten seedling per tray and they were averaged. This was giving an average plant height per tray of seedlings in centimeters (cm).This was done at three weeks interval until the nineth week

Measuring Leaf Area: The direct measurement of leaf area was done using graph paper. The leaf was placed flat on a graph paper The number of full squares covered by the leaf was counted .The number of squares were multiplied by the area of each square. The area of each square on a graph paper is $1CM^2$.This was done at three weeks interval until the nineth week

Number of the leaves: The number of leaves where physically counted. A sample of 5 seedling plants were taken per tray and they were average to give an average number of leave of seedlings per tray. This was done on a three weeks bases until the seedling reached its maturity stage at week nine.

Survival rate

Number of survival seedlings will be physically counted on a three weeks interval and the percentage number were calculated to show the variation in survival rate of the seedlings at a three week interval as a percentage (%).

Pest incidence

Scouting will be done on a three weeks interval to see if there is any pest which is developing and action will be taken before they cause any harm. The formula number of seedlings affected divided by the total number of seedlings in a tray multiplied by 100% will determine the percentage rate at which the pests were destroying. The scale 0-5 will be used on which 0= no infestation,1=very slight infestation,2slightly infested,3=optimal infestation, 4= high infestation, 5= very high infestation.

Diseases incidence

Disease symptoms if any will be monitored and rated on a three weeks interval on a scale 1-5, where 1= healthy and 5 = heavily infected.

Data analysis

Data analysis were done using the GernStart Analyzing Tool and where there were significant differences, the means were separated using the least significant difference at 0.05 probability level.

CHAPTER FOUR:

4.0 RESULTS

4.1Stem thickness

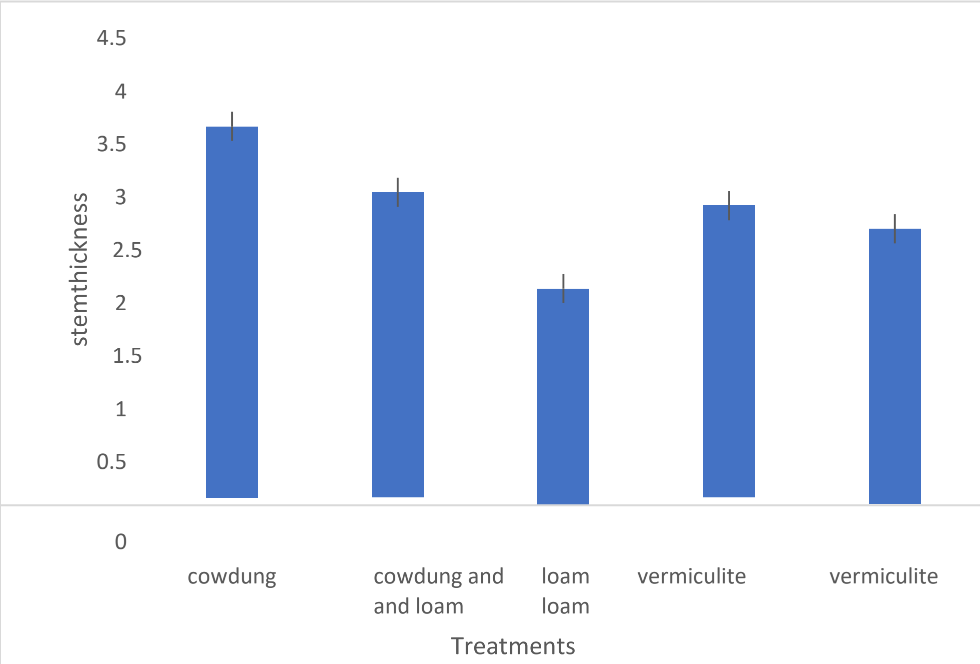

Fig 4.1 showing stem thickness at week 3

The results showed a highly significant effect on stem thickness (p=0.001) at week three. The treatments which were containing an organic growing medium cow dung showed a significant difference with respect to stem thickness of tomato seedlings. Cow dung showed the highest stem thickness of 3.733cm, followed by treatments which were having a mixture of cow dung and loam which had tomato seedlings with a stem thickness of 3.067cm, followed by treatments with vermiculite which had tomato seedlings with a stem thickness of 2.933cm, followed by treatments which were containing a mixture of vermiculite and loam which had a tomato seedlings with a stem thickness of 2.767cm and lastly was loam which had treatments with loam and had seedlings with the least stem thickness of 2.167cm.

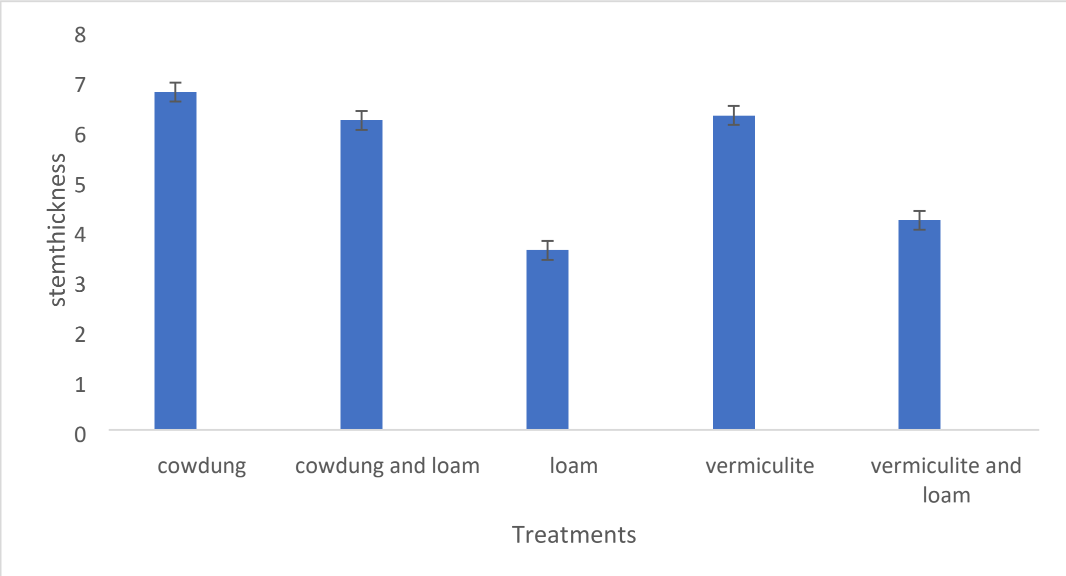

Figure 4.2 showing stem thickness at Week 6

At week six, the results showed a highly significant effect of stem thickness of the tomato seedlings (p=0.001). The treatments which were containing an organic growing medium cow dung showed a significant difference with respect to stem thickness of tomato seedlings. Cow dung had the highest had tomato seedlings which had a stem thickness of 6.3cm. This was followed by treatments with cow dung and loam which had tomato seedlings with stem thickness of 6.200cm, followed by treatments with vermiculite and loam which had seedling with stem thickness of 4.200cm and lastly wad loam alone which had the seedlings with stem thickness of 3.6cm.

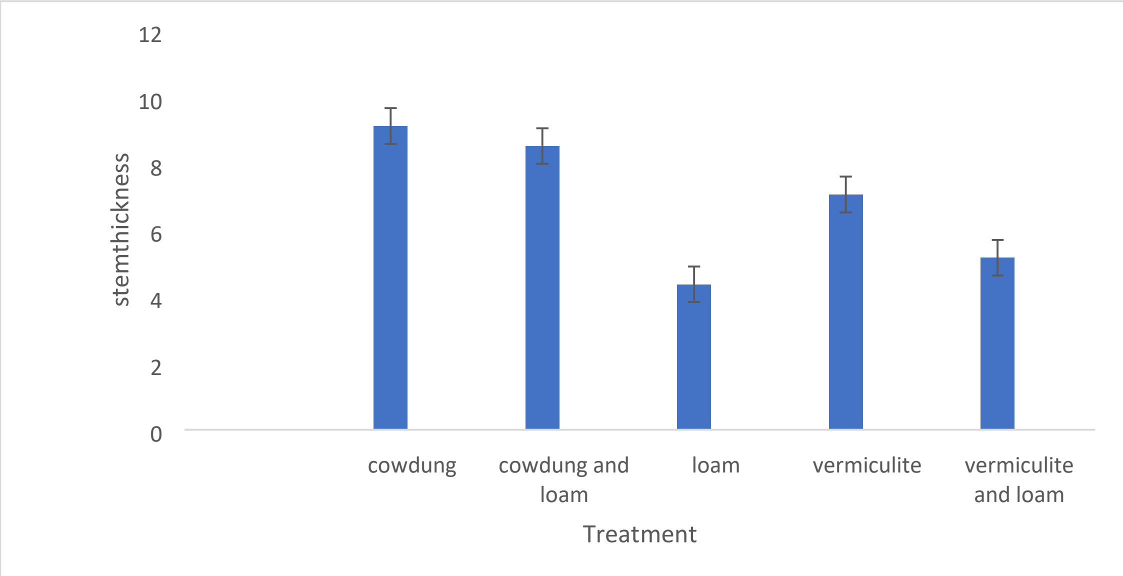

Fig 4.3: Showing stem thickness at wee 9

At week 9, the results showed that there was a highly significant difference of p=0.001 .Treatments with Cow dung had tomato seedlings with the highest stem thickness of 9.13cm, followed by tomato seedlings which were in treatments which were containing cow dung and loam which had 8.53cm, followed tomato seedling which were in treatments which were containing vermiculite which had stem thickness of 7.01, followed by seedling in treatments which were having a mixture of vermiculite and loam. It had a stem thickness of 5.17 and treatments with loam had the least support when it comes to stem thickness of the tomato seedling. It had a stem thickness of 4.37cm

4.2 Stem height

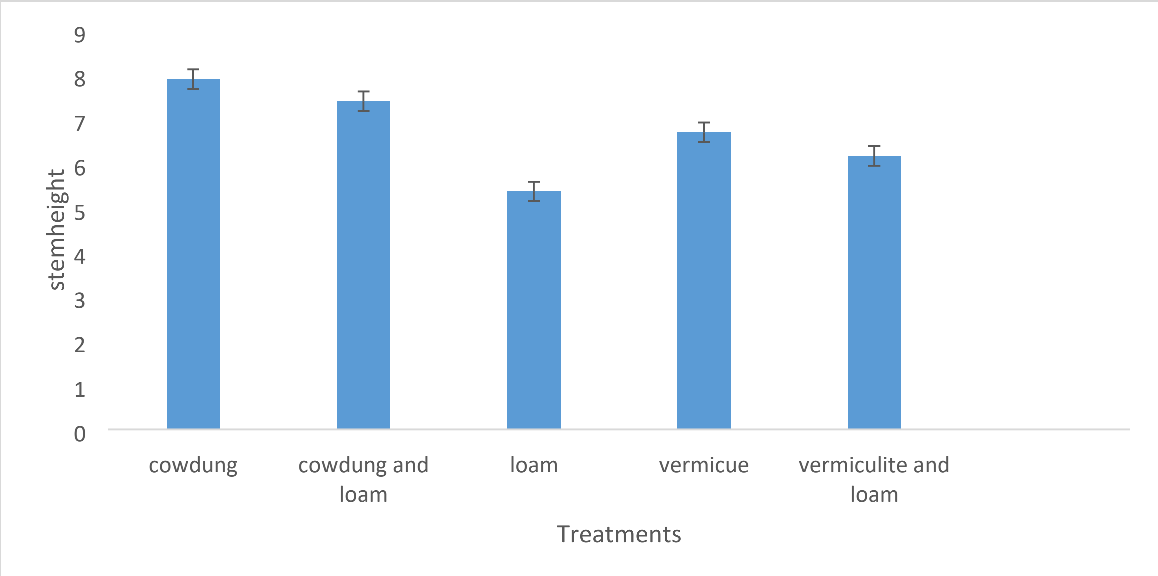

Fig 4.4 shows stem height at week 3

The results showed a highly significant treatment effect on stem height (p=0.001).Organic growing medium has proven to be of much positive effect on enhancing stem height on tomato seedlings. On week three, treatments containing cow dung had the highest tomato seedling stem height of 7.9cm, followed by the tomato seedling which were in treatments containing cow dung and loam which has a stem height of 7.4cm.This was followed by inorganic growing medium vermiculite which also supported stem height. The tomato seedling grown in vermiculite had an average stem height of 6.7cm, followed by tomato seedlings which were in treatments containing vermiculite and loam which had a stem height of 6.167cm and lastly the seedlings which were in treatments containing loam which had a stem height of 5.367cm.

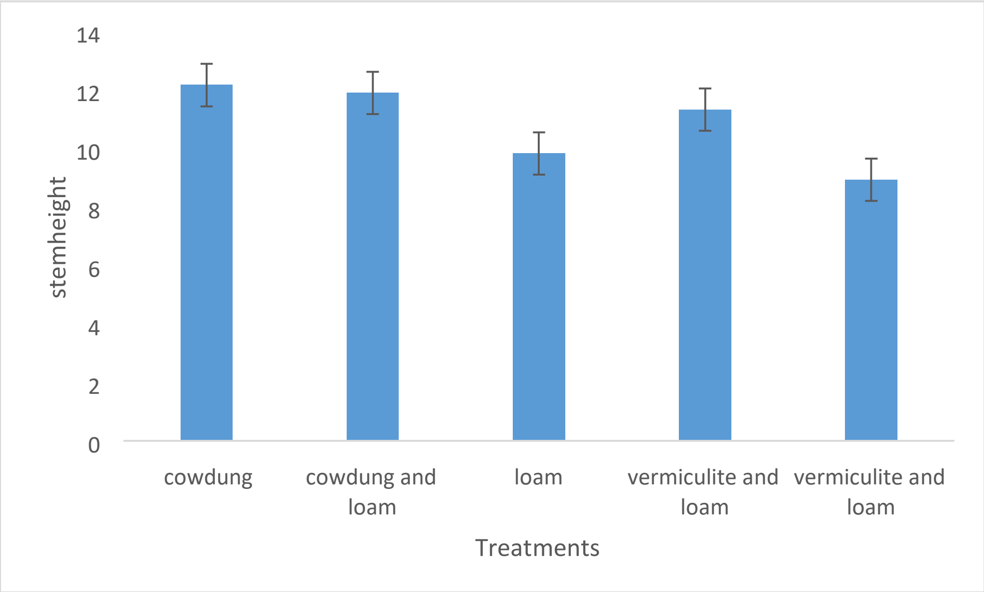

Fig 4.5 shows stem height at week 6

At week six, there was a significant stem height difference across the treatments with different growing mediums of 0.008 .Cow dung had tomato seedlings with the highest stem height of 12.17cm, followed by treatments which had an insignifint difference which were a mixture of cow dung and loam and vermiculite. They had 11.9cm and 11.33cm respectively. Treatment with loam produced tomato seedlings with a height of 9.83 and lastly was treatments with vermiculite and loam which had the height of 8.93cm.

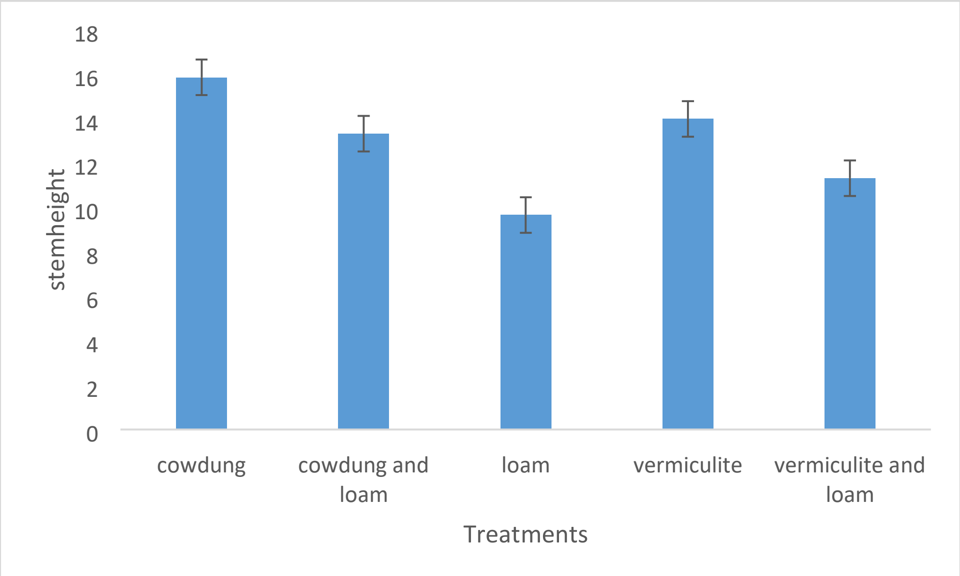

Figure 4.6 showing stem height at week 9

At week nine, the probability value across all the medium was 0.001 which was a significant difference. Treatments containing cow dung produced tomato seedlings with a stem height of 15.87cm, followed by treatments with inorganic vermiculite which produced seedlings with a height of 14cm, followed by treatments with a mixture of cow dung and loam which had seedling with a height of 13.33cm, followed by treatments with a mixture of vermiculite and loam which had seedlings with a height of 11.33cm and lastly was treatments containing loam which had seedlings with a height of 9.98cm.

4.3 Number of leaves

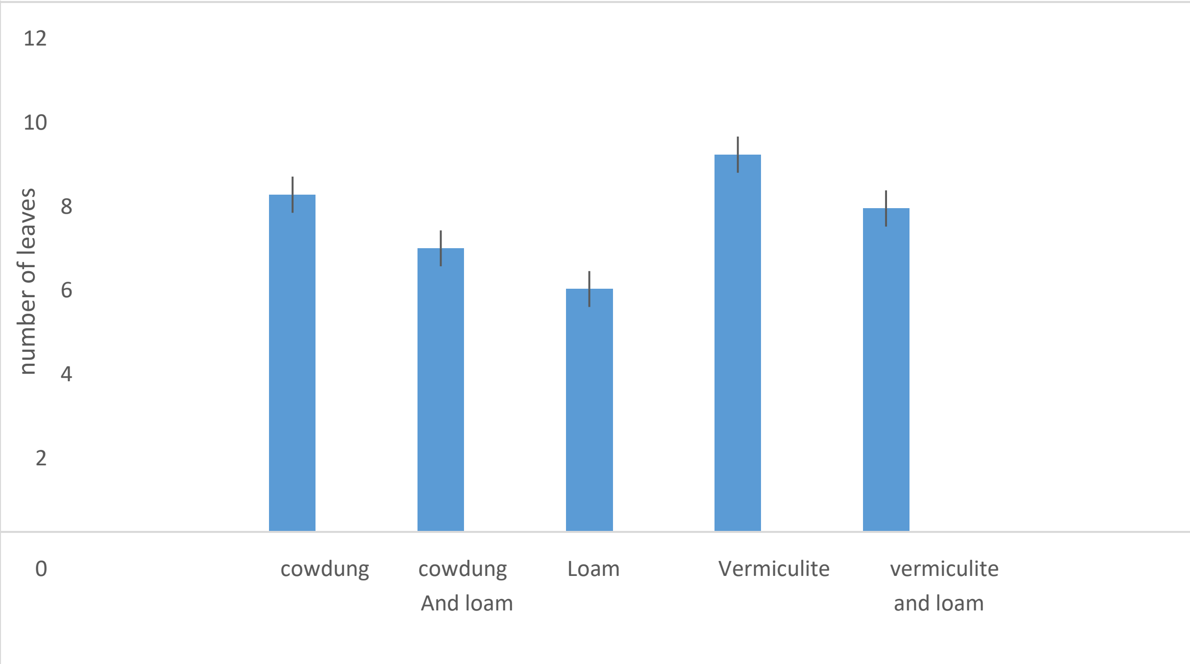

Figure 4.7 showing number of leaves at week 3

The results showed a highly significant treatment effect on the number of leaves at week three (p=0.001). Inorganic vermiculite promoted a high production of leaves, it had 9 leaves, followed by seedling which were in treatments with cow dung and vermiculite and loam which both produced seedling with 8 leaves, followed by treatments with cow dung and loam which produced seedling with 7 leaves and lastly were treatments with loam which had tomato seedlings with 6 leaves.

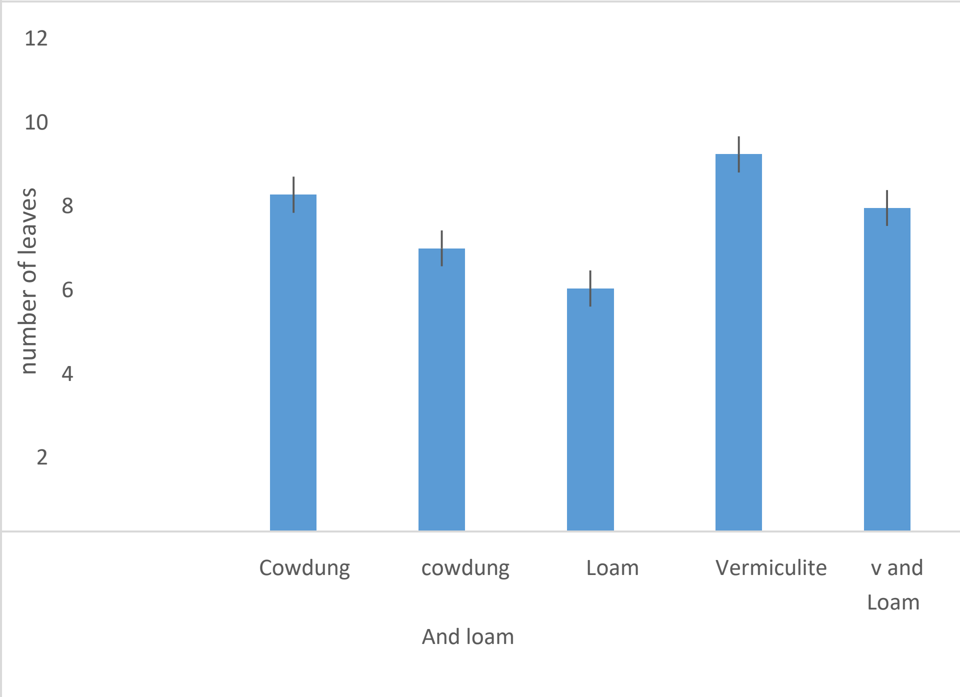

Figure 4.8 showing number of leaves at week 6

At week six, the results showed that the probability value was p= 0.062.The p value was above the accepted probability of 0.05 which shows that there was no significant different in number of leaves across all treatments. Treatments with cow dung and loam had seedlings with 14 leaves followed by seedlings in treatments with vermiculite as well as vermiculite and loam which had 12 leaves respectively, followed by cow dung which had 11 leaves and lastly was treatments with loam which had seedlings with 8 leaves.

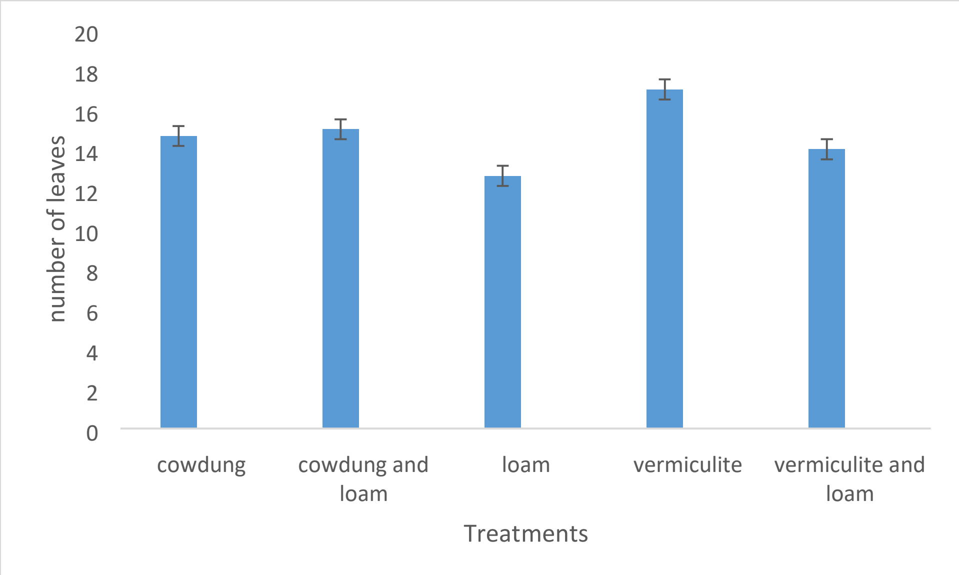

Figure 4.9 showing number of leaves at week 9

At week nine, the results show a highly significant treatment effect on number of leaves (p=0.003).Seedlings which were in treatments containing vermiculite had an average of 17 leaves, followed by seedlings that were in treatments containing cow dung and loam which had an average of 15 leaves, followed by seedlings which were in treatments containing cowdung as well as vermiculite and loam which had an average of 14 leaves and lastly was the seedlings in treatments containing loam which had the least average of 12 leaves

4.4 Leaf Area index

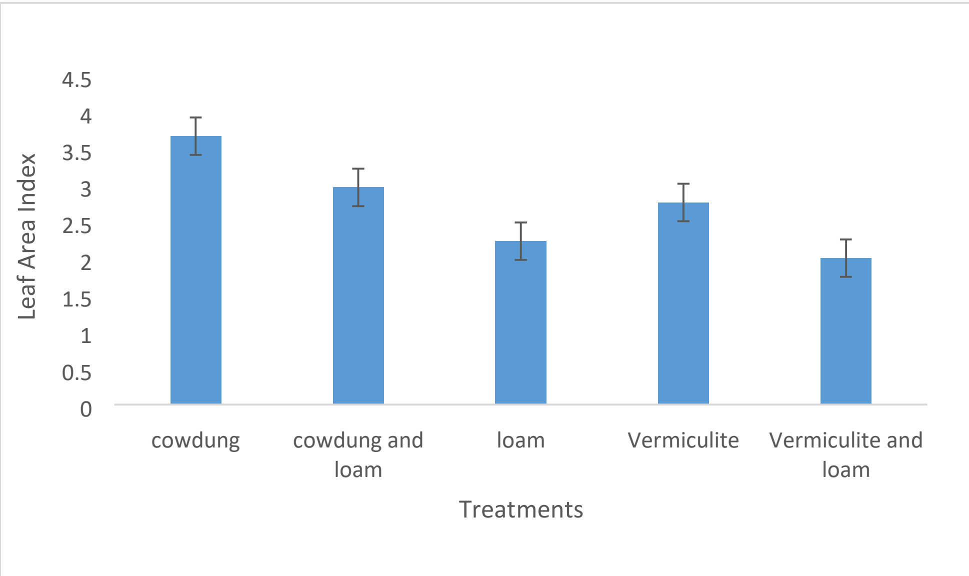

Fig 4.10 showing leaf area index at week 3

In week three, the P value was 0.001 ($P = 0.001$).This shows that there was a significant difference in leaf area index across all the five growing mediums. The results showed that high leaf area was recorded in all treatments which were containing cow dung, with pure cow dung (3.667 cm^2) being the highest treatment, followed by the treatment with a mixture of cow dung and loam with a leaf area of 2.967cm^2, followed by treatments with vermiculite which had the leaf area of 2.767cm^2, followed by treatments with vermiculite and loam which had seedlings with the leaf area index of 2.00cm^2 .Treatments which were containing loam produced tomato seedlings with the least leaf Area index.

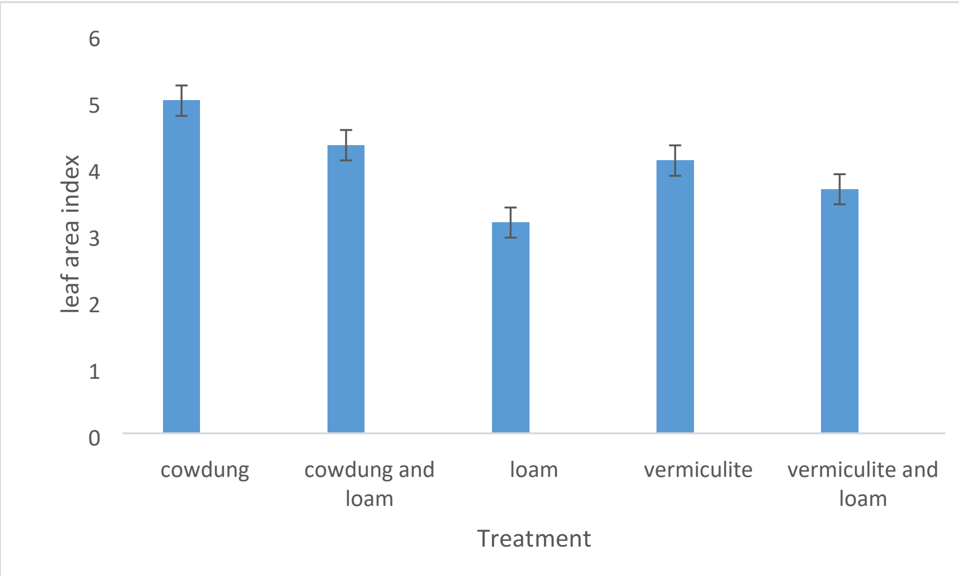

Figure 4.11 showing leaf area index at week 6

week six, the results showed a highly significant effect on leaf area index ($p= 0.004$).Cow dung treatment had the highest leaf area index of 5.00cm^2, followed by treatments with cow dung and loam, which had a leaf area index of 4.33cm^2, followed by treatments with vermiculite which had a leaf area of 4.10cm^2, followed by treatments with vermiculite and loam which had a leaf area of 3.67cm^2.Treatments with loam alone had the lowest performance intems of enhancing leaf area. They had a leaf area of 3.17cm^2.It was close to that of the mixture of vermiculite and loam.

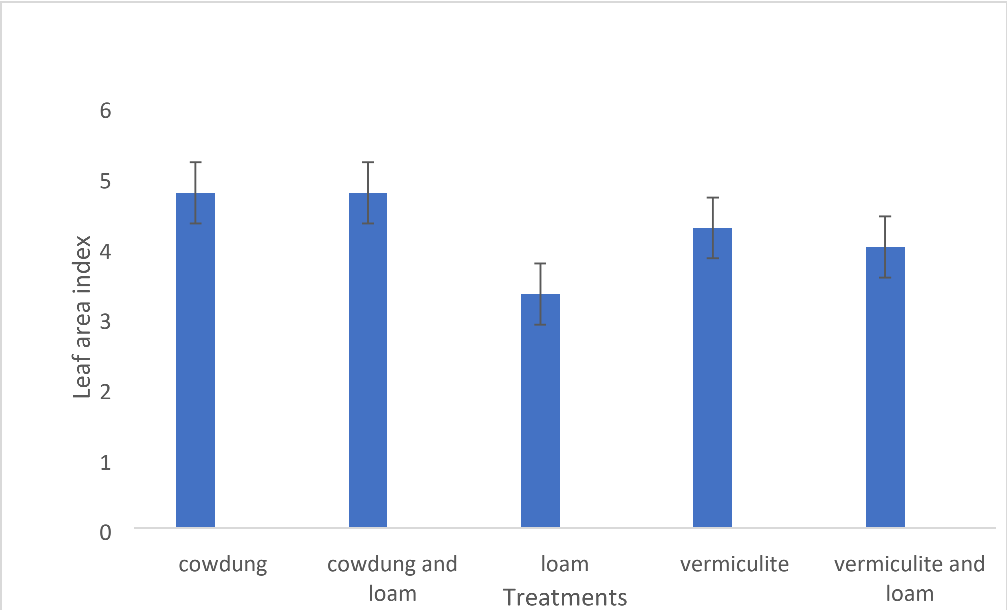

Figure 4.12 showing leaf area index at week 9

At week nine, there was no significant effect on the leaf area index in tomato seedlings which were across all growing medium. The p value of 0.294 was greater than the accepted one which is 0.294

4.5. The mean survival rate

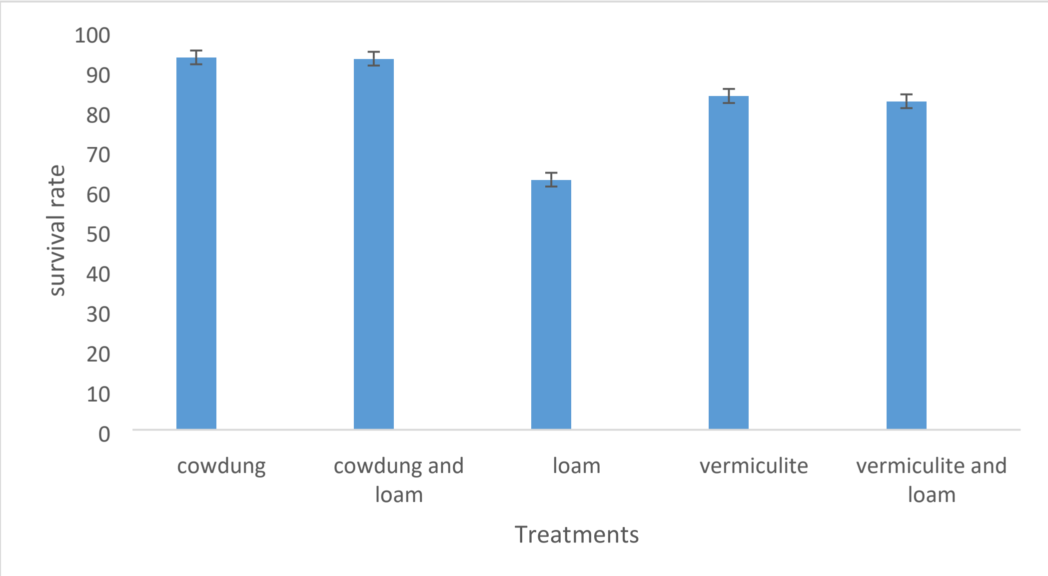

Fig 4.13 showing survival rate at week 3

At week three, results showed a significance treatment effect on survival rate ($p=0.001$).Treatments which were having cow dung as well as cow dung and loam had the seedlings which survived the most. They had a survival rate of 93.33% and 93% respectively. They were followed by treatments which were having inorganic growing medium vermiculite as well as vermiculite and loam. They had the seedlings which had a survival rate of 83.67% and 82.33% respectively. Seedlings which were in treatments containing loam alone had the seedlings which survived the least. Seedlings had a survival rate of 62.67%.

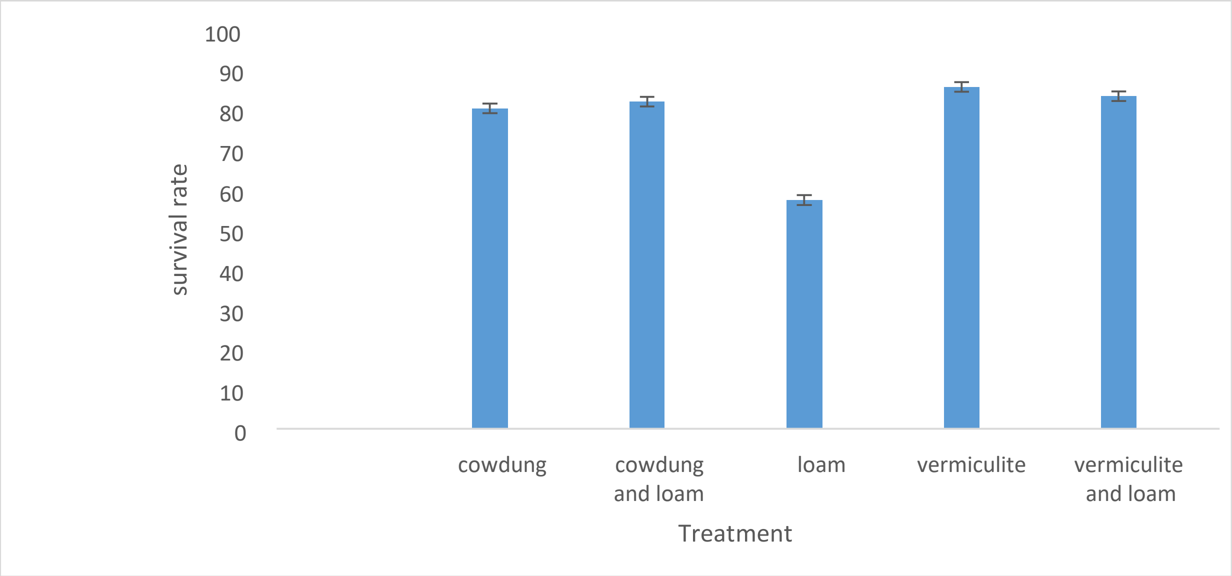

Fig 4.14 showing the survival rate at week 6

At week six, the results showed a highly significant treatment effect on survival rate (p= 0.001). Treatments which were containing inorganic vermiculite had the seedling which were surviving better in this week. They were surviving at 85.67%, followed by seedlings which were in treatments with a mixture of vermiculite and loam which were surviving at 83.33%.Treatments with organic growing medium cow dung and cow dung and loam had seedlings which were surviving at 80.33% and 82% respectively. Treatments with loam had seedlings which surviving at 57.33% which happened to be the least surviving.

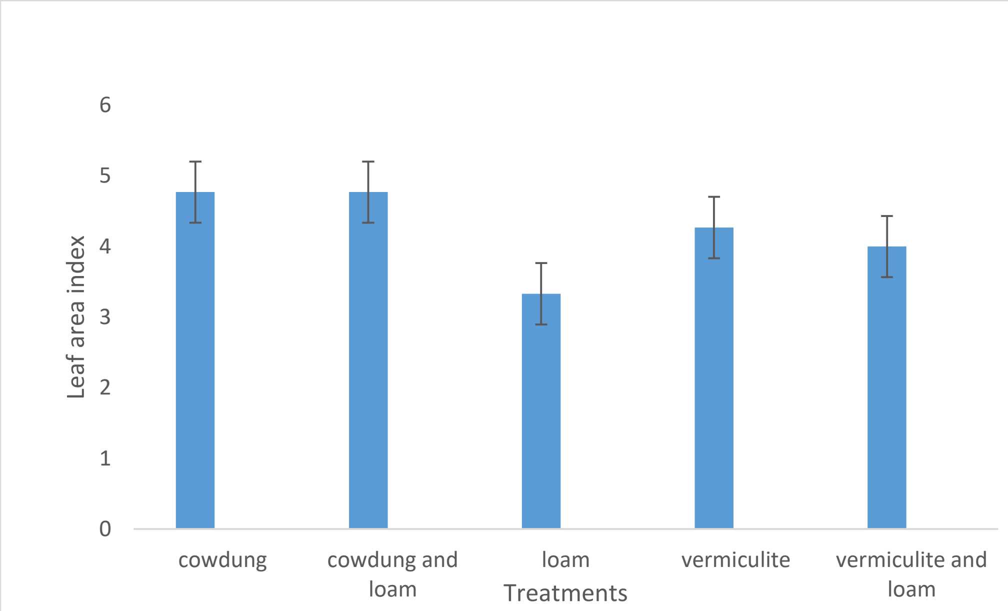

Fig 4.15 showing leaf area index at week 9

At week six, the results showed a highly significant treatment effect on survival rate (p= 0.001). Treatments which were containing inorganic vermiculite had the seedling which were surviving better in this week. They were surviving at 85.67%, followed by seedlings which were in treatments with a mixture of vermiculite and loam which were surviving at 83.33%.Treatments with organic growing medium cow dung and cow dung and loam had seedlings which were surviving at 80.33% and 82% respectively. Treatments with loam had seedlings which surviving at 57.33% which happened to be the least surviving

4.6 pest incidence

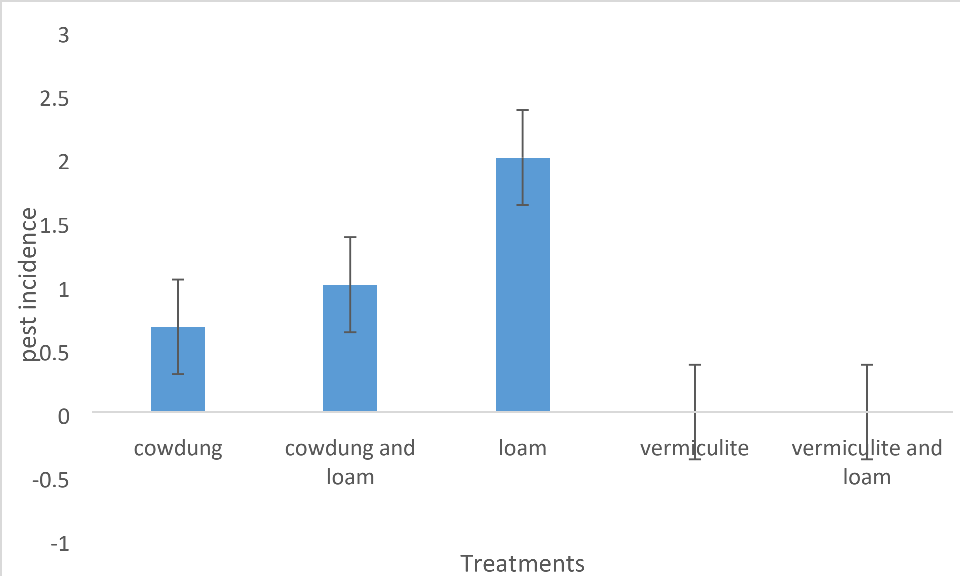

Fig 4.16 showing pest incidence at week 3

At week three, the results showed a significant treatment effect on pest incidence (p=0.026).Tomato seedlings which were in treatments containing loam had a high pest attack.it had a pest incidence of 2, followed by seedlings which were in treatments containing cow dung and loam which had 1 pest incident, followed by cow dung which had seedlings with 0.67 pest incidence. Treatments which were containing inorganic vermiculite had zero pest incidences.

Figure 4.16 showing pest incidence at week 3

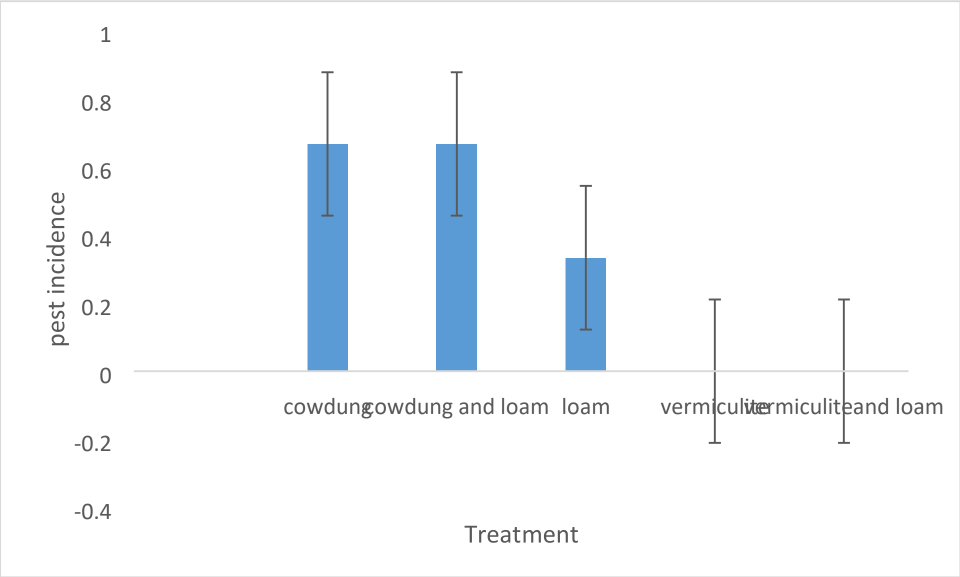

Fig 4.17 showing pest incidence at week 6

At week six, the results showed that there was no significant treatment effect on pest incidence (p=0.126).It was above the accepted probability of 0.05. Treatments containing cow dung as well as cow dung and loam had seedling which were highly affected and had pest incidence of 0.667, followed by seedlings which were in treatments containing loam which had 0.333 pest prevalence.

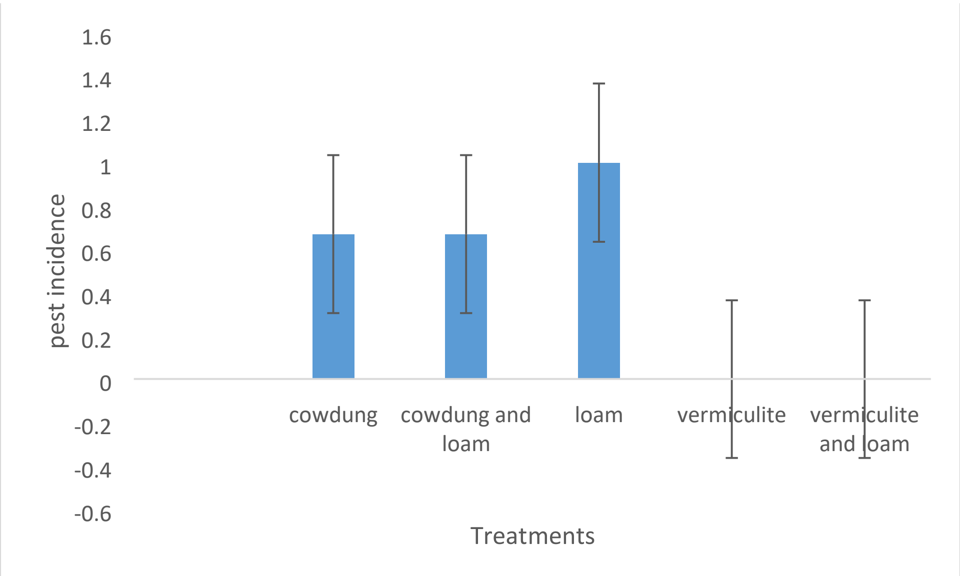

Figure 4.18 showing pest incidence at week 9

At week nine, results showed that there was no significant treatment effect on pest incidence (p=0.087) Tomato seedlings which were in treatments containing loam had the highest rate of 1, followed by cow dung as well as its mixture with loam which had 0.67 pest incidence rate.

4.7 Mean disease incidence

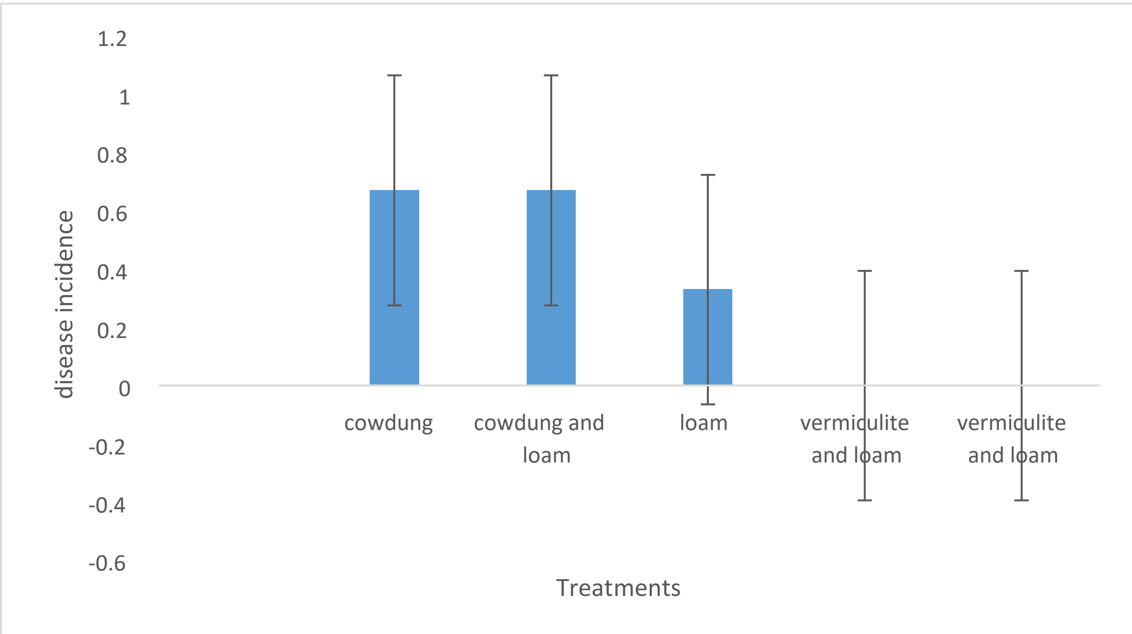

Fig 4.19 showing disease incidence at week 3

At week three, the results showed that there was no significant treatment effect on disease incidence (p=0.309).Treatments containing cow dung and cow dung and loam were having tomato seedlings which were mostly affected by the diseases. Both had a disease incidence of 0.67, followed by loam which had seedlings which had a disease incidence of 0.33.

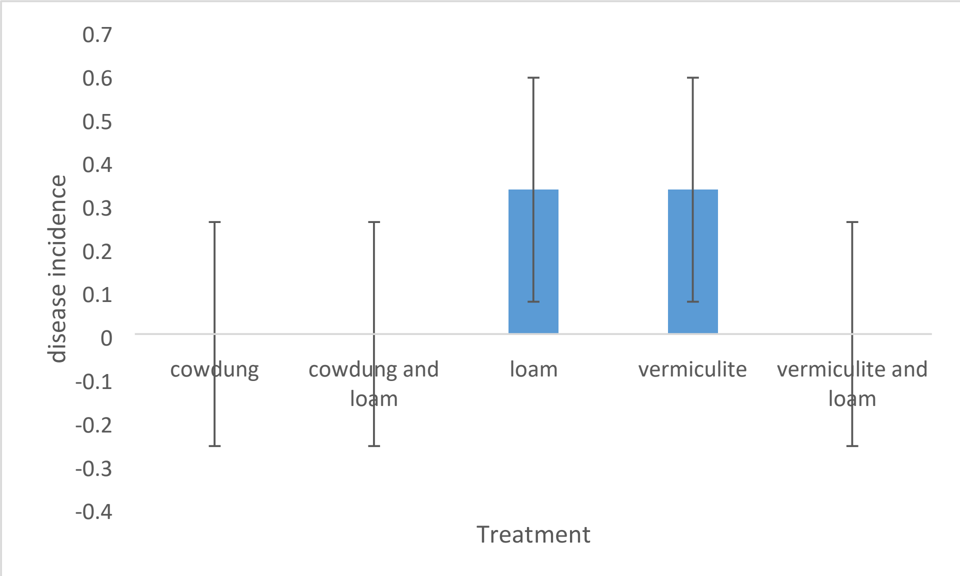

Fig 4.20 showing disease incidence at week 6

At week six, the results showed there was no significant treatment effect on disease incidence (p=0.461).This was far above the accepted on which is p=0.05.Treatments with vermiculite and those with loam only were equally affected by disease. They had a disease incidence of 0.333 and other treatments comprehending cow dung and loam, vermiculite and loam as well as cow dung were not attacked by the diseases.

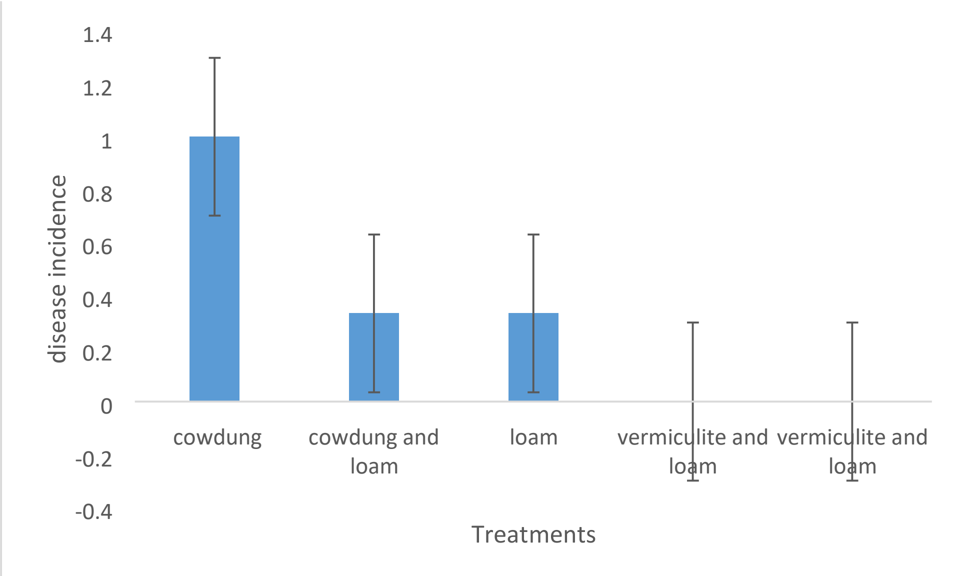

Figure 4.21 showing disease Incidence at week 9

At week nine, the results showed a significant treatment effect on disease incidence (p=0.041). Tomato seedlings which were in treatments containing cow dung had disease incidence of 1, followed by seedlings which were in treatments containing cow dung and loam and loam alone had 0.333 disease incidence.

CHAPTER FIVE

5.0 Discussion

5.1 The effect cow dung, cow dung and loam, vermiculite, vermiculite and loam as well as loam on the following growth parameters.

5.1.1 Stem thickness

The results showed that cow dung (alone or with loam) yields the best results for the stem thickness of the tomato seedlings. This was so because cow dung has high nutrient availability as it is rich in NPK which are macro-nutrient and some trace elements like calcium and magnesium. Nitrogen promotes vigorous vegetative growth, supporting the development of thicker stems (Madziwa 2015). Phosphorous strengthen root systems and enhancing nutrient uptake and stem support. Apart from stem support, thicker stems is also important because it ensures water and nutrient transport. A thicker stem often means larger vascular tissues, allowing more efficient transport of water nutrients and sugars made through the process of photosynthesis. Thick stems are better at withstanding drought, wind, and pest pressure due to their robustness. Some studies has alluded that cow dung contains natural growth hormones which enhance cell division and expansion, enhancing the thickness of tomato seedling. Vermiculite also perform better when it come to the thickness of tomato seedlings as compared to loam. Vermiculite has a high cat ion exchange capacity which enables them to hold and slowly release nutrient especially magnesium, potassium and calcium, and do well when mixed with fertilizers or other nutrient rich fertilizers (Murimba, *et al* 2015). Being an inert and heat treated, vermiculite is free from pathogens and provides a clean growing environment which reduces disease stress, allowing the seedling to invest more energy in to structural growth including the stem.

5.1.2 Stem height

Similar to thickness, growing medium with cow dung supports the tomato seedling stem height. Loam alone give the poorest height because of the absence of nutrients necessary for important processes like cell division, enlargement and elongation (Adamu, *et al* 2011). These are crucial for the enhancement of stem height. Its absence will definitely lead to poor height in the tomato seedlings. Tomato seedlings that were in the vermiculite were also doing well, but not as higher as cow dung. Treatments containing loam had the least support in stem height.

5.1.3 Leaf Area Index

Cow dung also gives the best performance for the tomato seedling leaf area. This is so because cow dung contain the macro-nutrients like nitrogen which are very important for the vegetative growth, increasing the leaf area. Leaf area index refers to the area of a leaf in relation to the ground area. Treatments containing cow dung had seedlings with large leaf surface area which increase the photosynthetic rate. Large leaf area allows for greater light capture, enhancing photosynthesis and overall seedling growth. Large leaf area index supported in treatments containing cow dung also enhance gaseous exchange, improving carbon dioxide which is an input in the process of photosynthesis. Leaf area index also help to increase infiltration which helps in moisture conservation and in agricultural context, a higher leaf area index often correlates with increased tomato yields due to improved photosynthesis and other growing conditions. Loam, whether alone or in mixture, generally reduce growth items of the leaf area (Adamu, *et al* 2011) and generally, a reduced leaf area is correlated with poor yield. Vermiculite has a moderate effect when it comes to leaf area index because it lacks macro-nutrients like nitrogen, potassium and phosphorous which are necessary for the growth of the leaves area.

5.1.4 Leaf number

The results showed that vermiculite boost leaf number, but causing a drop in the leaf area. This is so because vermiculite has an excellent moisture retention. This ensure a consistent moisture supply which is crucial for leaf formation and proliferation (Chikanda, 2019. Vermiculite also buffer against fluctuations in moisture and temperature. This stability allows tomato seedlings to grow continuously and uniformly, leading to a higher number of leaves. Vermiculite can retain and gradually release nutrients such as potassium, magnesium and calcium. These are vital for chlorophyll production and cell division. High leaf number can fend off disease better than a plant with fewer leaves, as it can devote more energy to defense mechanisms. Seedlings which were in other growing mediums were experiencing a decrease in leaf number. Gupta, 2013 state that cow dung has the ability to increase the number of leaves on a plant, but on this study, it was proven that vermiculite increase leaf formation of tomato seedlings.

5.1.5 Survival rate

The research shows that there was a significant difference across the growing medium items of the survival rates. The survival rate was p=0.001.Inorganic vermiculite had an outstanding survival rate. This was because vermiculite is highly sterile which does not promote the death of tomato seedlings by pest and diseases. The sterility of vermiculite cut off the chances of the media based disease (Bulletin et al, 2006). Vermiculite is so sustainable by maximizing seedlings survival. This make the farmers to reduce the need for agro-chemical intervention, promoting more sustainable farming practices. Tomato seedlings which were in treatments containing cow dung had a moderate survival rate. This is so because cow dung have some micro-bacteria which cause some disease and reduce the rate at which seedlings survive. The reduction in survival rate reduce production and profitability when doing commercial production.

5.1.6 Pest and disease incidences

Growing mediums which were containing cow dung and vermiculite showed strong resistance to pest incidents. Cow dung alone showed that there was a microscopic infestation of pests which later caused wilting of tomato seedlings. This gave an evidence that *Raulstonia solanacearum* used to infect the crops without noticing it (Denny, *et al* 2001). In most of the cases, vermiculite based growing medium suppress pests and diseases. This might be due to the sterility of the vermiculite .This prohibit the infestation of pests and diseases in the tomato seedlings grown in this growing medium. In some other cases, cow dung and its mixture with loam also show some resistance to pests and disease, but the resistance is weak. Loam alone have a poor resistance to pest and disease. This might be because most of the time, loam does not undergo sterilization, therefore the pests and disease will be transferred to panting stations with pests but at different stages of growth.

CHAPTER SIX

6.0Recommendations and conclusions

6.1Introduction

This saves to summarize the findings from comparative analyses of five different growing media (cow dung, vermiculite, loam, and their combinations) used in tomato seedling production. The aim is to determine the most effective medium based on stem thickness, stem height, leaf area index, leaf number, survival rate, pest incidence as well as disease incidence in tomato seedlings.

6.2Conclusions

Cow dung supports stem size (thickness), stem height and leaf area index. Stem thickness basically means high vascular tissues which contain many xylem and phloem vessels which facilitate the movement of nutrient from source to the sink as well as water and sugars produced in the process of photosynthesis. Stem height helps in the assessment of the growth of tomato seedlings. Large leaf area means high number of stomata for gaseous exchange, increase in the area that intercept light which is necessary for high photosynthetic output. On the other hand vermiculite support number of leaves, survival rate, pest and disease incidence in tomato seedling production. Both growing mediums have proven to be effective in different parameters in the production of tomato seedlings. Since cow dung supports stem thickness, stem height and leaf area index and vermiculite supports leaf number, survival rate, pest and disease incidence, the combination of two growing mediums in appropriate ratio of 1:1 can bridge the cavity that each growing medium has in the production of robust tomato seedlings. The combination of two growing medium will definitely, lead to the production of healthy tomato seedlings which are need for the increase of tomato production in which leads to reduction in nutrition based diseases, employments creations as well as poverty alleviation in remote areas. This combination will also reduce costs of the use of agro based chemicals in treatment of pests and disease since vermiculite is sterile and does not support pests and disease infections

6.3 Recommendations

Basing on the results and information generated from this study, the following recommendations can be made:

6.4 Primary Media Selection

- Both cow dung and vermiculite are cheap therefore tomato farmers should use cow dung for optimal tomato Stem thickness, stem height and leaf area index. They should also use vermiculite for increased leaf number, survival rate and reduce pest and disease incidence.

- Farmers should also use a ratio of 1:1 mix of cow dung + vermiculite (without loam) to combine nutrient richness and moisture stability.

- Farmer should avoid using loam alone or in mixtures, as it consistently lowers performance across all key growth parameters in the establishment of tomato seedlings.
- Farmers should use a mixture vermiculite or cow dung-based media to minimize seedling loss from pest and disease outbreaks.

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Appendix 1

Analysis of variance

Variate: Leaf area index

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block stratum	2	0.32533	0.16267	1.67	
block.*Units* stratum					
TREATMENTS	4	5.14267	1.28567	13.16	0.001
Residual	8	0.78133	0.09767		
Total	14	6.24933			

Appendix 2

Analysis of variance

Variate: Number of leaves

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block stratum	2	0.9333	0.4667	1.56	
block.*Units* stratum					
TREATMENTS	4	19.6000	4.9000	16.33	<.001

Residual	8	2.4000	0.3000		
Total	14	22.9333			

Appendix 3

Analysis of variance

Viriate: Pest incidence

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block stratum	2	3.3333	1.6667	4.00	
block.*Units* stratum					
TREATMENTS	4	8.2667	2.0667	4.96	0.026
Residual	8	3.3333	0.4167		
Total	14	14.9333			

Appendix 4

Analysis of variance

Variate: STEM_HEIGHT

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block stratum	2	0.24133	0.12067	1.69	
block.*Units* stratum					
TREATMENTS	4	11.97600	2.99400	41.87	<.001
Residual	8	0.57200	0.07150		
Total	14	12.78933			

Appendix 5

Analysis of variance

Variate: Stem thickness

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block stratum	2	0.01733	0.00867	0.27	
block.*Units* stratum					
TREATMENTS	4	3.82000	0.95500	29.84	<.001
Residual	8	0.25600	0.03200		

Total	14	4.09333

Appendix 6

Analysis of variance

Variate: Survival rate

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block stratum	2	26.800	13.400	2.99	
block.*Units* stratum					
TREATMENTS	4	1863.333	465.833	103.90	<.001
Residual	8	35.867	4.483		
Total	14	1926.000			

Appendix 7

Analysis of variance

Variate: Survival rate

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block stratum	2	26.800	13.400	2.99	
block.*Units* stratum					
TREATMENTS	4	1863.333	465.833	103.90	<.001
Residual	8	35.867	4.483		
Total	14	1926.000			

Appendix 8

Analysis of variance

Variate: Disease incidence

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block stratum	2	0.5333	0.2667	2.67	
block.*Units* stratum					
TREATMENTS	4	0.4000	0.1000	1.00	0.461

Residual	8	0.8000	0.1000		
Total	14	1.7333			

Appendix 9

Analysis of variance

Variate: Leaf area index

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block stratum	2	2.7253	1.3627	8.83	
block.*Units* stratum					
TREATMENTS	4	5.7373	1.4343	9.29	0.004
Residual	8	1.2347	0.1543		
Total	14	9.6973			

Appendix 10

Analysis of variance

Variate: Number of leaves

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block stratum	2	9.221	4.611	1.05	
block.*Units* stratum					
TREATMENTS	4	61.723	15.431	3.50	0.062
Residual	8	35.285	4.411		
Total	14	106.229			

Appendix 11

Analysis of variance

Variate: Pest incidence

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block stratum	2	0.9333	0.4667	3.50	
block.*Units* stratum					
TREATMENTS	4	1.3333	0.3333	2.50	0.126

Residual	8	1.0667	0.1333		
Total	14	3.3333			

Appendix 12

Analysis of variance

Variate: STEM_HEIGHT

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block stratum	2	3.4893	1.7447	2.22	
block.*Units* stratum					
TREATMENTS	4	23.3267	5.8317	7.43	0.008
Residual	8	6.2773	0.7847		
Total	14	33.0933			

Appendix 13

Analysis of variance

Variate: STEM_HEIGHT

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block stratum	2	3.4893	1.7447	2.22	
block.*Units* stratum					
TREATMENTS	4	23.3267	5.8317	7.43	0.008
Residual	8	6.2773	0.7847		
Total	14	33.0933			

Appendix 14

Analysis of variance

Variate: Stem thickness

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block stratum	2	0.10133	0.05067	0.95	
block.*Units* stratum					
TREATMENTS	4	23.99067	5.99767	112.81	<.001

Residual	8	0.42533	0.05317
Total	14	24.51733	

Appendix 15

Analysis of variance

Variate: Stem thickness

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block stratum	2	0.10133	0.05067	0.95	
block.*Units* stratum					
TREATMENTS	4	23.99067	5.99767	112.81	<.001
Residual	8	0.42533	0.05317		
Total	14	24.51733			

Appendix 16

Analysis of variance

Variate: Survival rate

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block stratum	2	12.933	6.467	2.92	
block.*Units* stratum					
TREATMENTS	4	1606.267	401.567	181.16	<.001
Residual	8	17.733	2.217		
Total	14	1636.933			

Appendix 17

Analysis of variance

Variate: Disease incidence

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block stratum	2	0.5333	0.2667	2.67	
block.*Units* stratum					
TREATMENTS	4	2.0000	0.5000	5.00	0.026

Residual	8	0.8000	0.1000		
Total	14	3.3333			

Appendix 18

Analysis of variance

Variate: Leaf area index

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
block stratum	2	0.1720	0.0860	0.15	
block.*Units* stratum					
TREATMENTS	4	3.3493	0.8373	1.48	0.294
Residual	8	4.5147	0.5643		
Total	14	8.0360			

Appendix 19

Analysis of variance

Variate: Number of leaves

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block stratum	2	3.3333	1.6667	2.22	
block.*Units* stratum					
TREATMENTS	4	30.0000	7.5000	10.00	0.003
Residual	8	6.0000	0.7500		
Total	14	39.3333			

Appendix 20

Analysis of variance

Variate: Pest incidence

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block stratum	2	1.7333	0.8667	4.33	
block.*Units* stratum					
TREATMENTS	4	2.4000	0.6000	3.00	0.087
Residual	8	1.6000	0.2000		

Total	14	5.7333

Appendix 21

Analysis of variance

Variate: STEM_HEIGHT

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block stratum	2	0.4480	0.2240	0.23	
block.*Units* stratum					
TREATMENTS	4	69.2693	17.3173	18.09	<.001
Residual	8	7.6587	0.9573		
Total	14	77.3760			

Appendix 22

Analysis of variance

Variate: Stem thickness

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block stratum	2	4.4373	2.2187	5.17	
block.*Units* stratum					
TREATMENTS	4	51.2840	12.8210	29.85	<.001
Residual	8	3.4360	0.4295		
Total	14	59.1573			

Appendix 23

Analysis of variance

Variate: Survival rate

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block stratum	2	116.133	58.067	6.46	
block.*Units* stratum					
TREATMENTS	4	1620.933	405.233	45.11	<.001

Residual	8	71.867	8.983
Total	14	1808.933	

Appendix 24

Analysis of variance

Variate: Survival rate

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block stratum	2	116.133	58.067	6.46	
block.*Units* stratum					
TREATMENTS	4	1620.933	405.233	45.11	<.001
Residual	8	71.867	8.983		
Total	14	1808.933			

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