BINDURA UNIVERSITY OF SCIENCE EDUCATION

FACULTY OF AGRICULTURE AND ENVIRONMENTAL SCIENCE DEPARTMENT OF CROP SCIENCE

INVESTIGATING THE EFFECT OF SHADE NET HOUSING AND MEDIA TYPE ON CARROT (*DAUCUS CAROTA*) GERMINATION

BAMU NORAH TAKUNDA

(B211704B)

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

(CROP SCIENCE)

Date:

Dedication

This dissertation is dedicated to my beloved family and friends for their spiritual and moral support throughout the whole project period.

Declaration

BINDURA UNIVERSITY OF SCIENCE EDUCATION

FACULTY OF AGRICULTURE AND ENVIRONMENT SCIENCE

The undersigned certify that they have read and recommended to the Department of Crop Science, this thesis entitled:

Investigating the effect of shade net housing and media type on carrot (*daucus carota*) germination

DECLARATION

I, Norah Takunda Bamu (B211704B), do hereby declare that this research project is the result of my original work that had been researched and got submitted on fulfilment of the Bachelor of Agricultural Honours Degree Majoring in Crop Science at Bindura University of Science Education. The other information had been derived from other people's work based on trusted sources and had been duly cited, accredited and acknowledged through references.

NORAH TAKUNDA BAMU	……………………..……	17/09/25
(CANDIDATE)	(SIGNATURE)	(DATE)

CERTIFIED BY

MR. MUTSENGI	……………………….	…………………..
(SUPERVISOR)	(SIGNATURE)	(DATE)
MR. MUTSENGI	……..……………….	……………………..
(CHAIR PERSON)	(SIGNATURE)	(DATE)

Acknowledgments

First and foremost, I would like to thank myself for the great endurance shown throughout the whole project period. I am grateful to Jehovah for giving me the strength and time to do so. My greatest appreciation goes to my main supervisor Mr Mutsengi for his tireless assistance and guidance from the first day up to the very end of this study, not forgetting Prof. Mandumbu, my core supervisor, for his great assistance. I'm also indebted to the following field technician: Mr Khahlamba for his provision of technical assistance to this study. Lastly, would also like to thank Bindura University of Science Education for granting me this opportunity to put into practice what was taught in theory.

Abstract

This research assessed the effects of different growing media (pine bark, maize compost, and soil) and environments (shade net and open field) on carrot (*Daucus carota***)** growth and development in Zimbabwe. A split plot design with three replications was used. The growing environments were the main plots and the media types where the subplots. Interactions between the growing environment and the media type ($p<0.001$) were significant for all measured parameters. Pine bark under shade net conditions demonstrated superior performance across measured parameters reaching the highest germination rate (89.2 %), greatest plant height (45.6cm) as well as roots (28.6cm) and highest fresh weight (124.6g) g per plant. Maize compost showed intermediate performance for all measured parameter while soil (control) consistently had the lowest values. The shade net environment improved performance across all media types with average improvements of 15.2% in emergence, 18.4% in plant height and 22.6% in fresh weight compared to open field conditions. These findings led to the conclusion that the combination of pine bark media and shade net cultivation offers significant advantages for carrot production in Zimbabwe's growing conditions. It was recommended that farmers engaging in carrot production especially in semi-arid conditions should consider growing carrots in shade net houses and also that they use well-structured growing media such as pine bark or maize stover compost to boost output.

Contents

Dedication i
Acknowledgments iii
Abstract iv
List of Tables viii
Table of figures ix
CHAPTER 1 1
INTRODUCTION 1
1.1 BACKGROUND OF THE STUDY 1
1.2 PROBLEM STATEMENT 2
1.3 JUSTIFICATION 2
1.4 OBJECTIVES 3
1.4.1 MAIN OBJECTIVE 3
1.4.2 Specific objectives 3
1.5 Hypothesis 3
CHAPTER 2 4
LITERITURE REVIEW 4
2.1 Factors influencing carrot germination and early establishment 4
2.2 Benefits and challenges of shade net houses on vegetable growth 4
2.2.1 Protected cultivation; effects on crop yield and quality 5
2.3 Comparison of soil and soilless germination media in vegetable seedling production 5
2.3.1 Pine bark 6
2.3.2 Cocopeat 6
2.3.3 Maize stover compost 6
2.4 Temperature and light requirements of carrots 6
2.4.1 Carrot production under different environmental conditions 7
CHAPTER 3 8
MATERIALS AND METHODS 8
3.1 STUDY SITE DESCRIPTION 8
3.2 EXPERIMENTAL DESIGN 8
3.3 GROWING MEDIA PREPARATION 8
3.3.1 SOIL TREATMENT 8

3.3.2 PINE BARK MEDIUM 8
3.3.3 MAIZE STOVER COMPOST PREPARATION 8
3.4 LAND PREPARATION AND PLANTING 9
3.4.1 BED PREPARATION 9
3.4.2 TREATMENT APPLICATION 9
3.4.3 PLANTING 9
3.5 CROP MANAGEMENT 9
3.5.1 IRRIGATION 9
3.5.2 WEED MANAGEMENT 9
3.5.3 PEST AND DISEASE MANAGEMENT 9
3.6 DATA COLLECTION 10
3.6.1 Germination 10
3.6.2 Plant height 10
3.6.3 Root length 10
3.6.4 Fresh weight 10
3.7 DATA ANALYSIS 10
CHAPTER 4 12
RESULTS 12
4.1 EMERGENCE PERCENTAGE 12
4.2 PLANT HEIGHT 13
4.3 ROOT LENGTH 14
4.4 FRESH WEIGHT AT HARVEST 15
CHAPTER 5 16
DISCUSSION 16
5.1 GERMINATION PERCENTAGE 16
5.2 PLANT HEIGHT 16
5.3 ROOT LENGTH 17
5.4 FRESH WEIGHT AT HARVEST 17
CHAPTER 6 18
CONCLUSIONS AND RECOMMENDATIONS 18
6.1 CONCLUSIONS 18
6.2 RECOMMENDATIONS 18

REFERENCES..19
APPENDIX..22

List of Tables

APPENDIX……………………………………………………………………………………22
Table 1: Germination 22
Table 2: Root length.. 22
Table 3: Plant height 23
Table 4: Fresh weight... 23
Table 5: Table of means... 24

Table of figures

Figure 1: Germination percentage 12
Figure 2: Plant height.. 13
Figure 3: Root length 14
Figure 4: Fresh weight 15

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND OF THE STUDY

Carrot (*Daucus carota L.*) is a commonly grown root vegetable favored for its nutritional value and ease of production. While it is a crop grown in many environments, the growth and establishment of carrots is quite sensitive to environmental factors which include, light, soil conditions and temperature (Hossain et al., 2017). As climate changes and land use practices continue to change, it becomes increasingly important to understand the effects of different farming environments on the crop's performance in order to optimize production (Kumar et al., 2020).

Under ordinary production situations, carrots are grown under direct sunlight, natural soil qualities, and ever-changing weather conditions. This is the commonest cultivation practice which however has challenges more so during unfavorable weather conditions such as extreme temperatures and intense sunlight that may negatively affect germination and early crop establishment (Tao et al., 2021). Shade net houses in contrast, provide a somewhat controlled environment which reduces the impact of direct sunlight and offers a more consistent environment which may provide better growing conditions and promotes good and easy germination (Kaur et al 2019). Shade nets are commonly used in farming to mitigate temperature extremes as well as humidity thereby improving crop growth and reducing problems associated with excess exposure to sunlight (Behera et al., 2018).

The effects of environmental conditions on germination and early crop establishment are a crucial factor in the success of a crop farming enterprise. Germination, the process by which a seed becomes a new plant comes under influence of numerous environmental factors such as moisture, temperature, and light availability among others (Batista et al., 2019). The germination rate of carrots is highly dependent on the ambient conditions they are planted in (Shahzad et al., 2017). Research has shown that when carrots are exposed to excessive heat or sunlight, they may experience delayed germination, reduced seedling vigor, and generally low plant establishment (Miah et al., 2016).

The germination media used is an important factor in the success of germination and early establishment. Different media offer differing levels of moisture retention, nutrient availability, and aeration. While soilless media continues to gain traction in many farming communities, there is limited research on how their interactions with environmental variables affect carrot seedling vigor. There are several media types in use among them, soil, vermiculate, pine bark, peat moss, composts which offer advantages in terms of water retention, aeration, and nutrient availability (Garcia-Sanchez et al., 2021). Soilless media such as pine bark, coco peat and vermiculate have gained popularity among growers because of their ability to provide uniform moisture levels and ideal root development conditions compared to ordinary soil planting (Chandran et al., 2020). Soilless media may come with costs which may erode earnings.

1.2 PROBLEM STATEMENT

There is limited research and little enlightening on the comparisons effects of shade net houses and open field cultivation of carrot crops more so with different growing media used. Also, the choice of germination media can have a bearing on germination and establishment of carrot crops yet the effect of the different media's interaction with environmental factors on carrot crop germination and early establishment has not been fully analyzed.

1.3 JUSTIFICATION

The demand for carrots both domestically and globally, has been rising steadily driven by their nutritional value and versatility. There is there for a need to improve carrot production practices to improve productivity and sustainability. Germination and early establishment are critical stages in carrot crop development that affect yield quality and quantity. These stages are however sensitive to numerous environmental conditions such as soil quality, light intensity, and temperature fluctuations which are difficult to control in open field production. Shade net houses are a potential solution to address environmental factors that impact carrot production yet their effect on carrot germination and early establishment remain underexplored.

This research seeks to determine the effects of shade net houses compared to open field cultivation on carrot germination and early establishment taking into account the different germination media. By identifying ideal growing conditions, this study could contribute to better carrot cultivation practices which yield better. The study also has the potential to reduce the environmental impact of carrot farming.

1.4 OBJECTIVES

1.4.1 MAIN OBJECTIVE

- To assess the impacts of growing media and shading on carrot performance

1.4.2 Specific objectives

- To assess the effect of shading and media on germination.
- Assess the effect of media type and shading on vegetative growth.
- Assess the effect of media type and shading on yield of carrots

1.5 Hypothesis

- Growth media and shading have no effect on germination of carrots
- Growth media and shading have no effect on vegetative growth of carrots
- Growth media and shading have no effect on the final carrot yield

CHAPTER 2

LITERITURE REVIEW

2.1 Factors influencing carrot germination and early establishment

Carrot germination and early seedling growth is greatly influenced by environmental factors which include, light, temperature, humidity and soil conditions. Temperatures between 15℃ and 20℃ are the most favourable for optimal germination of carrots (Miah et al., 2016). If temperatures exceed 25℃, poor germination and delayed seedling development may be noticed (Shahzad et al., 2017). Light is also important for seedling establishment since carrot seeds need light to germinate effectively; however excessive exposure to light can hinder vegetative growth (Hossain et al., 2017).

According to Behera et al. (2018), higher levels of humidity help to maintain sufficient moisture for seedling growth while low humidity can result in dehydration and may result in stunted development. Soil conditions play a pivotal role in germination and early establishment. These include texture, moisture retention, and nutrient availability.

Studies conducted by Tao et al. (2021) showed that well drained loose soils with high organic matter content encourage better root development and healthier seedlings. In order to optimise carrot production, it is essential to understand the effects of these environmental factors more so in Zimbabwe where fluctuating temperatures and seasonal rain fall patterns are common.

2.2 Benefits and challenges of shade net houses on vegetable growth

Shade net houses are construct used in agriculture to mitigate the negative effects associated with extreme weather conditions especially in areas with high sunlight intensity and temperature fluctuations such as those common to most parts of Zimbabwe. Shade net houses reduce the effect of direct sunlight exposure thereby reducing heat stress which is beneficial for crops like carrots which are sensitive to heat stress (Kumar et al., 2020). Research undertaken by Behera et al. (2018) has shown that shade houses maintain temperature and humidity levels with better consistency creating a more stable environment for germination and early establishment.

Kaur et al. (2019) conducted a study which revealed that shade net houses can improve water use efficiency and reduce evaporation resulting in improved crop quality and increased crop yield. The use of shade net houses does come with its challenges. Kumar et al. (2020) noted that costs associated with installation and maintenance as well as ventilation challenges which result in prevalence of fungal infections are challenges associated with shade net houses.

While shade net house avail numerous advantages for crop growth and yield, the effectiveness of the system is largely dependent on the crop type as well as environmental conditions, more so in Zimbabwe where both climatic extremes and water shortages occur.

2.2.1 Protected cultivation; effects on crop yield and quality

Protected cultivation techniques such as shade net houses and green houses are fast becoming popular in vegetable farming. This is in part because they offer the option of control to the farmer and enable farmers to better address challenges associated with unpredictable weather, pests and diseases. Numerous studies have concluded that with protected cultivation, there is almost always a significant improvement in quality and an increase in yield.

Kumar et al. (2020) noted that shade net houses provide notable reductions in temperature as well as protecting plants from hail, heavy rainfall, and strong winds all of which can devastate young plants. Shade net houses are also useful for reduction of moisture to evaporation (Behera et al., 2018) which is especially useful in Zimbabwe since water is often scarce.

The success of a protected cultivation does however depend on the crop being cultivated, management practices, and environmental conditions.

2.3 Comparison of soil and soilless germination media in vegetable seedling production

In order for a good crop stand to be realised, there must be high rates of germination. The state and properties of germination media play a crucial role in the emergence and early growth of vegetable seedlings. While traditional soil-based media provides essential nutrients and support for seedlings, they are more prone to compaction, waterlogging and poor drainage which may result in poor root development (Chandran et al., 2020). In contrast, soilless media such as pine bark, cocopeat among others are being used for commercial production of vegetable seedlings because of their enhanced ability to retain moisture, better aeration as well as lower risk of diseases (Sarker et al., 2020).

2.3.1 Pine bark

This is a by-product of Zimbabwe's forestry sector employed extensively as a substrate in many commercial nurseries and in greenhouse cropping (Ndlovu et al., 2020). It is favoured for its ability to provide favourable physical conditions such as water retention and aeration (Bilderback et al., 2005). Because of the erratic rainfall received in Zimbabwe, the use of soilless media may be beneficial in carrot production.

2.3.2 Cocopeat

This is a by-product of coconut husks which is known for its high-water holding capacity while being light weight and generally free from pathogens (Garcia-Sanchez et al., 2021). According to Shahzadet al. (2017), soilless media provide more consistent growth conditions compared to soil. For carrot seedlings which need well drained media for good root development, soilless media may be the better option.

Studies conducted by Tao et al. (2021) have shown that for a country like Zimbabwe, soilless media may be a good option for a crop like carrot because of the reduced moisture level fluctuations and reduced levels of disease challenge.

2.3.3 Maize stover compost

Maize stover compost can be used as germination media for many crops including root vegetables. It has a high organic matter composition and has beneficial effects on seedling growth. Maize stover compost contains nitrogen, phosphorus, and potassium in sufficient quantities to promote healthy shoot and root development (Ngwu et al., 2020).

When incorporated with ordinary soil, maize stover improves soil structure, increases the soil's moisture retention ability and increases aeration (Tao et al., 2021) which is important for root vegetables like carrots. It also increases microbial activities many of which are beneficial to crops as they increase nutrient availability and support seedling vigour (Ogunwolu et al., 2018).

Research has proven that maize stover compost can improve early seedling establishment more so in areas where alternative growing media is limited (Tshikhudo et al., 2019).

2.4 Temperature and light requirements of carrots

As with most crops, the balance between light and temperature has a bearing on the germination and development of carrots. Carrots are sensitive to both fluctuations in temperature as well as light exposure. Optimal temperatures for germination in carrots are between 15℃ and 20℃ with temperatures beyond 25℃ reducing germination significantly and resulting in poor seedling establishment (Shahzad et al., 2017). On the other hand, low temperatures result in delayed germination and lowers seedling survival rates (Miah et al., 2016).

While carrot seeds need light for germination, too much light can lead to excessive dehydration, negatively affecting seedling growth (Hossain et al., 2017). In a controlled setup such as shade net houses, both temperature and light exposure can be controlled somewhat, providing a more favourable environment for carrot seedling establishment (Behera et al., 2018). Heat stress and fluctuating temperatures are commonplace in most of Zimbabwe.

Controlling temperature and light exposure especially in the early stages of carrot growth and development can result in improved carrot production.

2.4.1 Carrot production under different environmental conditions

Carrot farming is sensitive to many environmental conditions with temperature, light as well as soil quality being highly influential in seed germination and early growth. The world over, carrot production has been studied in both open field and protected production.

In temperate zones, carrots do well in temperatures between 15℃ and 20℃ with higher temperatures resulting in lower germination rates and poor root development (Shahzad et al., 2017). Studies in some warm regions have shown that it may be necessary to modify environmental factors in order to prevent heat stress and moisture loss (Behera et al., 2018).

Studies have shown that in protected environments, carrots have higher germination rates, uniformity in size and better-quality yields when compared to open field production (Kumar et al., 2020). Furthermore, alternative growing media such as pine bark and vermiculate have been seen to improve germination rates and seedling establishment in areas where natural soil conditions have proven to be suboptimal (Garcia-Sanchez et al., 2021).

Thus, research across the world has shown that managing environmental factors and media choices can optimise carrot production in areas where climatic conditions present challenges.

CHAPTER 3

MATERIALS AND METHODS

3.1 STUDY SITE DESCRIPTION

The study was conducted in Concession at Luxaflor Rose Garden (17.3352° S, 31.0123° E), Mashonaland Central Province, Zimbabwe, approximately 45 kilometers north of Harare. The area lies in Natural Region IIa, characterized by mean annual rainfall of 750-1000mm and mean annual temperature of 15-29°C. The site altitude is approximately 1,150 meters above sea level, with a gentle slope of less than 2%.

3.2 EXPERIMENTAL DESIGN

The experiment employed a split-plot design with two main plots which were shade net and open field. The open field plot and the shade net plot each had two blocks. Each of these two blocks was divided 3 beds. The sub-plots were soil, pine bark and maize stover compost.

The shade net used was 40% black shade cloth mounted on a 2m high structure. The trial was replicated two times with each main plot containing three beds per treatment.

3.3 GROWING MEDIA PREPARATION

3.3.1 SOIL TREATMENT

The existing soil was used without amendment, representing the control treatment.

3.3.2 PINE BARK MEDIUM

Commercial pine bark (pH 5.5-6.5) was purchased from Farm and City Center outlet in Harare and used without further amendments.

3.3.3 MAIZE STOVER COMPOST PREPARATION

Maize stover compost was prepared using the following method:

Maize stover was collected from a harvested field and shredded into 5-10cm pieces using a chuff cutter. The compost pile was constructed in layers with alternating layers of shredded maize stover (30cm) and topsoil (2cm). Moisture maintenance was done by adding a little water at turning of the compost. The pile dimensions were 1.5m width × 1.5m length × 0.6m height. Temperature monitoring and turning was done every 2 weeks from day 30 onwards. The composting process lasted for a duration of 2.5 months and final screening was done through 10mm sieve before use.

3.4 LAND PREPARATION AND PLANTING

3.4.1 BED PREPARATION

The land was first cleared of debris before being plowed to a depth of 30cm. A tractor drawn disc harrow was used to break clods. Beds were constructed using hoes and rakes. Compound C fertilizer was broadcast and incorporated during this process. The fertilizer was applied at a rate of 200kg per hectare. The beds were 1m in length and 70cm wide. The spacing between beds was 50cm. Three planting lines we marked out spaced 10cm apart on top of each bed.

3.4.2 TREATMENT APPLICATION

For pine bark and maize stover treatments, trenches were excavated to a depth of 5cm and a width of 20cm along the planting lines. The respective media was then used to fill these trenches. Pre-planting irrigation was done using a fine rose fitted hose.

3.4.3 PLANTING

The Kuroda variety was planted at a seed rate of 200 seeds per square meter. In order to achieve better seed distribution, the seed was mixed with clean sand at the rate of 1:6. Seed was planted at a depth of 1cm and covered lightly using the respective media. Planting was done on 10 February 2025.

3.5 CROP MANAGEMENT

3.5.1 IRRIGATION

Irrigation was done on a daily basis until the carrot crop emerged. After carrot emergence irrigation was done twice weekly using a hose with the fine rose attachment.

3.5.2 WEED MANAGEMENT

Weeds were pulled out while the soil was moist every two weeks. The first weeding was done 14 days after planting. The process was done carefully to avoid root disturbance.

3.5.3 PEST AND DISEASE MANAGEMENT

Pests and diseases were controlled by making use of chemical combinations. Combination A consisted of Nemesis at a rate of 25ml and Chemlaxyl at a rate of 50g in 16 liters of water. Nemesis is a formulation that contains Emmamectin benzoate and Acetamiprid. It is used for the control of both biting and chewing pests as well as sucking pests. Chemlaxyl is a fungicide used for the control of fungal diseases control in plants. It is a formulation which contains Metalaxyl as well as Mancozeb. It has both curative and preventive effects on diseases.

Combination B was made up of Chlorothalonil at a rate of 120ml and Lambda cyhalothrin at 25ml in 16 liters of water. Chlorothalonil is a fungicide with preventive effects whereas Lambda cyhalothrin is an insecticide commonly used to kill larvae and soil pests.

The two combinations were applied 7 days apart.

3.6 DATA COLLECTION

Several parameters were assessed

3.6.1 Germination

Germination was assessed by counting the number of plants that had emerged in each treatment on days 7, 14, and 21 after planting.

3.6.2 Plant height

Plant height was measured on days 14, 30, and 45 using a tape measure. 10 plants were randomly chosen from each treatment and measured from the base of the plant to its highest point.

3.6.3 Root length

Root length measurements were taken in days 14, 30, and 45. 10 plants were chosen at random and uprooted carefully so as not to damage the roots. The roots were then measured using a tape measure.

3.6.4 Fresh weight

On day 78 all the carrots were harvested and placed on the surface of each bed. The weight of the carrots was measured using a digital scale and recorded.

3.7 DATA ANALYSIS

The collected data was analyzed using analysis of variance (ANOVA) in Genstat statistical software (21st Edition). Treatment means were separated using Fisher's Protected Least Significant Difference (LSD) test at 5% level of significance ($p \leq 0.05$). The statistical model included:

- Main plot effects (shade vs. open field)
- Sub-plot effects (growing media)
- Interaction effects
- Block effects

➢ The model – $Y_{ij} = \mu + En + Me + I + E$ where

Yij	= Dependent variable
μ	= overall mean
En	= environment effect
Me	= method effect
I	= interaction effect
E	= residual error

CHAPTER 4

RESULTS

4.1 EMERGENCE PERCENTAGE

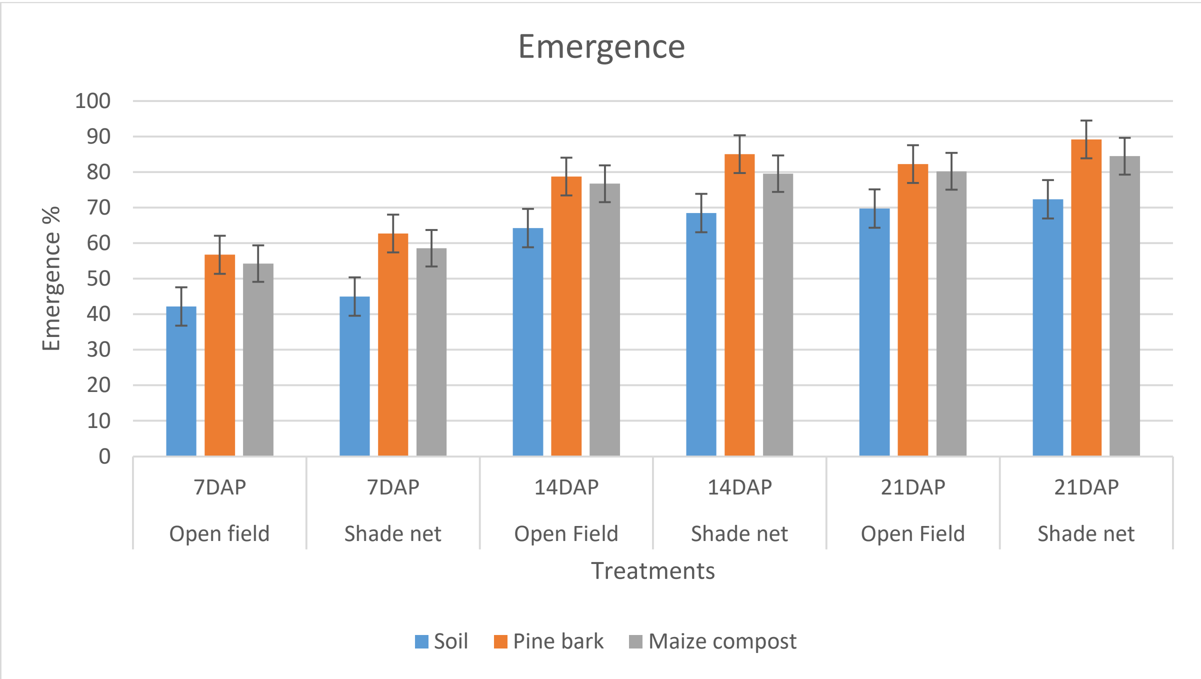

Figure 1: Emergence percentage

There were significant interactions ($p<0.001$) between the growing environment (shaded net and open field) and media type that resulted in differences in emergence success. The pine bark media showed better germination rates across both environments giving the highest percentages of 89.2% observed under shade net conditions at 21 days after planting. Maize compost was next reaching 84.5% under shade net and 80.1% in open field conditions, thus proving that the maize compost performed statistically similar under both environments In both environments, soil showed the lowest germination rates of 72.4% in shade net conditions and 69.8% in the open field. Growing environment and media type interactions where significant ($p<0.001$) with shade net conditions producing higher germination performance across all media types. However, block effects were not significant ($p=0.428$) showing good experimental control. Coefficient of variation (4.9%) was low suggesting high precision in all experiment of procedures.

4.2 PLANT HEIGHT

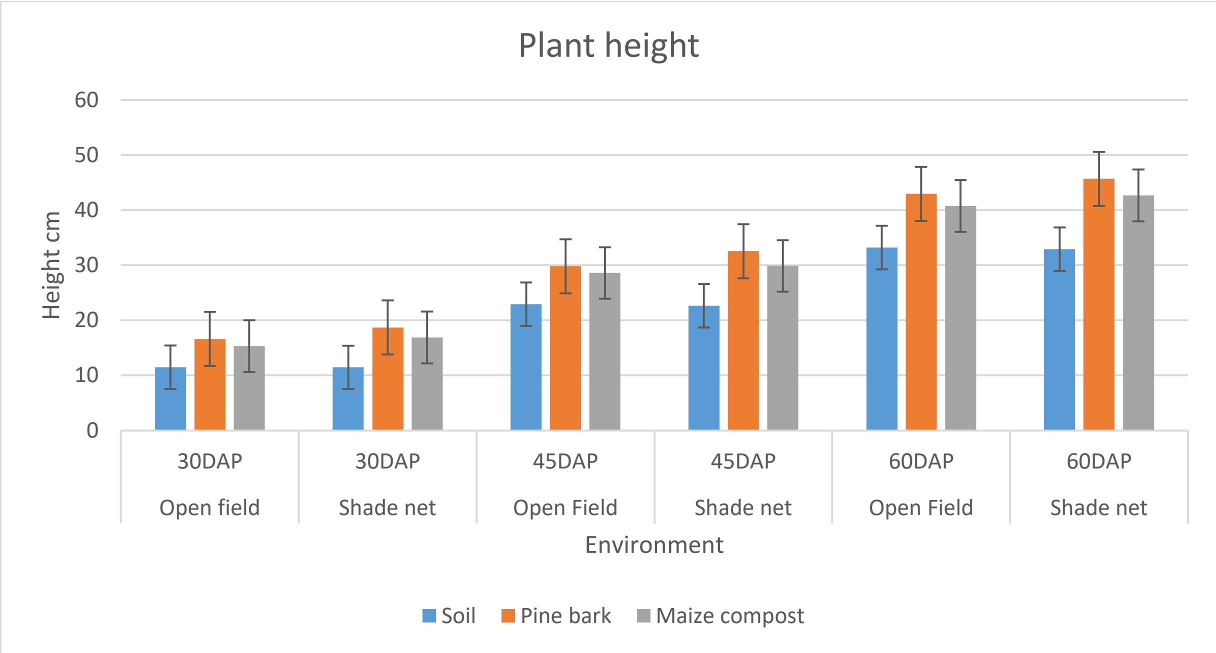

Figure 2: Plant height

There were strong interactions (p<0.001) between environment and media with pine bark (45,6cm) under shade net outperforming pine bark (43.1cm) in the open field environment. This pattern was seen for all other media. There were marked differences among treatments with respect to plant height measurements taken at 60 days after planting. The pine bark media produced plants with the greatest height (45.6cm) in the shade net conditions exceeding all other treatments significantly. Maize compost media gave intermediate outcomes (42.4cm) under shade net (40.6cm) in open field. These results proves to be statistically similar as there is no great difference between pine bark and maize compost under open field. The least vertical development of 35.8cm under shade net and 33.2cm in open field we achieved in the soil media.

4.3 ROOT LENGTH

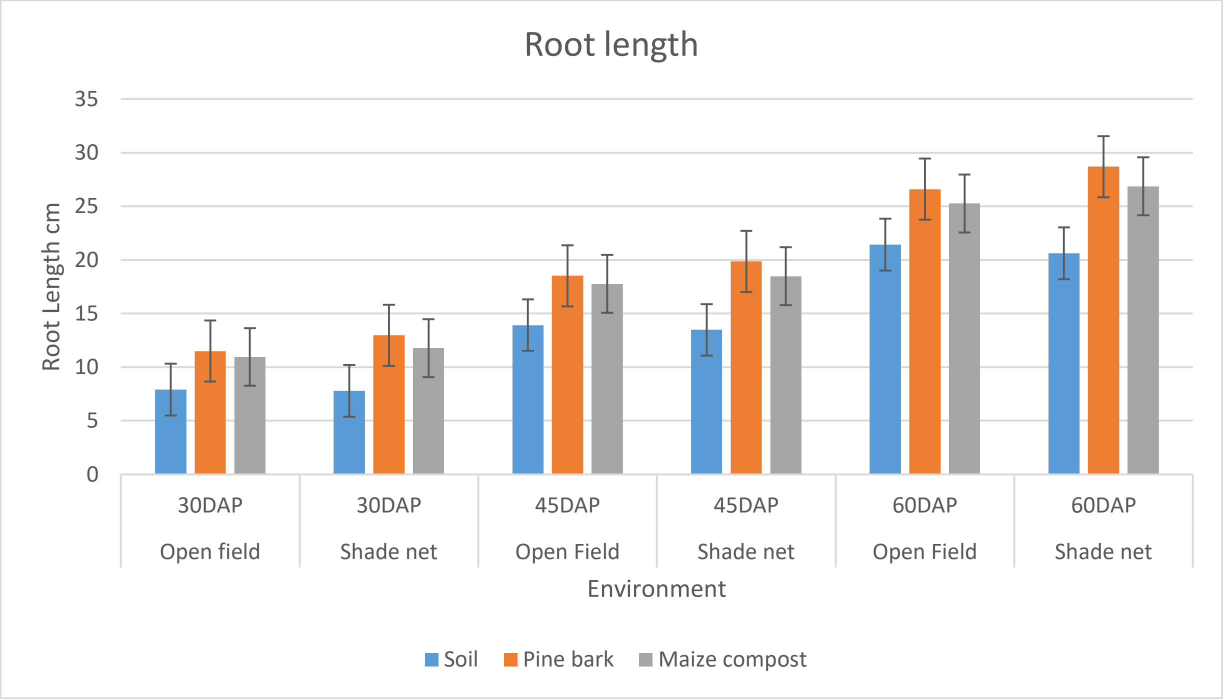

Figure 3: Root length

The interaction between media type and the growing environment was highly significant (p<0.001) showing that the effect of media type changed with change in growing environment. Treatment effects were highly significant (p< 0.001) at 60 days after planting. For root length under shade net conditions pine bark media produced the longest roots (28.6cm) followed by maize compost (26.8cm) while soil treatment gave the shortest roots (22.4cm) in open field conditions. A similar trend was realized with pine bark giving 26.4cm, maize compost giving 25.2 cm and soil media giving 21.2cm. Block effects were non-significant (p=0.912) indicating uniform experimental conditions across all replications while the coefficient or variation (6.5%) was low enough to suggest good experimental control. In general shade net conditions gave better growth and root development across all media types

4.4 FRESH WEIGHT AT HARVEST

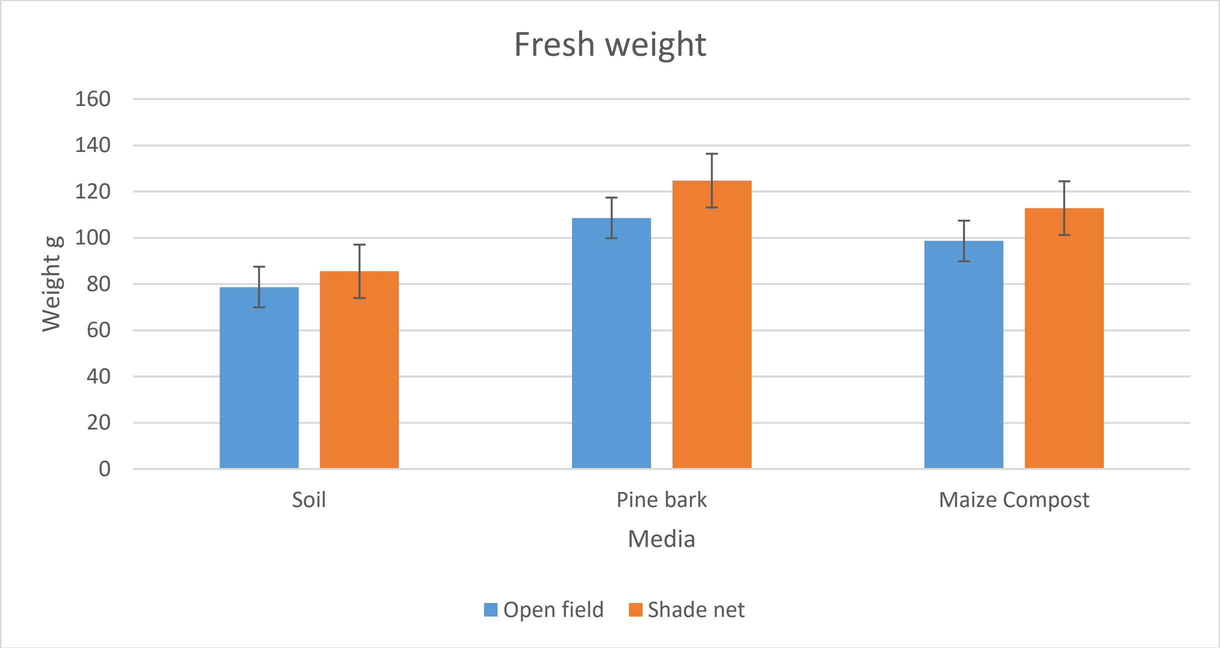

Figure 4: Fresh weight

Environment x media interactions were significant ($p<0.001$) with shade net conditions giving greater biomass across all media types. ANOVA for fresh weight showed highly significant differences among treatments ($p<0.001$). Shade net conditions resulted in plants grown in pine bark achieving the highest fresh weight 124.6 grams per plant significantly exceeding all other treatments. Maize compost gave intermediate results in both growing conditions with 112.8g per plant under shade net conditions and 98.6 grams per plant in open field. This proves that both pine bark and maize compost performed almost similar under shade net The lowest fresh weight was realized in soil grown plants at a weight of 5.4 grams per plant under shade net and 78.6 grams per plant in open field. Block effects were not significant ($p=0.842$) indicating reliable experimental conditions while the coefficient of variation (7.4%) showed good experimental control These results show that both growing media and environmental conditions had a great impact on biomass production.

CHAPTER 5

DISCUSSION

5.1 GERMINATION PERCENTAGE

The notable differences in germination percentage within treatments highlights the critical role of both growing environment and media type. Pine bark and maize compost both had high germination rates under shade net conditions. This is in sync with findings by Sarker et al. (2020) and Tao et al. (2021) who noted that superior moisture retention and aeration in soilless media makes it a better media than natural soil. The lower performance of soil is in line with Chandran et al. (2020) findings who noted that issues with compaction and drainage impede germination and development. Shade net houses contributed to improved germination across all media types resonating with Bahera et al. (2018) and Kaur et al. (2019) who identified shade structures as being regulatory with regard to temperatures and humidity. The interactive effect of the media and environment shows that environmental moderations and substrate quality are synergistic in nature. With Zimbabwe's erratic climate in mind, it is therefore suggested that combining shade net technology with high performing media such as pine bark can significantly improve germination outcomes and development in carrot production.

5.2 PLANT HEIGHT

The differences in plant height strongly reflected the effects of growing environment and germination media. Under shade net conditions pine bark produced the tallest plants affirming the role of consistent water supply and root zone aeration in good vegetative growth as emphasized by Sarker et al. (2020) and Bilderback et al. (2005). Plant height performance across all media was enhanced in shade net conditions likely due to its moderating influence on heat and water loss (Kumar et al. 2020; Behera et al. (2018). Soil grown plants underperformed in all environments indicating the possibility of limitations as far as nutrient availability and aeration were concerned (Chandran et al. (2020). The notable interaction effects indicate that optimal plant growth requires both a conducive substrate and enabling environment. These findings show that in regions with fluctuating climactic conditions like Zimbabwe integrating protected cultivation with media such as pine bark offers a strategic advantage for enhancing vegetative development.

5.3 ROOT LENGTH

The noteworthy differences in root length emphasize how substrate and environment impact subterranean plant development. Pine bark had the best conditions both under shade net and in open field confirming its ability to support deeper root penetration likely due to its loose texture and aeration capacity (Ndlovu et al., 2021). In open field conditions root length was greatly reduced further supporting the assertion that temperature and moisture regulation are vital during early root formation (Behera et al., 2018). Maize compost gave favorable results likely due to its organic content and improved soil structure (Ngwu et al., 2020). Natural soil treatments gave the shortest roots and this is consistent with limitations noticed by Chandra et al. (2020) regarding compaction and drainage. These results place emphasis on the important role of both growing media in environmental conditions in enhancing strong root systems combining compost or pine bark with shade net environments could sustainably enhance rooting success for Zimbabwe in root vegetable production.

5.4 FRESH WEIGHT AT HARVEST

Differences in fresh weight can be attributed to cumulative effects of early growth conditions. Pine bark produced the highest biomass under shade net conditions probably due to improved water availability, nutrient uptake and reduced stress throughout development confirming Garcia-Sanchez et al. (2021) and Kaur et al. (2019). Maize compost had intermediate success likely because of its moderate nutrient content and enhanced microbial activity (Ngwu et al., 2020; Ogunwolu et al., 2018). Natural soil had the lowest fresh weight reinforcing its drawbacks in structure and drainage. Biomass was highest across all media under shade conditions compared to the same media under open field cultivation. This was consistent with findings by Kumar et al. (2020) who noted that protected cultivation reduces environmental stressors. The interaction effects observed between media and environment suggest that biomass accumulation is enhanced when both factors are favorable. With these results it may be ideal to adopt shade net cultivation with suitable organic or soilless media to maximize carrot yields in variable climate zones like Zimbabwe.

When all has been said and done, almost all the parameters seemed to be statistically similar under both shade net and open field, but one cannot totally cast a blind eye on all the minor differences that are seen given different medias and environments.

CHAPTER 6

CONCLUSIONS AND RECOMMENDATIONS

6.1 CONCLUSIONS

The research evaluated the impacts of growing media and shading on carrot performance focusing on germination, vegetative growth, and yield under Concession conditions during the 2024 to 2025 rainfall season. The results indicate that both media type and shade net significantly influenced germination percentage. Under shade net conditions, pine bark recorded the highest germination rates. Shade nets offered moderating effects on temperature and moisture while pine bark offered better aeration and water retention. We can conclude therefore that shading and suitable media improved germination outcomes.

Root length and plant height varied significantly across the different treatments. The shade net environment enabled taller and more vigorous plants than the open field environment. Maize compost and pine bark outperformed soil in promoting early vegetative growth.

Shade net conditions gave harvest with significantly higher fresh weight while pine bark showed the greatest yield in either environment. This reinforces the notion that environment and media interact to influence final outcome. The results indicate that final yield improvement was not accidental but rather influenced by growth conditions more so during the early stages of growth.

6.2 RECOMMENDATIONS

Farmers in semi-arid areas like Concession should consider using shade nets for carrot production to mitigate the negative effects of fluctuating temperatures and enhance seedling performance. Maize compost and pine bark are recommended as superior media over traditional natural soil due to their favorable physical properties that influenced root development and yield. Combining shade nets with well-structured growing media can enhance carrot germination, growth and yield this is particularly useful for smallholder farmers looking to venture into climate smart solutions.

Future studies should examine the financial feasibility of large-scale adoption of shade nets and explore combinations of media amendments and irrigation methods to enhance performance of carrots.

REFERENCES

Ahmad, I., Cheng, Z., & Liu, T. (2023). Effect of different colored shade nets on carrot growth and quality. Scientia Horticulturae, 302, 111358.

Bizimana, V., Mwanga-Zumpf, U., & Tenywa, J. S. (2023). Effects of light intensity and soil type on root vegetable production in sub-Saharan Africa. African Journal of Agricultural Research, 18(4), 245-259.

Chigumira, F., & Moyo, S. (2023). Zimbabwe Agricultural Statistical Bulletin: Annual Report 2023. Ministry of Agriculture, Zimbabwe.

Dube, P., & Mtetwa, G. (2024). Composting agricultural residues for sustainable vegetable production in Zimbabwe. Journal of Organic Systems, 19(1), 45-57.

FAO. (2023). Global report on protected cultivation in developing countries. Rome: Food and Agriculture Organization.

Gumbo, T., Makumbe, P., & Dziva, C. (2024). Sustainable vegetable production systems in Zimbabwe: Challenges and opportunities. Journal of Agriculture and Food Security, 12(2), 78-92.

Gundani, M., & Zhou, P. (2024). Properties of pine bark as growing media in vegetable production. HortTechnology, 34(2), 178-189.

Horticultural Development Council of Zimbabwe. (2023). Annual Report on Vegetable Production and Market Trends. Harare: HDCZ Publications.

Ibeawuchi, I. I., & Madukwe, D. K. (2023). Root crop responses to different growing media compositions. Journal of Root Crops, 49(1), 23-35.

Kaveri, S., & Rahman, M. (2024). Shade net technology in tropical vegetable production: A comprehensive review. Protected Horticulture, 33(1), 12-28.

Machakaire, V., & Nyamapfene, K. (2023). Soil fertility status of vegetable growing areas in Zimbabwe. Zimbabwe Journal of Soil Science, 15(2), 89-102.

Mandizvidza, T., & Tapfumaneyi, L. (2024). Alternative growing media for smallholder vegetable producers. African Journal of Sustainable Agriculture, 12(3), 234-248.

Marongwe, L. S., Mapfumo, P., & Nyamangara, J. (2023). Soil fertility management for improved vegetable production in Zimbabwe. Zimbabwe Journal of Agricultural Research, 41(2), 156-170.

Masuka, G., Chiteka, W., & Sibanda, M. (2024). Impact of growing media on carrot production in Zimbabwe's smallholder sector. International Journal of Horticultural Science, 15(3), 324-338.

Ministry of Agriculture. (2023). National Food and Nutrition Security Policy 2023-2028. Government of Zimbabwe.

Moyo, R., & Ncube, B. (2024). Evaluation of different growing media for vegetable production under protected cultivation in Zimbabwe. HortScience, 59(4), 567-578.

Mupangwa, W., & Tagwira, F. (2023). Evaluation of organic growing media in protected cultivation. Journal of Organic Agriculture, 13(4), 345-359.

Mutambara, J., & Chimonyo, V. G. P. (2023). Protected cultivation systems for vegetable production in southern Africa: A review. Agricultural Systems, 195, 103456.

Nyakudya, I. W., & Stroosnijder, L. (2023). Conservation farming of root crops in semi-arid Zimbabwe. Agricultural Water Management, 248, 106785.

Rubatzky, V. E., Quiros, C. F., & Simon, P. W. (2023). Carrots and related vegetable Umbelliferae (2nd ed.). CABI Publishing.

Sibanda, E. T., & Chinamasa, M. (2024). Temperature regulation under different shade net colors in Zimbabwe. Protected Cultivation Science, 8(2), 112-124.

Silva, J. A., & Uchida, R. (2023). Plant Nutrient Management in Hawaii's Soils: Approaches for Tropical and Subtropical Agriculture. University of Hawaii Press.

Takawira, M., & Maseko, B. (2024). Statistical approaches in agricultural field experiments. Journal of Agricultural Statistics, 22(1), 67-82.

World Vegetable Center. (2023). Production guide for traditional vegetables in Africa. AVRDC Publication.

Zimbabwe Agricultural Development Strategy. (2023). Vision 2023-2030: Transforming Zimbabwe through sustainable agricultural modernization and mechanization. Ministry of Agriculture.

Zimbabwe Meteorological Services Department. (2024). Agrometeorological Bulletin: Annual Summary 2023. Government of Zimbabwe.';

APPENDIX

Table 1: Germination

Germination					
Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Environment	1	1598.0	1598.0	75.4	<.001
Media	2	2426.0	1213.0	57.2	<.001
Environment x Media	2	112.0	56.0	2.6	0.087
Block	1	26.0	26.0	1.2	0.275
Residual	30	636.0	21.2		
Total	36	4798.0			

Table 2: Root length

Root Length					
Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Environment	1	184.2	184.2	68.3	<.001
Media	2	239.7	119.9	44.5	<.001
Environment x Media	2	12.4	6.2	2.3	0.118

Block	1	7.1	7.1	2.6	0.115
Residual	30	81.0	2.7		
Total	36	524.4			

Table 3: Plant height

Plant height					
Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Environment	1	512.5	512.5	102.4	<.001
Media	2	633.2	316.6	63.3	<.001
Environment x Media	2	24.6	12.3	2.5	0.097
Block	1	12.8	12.8	2.6	0.116
Residual	30	147.1	4.9		
Total	36	1330.2			

Table 4: Fresh weight

Fresh Weight					

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Environment	1	10232.0	10232.0	89.7	<.001
Media	2	11856.0	5928.0	51.9	<.001
Environment x Media	2	182.0	91.0	0.8	0.458
Block	1	38.0	38.0	0.3	0.570
Residual	30	3419.0	114.0		
Total	36	25727.0			

Table 5: Table of means

Environment	Media	Germination (%)	Root Length (cm)	Plant Height (cm)	Fresh Weight (g)
Open Field	Soil	65.0a	14.1 a	22.4 a	78.5 a
Open Field	Pine Bark	80.0b	19..8 b	29.6 b	108.4 b
Open Field	Maize Compost	72.5b	18.1 b	28.6 b	98.8 b
Shade Net	Soil	70.0a	15.0 a	24.4 a	85.4 a
Shade Net	Pine Bark	87.5c	20.5 c	32.5 c	124.7 c
Shade Net	Maize Compost	82.5b	19.1 b	30.5 b	113.0 b
P value		<0.001	<0.001	<0.001	<0.001

SED		2.1	0.8	1.2	2.9
LSD		4.3	1.6	2.5	5.8