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FACULTY OF AGRICULTURE AND ENVIRONMENTAL SCIENCE

TOPIC: *EVALUATING THE EFFECT OF VARIETY AND ROOTING AGENTS AND VEGETATIVE DEVELOPMENT OF SWEET POTATO VINES.*

Rumbidzai Maketa

B211779B

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DECLARATION

I, Rumbidzai Maketa, do hereby declare that this research project is a result of my original research work undertaken by myself, except where clearly and specifically acknowledged. It is being submitted in partial fulfillment of the Bachelor of Agricultural Science Honors Degree (Crop Science). It has not been submitted before for any degree or examination at any other university.

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DEDICATION

This dissertation is dedicated to my family.

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ABSTRACT

Sweet potatoes are a vital source of food, especially in rural areas, and their resilience to drought makes them a reliable crop in the face of climate change. The objective of this study was to evaluate the efficacy of the effect of variety and rooting agent, and vegetative development of sweet potato vines. The research was conducted using a factorial experimental design laid down as a randomized complete block design. Vine length, number of roots, root length, and yield were observed daily; the data which was analyzed for variance using Genstat version 18. The results showed that there was an interaction between rooting agents and variety on all measured growth parameters ($p<0.05$). Zimbabwe Red variety had longer vines>longer roots>number of roots>yield than White Jewel variety. Integrating natural rooting agents such as Honey, with Zimbabwe Red promotes the achievement of roots and plant health, leading to increased yields. This helps farmers to attain better yields and supply food security to communities. It is therefore recommended that farmers should integrate effective rooting agents, especially Seradix and Honey, in sweet potato propagation.

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CHAPTER 1

1.0 Background of the study.

Sweet potatoes (*Ipomoea batatas*) belong to the family Convolvulaceae, which is one of the 400-500 species and among 50 genera of the Convolvulaceae family (Dinu *et al.*, 2021). Sweet potato is one of the major food crops in the world. However, the productivity of sweet potato is often limited by the availability of high-quality planting material. The use of sweet potato vines as planting materials has become increasingly popular, but the success of vine-based propagation depends on the ability to efficiently root and establish the vines.

This study aims to investigate the effects of variety and rooting agent on the rooting and vegetative development of sweet potato vines, using Aloe *vera* gel, honey, and Seradix as a rooting agent and evaluating their interaction with sweet potato varieties, white variety (white jewel), and red variety (Zimbabwe red).

According (Dussaubat *et al.*, 2013) to the production of sweet potatoes has been only for human consumption, however sweet potatoes are not only for human consumption but for forage, which is very important for the feeding of animals which may include sheep, goats and cattle and is also used in industrial processes which may include sweet potato chips and also used for sweet potato juice. Sweet potatoes have got high content of sugars, which is essential for the production of ethanol and also the production of biogas. Waste that comes from sweet potato production is used in the manufacturing of biogas.

In Zimbabwe, sweet potatoes are mainly grown for human consumption, which is used as a substitute for rice and bread. The economic significance of sweet potatoes has led to an increase in their consumption in both rural and urban markets overall. Compared to other tuber crops like Irish potatoes, sweet potatoes have a higher energy content. The production of sweet potatoes is cheaper as compared to the production of Irish potatoes. Because of this, smallholder farmers in Zimbabwe may prefer to grow sweet potatoes.

According (Mng'omba (2023), sweet potatoes can be grown in a wide range of soils, but they favor soils that have high organic matter content, good aeration, and well-drained soils. The best soils for sweet potato production may include sandy loam, clay loam, and silt loam. Ridges are essential in increasing water infiltration, thereby reducing the effects of runoff. The use of ridges in the production of sweet potatoes controls the rate of soil erosion and helps in the conservation of moisture content levels (Mizutani *et al.*, 2023). The days to maturity of this crop vary depending on the climate, soils, and variety. For early maturity varieties, it takes up to 70-90 days, medium 90-120 days, and late maturity takes up to 120- 150 days Yanfu *et al.*, 1989).

The use of rooting agents such as Aloe vera gel, Honey and Seradix on vegetative propagation in sweet potatoes production is very essential as it is cost effective, easy to implement and also it matches with the needs and limitations of resource poor farmers therefore this helps in promoting root development and yield(Dinu *et al.*, 2021).

1.1 Problem statement

A critical factor influencing the rooting and development of sweet potato vines is the interaction between variety and rooting agent. Despite the importance of this interaction, there is limited information on the effect of different sweet potato varieties and rooting agents on vine rooting and development.

1.2 Justification of the study

Sweet potatoes provide food and growth of the economy. However, the production of sweet potatoes is reduced by insufficient propagation technologies, which include the application of improper varieties and rooting agents. By examining the effects of different sweet potato varieties and rooting agents on reproduction, this investigation can offer beneficial insights to optimize methods, enhancing crop yields and increasing the overall productivity of sweet potatoes, eventually contributing to food availability and economic growth.

1.3 Objective of the study

This study aims to investigate the effects of variety and rooting agent on the rooting and vegetative development of sweet potato vines, using Aloe vera gel, Honey, and Seradix as a rooting agent and evaluating their interaction with sweet potato varieties, white variety (white jewel), and red variety (Zimbabwe red).

Specific objectives

- To evaluate the effect of variety and rooting agent on the vegetative growth of sweet potatoes.
- To assess the effects of variety and rooting agent on the yield of sweet potatoes.
- To compare the effectiveness of Seradix, Honey, and Aloe vera gel in promoting root development in sweet potatoes

Hypothesis

- Variety and rooting agent have significant effect on vegetative growth of sweet potatoes
- Variety and rooting agent have significant effect on sweet potato yield
- Variety and rooting agent have significant effect on root development in sweet potatoes.

CHAPTER 2

2.0 Literature Review

Zimbabwe Red variety is another variety that the researcher used in the research project. The Zimbabwe red variety is primarily grown for the local market, with some exports to neighboring countries. The Zimbabwe red requires an optimal temperature range from 18ºc to 28ºc. It also prefers well-drained sandy loamy soils with a pH of 5.5 to 6.5.The yield of Zimbabwe ranges from 8-10 tons per hectare and requires adequate rainfall of a minimum of 600mm per growing season.

2.1 Functions of rooting hormones

According to Johnson *et a*l (2016), *Ipomoea batatas* is not consumed only as a staple food but rather as a powerhouse for many essential nutrients needed. Sweet potatoes are an excellent source of vitamin A, vitamin C, and fiber. However, their successful cultivation often depends on the successful root development, which is required for the maximum uptake of nutrients, water absorption and also is needed for plant growth and development. The potential of natural substances to enhance root development in sweet potatoes has been informed, such as Aloe vera gel, Honey, and Seradix.

Rooting agents, which are also known as rooting hormones, are substances that stimulate root growth and development in plants. While they are called hormones, not all rooting agents contain actual plant hormones. The agents play a vital role in plant propagation, which is important for the production of sweet potatoes and for many plants that are grown. Rooting agents are very important in the agricultural sector as they provide a wide range of advantages for both the farmer and the economy. These agents have different functions that promote the establishment of roots in sweet potato vines (Mukhopadhyay *et al*., 2011).

2.1.1 Aloe vera

According to Boudreau *et al*., (2006), aloe vera gel which is known as (*Aloe barbadenis* Miller) is a plant that is mostly used in agricultural production, such as in animal production, crop production and is also used up by human beings as medical properties of skin benefits. The gel is collected in plants that are rich in vitamins, minerals and enzymes making it a popular product to be used. Research has shown that sweet potato vines exhibit improved rooting and vegetative growth. For example, the research done by (Khan *et al.*, 2023) found that aloe vera gel increased root length in sweet potato vines by 60%. Another research done by (Rajakeerthi and Nivedhitha, 2019) reported that aloe vera gel treated vines have high leaf area and dry matter accumulation compared to untreated vines.

Aloe vera gel promotes root development, the gel consists of plethora of bioactive compounds that include auxins, cytokinins and gibberellins which are plant growth hormones, these hormones are known to manage growth and development of the plant. The gel plays a crucial role in cell division and elongation which is required in root formation (Mishra, Pandey and Singh, 2017).

When the gel is applied to sweet potato cuttings, this improves the development of roots. The gel also promotes the formation of root hairs, which allows to extraction of water from the soil. Studies have indicated that sweet potato cuttings handled with aloe Vera gel demonstrated a higher root biomass compared to untreated controls, emphasizing its effectiveness in root development. (Mishra, Pandey, and Singh, 2017). The gel contains bioactive compounds such as amino acids, vitamins and minerals that can be released into the soil, these bioactive helps in promoting soil fertility. The bioactive compounds which comes from aloe vera gel can be absorbed by plants, but often taken in small quantities and benefit the plant indirectly, by improving the soil structure and fertility.

Aloe vera gel is crucial in moisture retention in the soil and ensure that the sweet potato have enough access to the extraction of water from the soil. The gel works as a natural hydrogel, which retains moisture in the soil. The use of Aloe vera gel increases water holding capacity, hence improving soil structure.

According to Das *et al.*, (2022), Aloe vera gel is used as a stimulate to reduce pest infections and stress tolerance in sweet potato cuttings. The gel retains antimicrobial properties that help in the prevention of young roots from being attacked by pathogenic fungi and bacteria. By forming a protective barrier around the roots, Aloe vera gel limits the risk of root rot and soil borne diseases that can delay growth and development of sweet potatoes' roots. (Behera *et al.*, 2022) farmers can easily combine Aloe vera gel into their cultivation practices by adding it into the soil or mixing it with water for folia sprays. This method can be advantageous for most small and commercial farmers in Zimbabwe.

Aloe vera gel has been widely used in plant propagation due to its antimicrobial and anti flammatory properties in the realm of horticulture.(Rajakeerthi and Nivedhitha, 2019) reported that aloe Vera gel promotes root growth, development of the seed, and enhances the survival of the plant in stressful conditions. The plants that were treated with Aloe vera gel performed well, as there was improvement in vigor and resilience. Less prone to diseases and pests due to the gel's antimicrobial properties.

2.1.2 Honey

Honey is a sweet juice which is produced by bees, and is an effective rooting agent in sweet potatoes. The honey contains hydrogen peroxide, a natural antiseptic that stimulates root growth and wound healing.(Karuniawan *et al.*, 2021) States that Honey also contains antioxidants that protect the plant from oxidative stress and promote healthy root development.

According to (Souza Cunha *et al.*, 2020), the maintenance of healthy balance in the soil is very crucial for the development of roots. The availability of glucose and fructose provides quick energy for microbial activity. Honey with a natural antimicrobial properties facilitate in protecting young sweet potato shoots and tubers from fungal and bacterial infections, thus aiding in healthy early stage growth.

The use of honey in the development of sweet potatoes promotes root formation in cuttings due to its natural plant hormone. Auxins are plant hormones that initiate root development in sweet potato cuttings, specifically when applied to the nodes of the cuttings before planting. By doing so, this leads to the sprouting and faster establishment in the soil. By supporting a stronger root system and enhancing resistance to build up of disease build-up, it indirectly boosts better tuber development, improved yields, and overall growth of healthier sweet potato crops. Honey aligns well with organic farming practices; it is an eco-friendly and responsible option for highlighting sweet potato cultivation (Almasaudi, 2021).

2.1.3 Seradix

Seradix is a commercial man-made rooting hormone product that involves Indole-3-butyric acid (IBA) and it's an active ingredient. One of the functions of Seradix is the enhancement of root development (Aini *et al.*, 2010). When applied to sweet potato cuttings, Seradix boosts the formation of adventitious roots, which are needed for anchoring the plant and assist in nutrient uptake. This is why sweet potatoes have got strong root system when applied Seradix. This is very crucial in sweet potato production, where a strong root system directly connects with the size and quality of the tubers produced. Seradix allows a fast growth rate of roots, reducing the time needed for the establishment of roots, leading to faster growth and earlier harvest. The hormones present in Seradix include indole-3 butyric acid (ABA) (Diaz *et al.*, 2023).

According to Keswani *et al.,* (2020) the use of Seradix improves nutrient absorption, developed root system increases the surface area for the uptake of nutrients needed by the plant, allowing sweet potatoes to access minerals and water needed for development. Healthy root systems are important for nutrient absorption. Seradix not only promotes the quantity of the roots but also promotes the quality of the roots of sweet potatoes. The surface area of roots is improved by the rooting agents such that they are able to source nutrients from the soil which is vital for the growth and development of the plants. This is important in areas where nutrients are poor in the soil, where sweet potatoes may thrive.

Due to the use of the rooting hormones, plants increase resistance to stress in areas where there is salinity, drought, and diseases, by promoting a robust root system. Seradix helps sweet potatoes withstand adverse weather conditions. Seradix facilitates in propagation of sweet potatoes. Caplan *et al.,* (2018) the rooting hormone improves the success rate of vegetative propagation which is the best method that is used in vegetative propagation. Cuttings are treated with Seradix before being planted in the soil, which promotes the growth of roots. The purpose of propagating sweet potatoes properly is important for meeting the growing demand for the nutritious tuber.

2.2 Other parameters that can be used as rooting hormone

Besides the use of the above rooting hormones, there are other natural hormones that can be used in the propagation of sweet potatoes, such as cinnamon and willow water, to improve the rooting system. (Chen *et al*, 2021) Willow water is responsible for enhancing the rooting capability of sweet potatoes. The bark of the young shoots of the willow comprises of high concentration of salicylic acid. This is a natural auxin that is used for the development of the root of sweet potatoes. To obtain willow water. Willow branches are taken and put in water for several days, allowing the compounds to drain into the liquid. After the solution is extracted, sweet potato cuttings are treated with the solution before planting. This creates a vigorous root system that supports flourishing growth.

CHAPTER 3: METHODOLOGY

3.1 Experimental Site

The research was conducted at Oribi Park Farm in Karoi, which is in Mashonaland West Province, located in Natural Region 11 of Zimbabwe. The farm's geographic coordinates are approximately 16.8155ºS latitude, 29.6905ºE longitude of Karoi. The climate at the farm is a subtropical climate with warm summers and mild winters. The annual rainfall ranges from 850mm to 1000mm and primarily occurring in November to March, with most rainfall occurring in December and January. It is characterized by mid-season dry spells with summer temperatures ranging between 27℃ and 38℃ and winter temperatures between 6℃ and 25℃. The land is slightly gentle with sandy loam soils 0.5 m deep. The soil pH range is 5.8, and the soil type is sandy loamy soils.

3.2 Experimental Design

A Randomised Complete Block Design arranged

arranged in a factorial manner was used. There were two factors: the first factor was variety, and the second factor was the rooting agent. Rooting agent had three levels: Aloe Vera gel, Honey and Seradix, while the variety had two levels: (Zimbabwe Red and White Jewel). The trial was replicated four times and the blocking factor was soil type.

3.2 General management of the trial

3.2.1 Land preparation

The land was cleared using slashes and hoes because the weeds were at an advanced vegetative stage. The land was prepared through hoeing and slashing to obtain a fine tilth. Hoeing depth was done to a depth of 5-15cm.

3.3.1 Agronomic Practices

3.3.2.1 Soil Testing

Before planting, soil tests were conducted to determine nutrient levels, and soil pH was used. The soil pH range was 5.8. It is most likely that most of the crops grow absolutely well in that pH, but some crops need management.

3.3.2.2 Weed Control

The pre-emergence herbicide was applied on the 9th of December 2024. Clomazone was applied at a rate of 0.5kg ai/ha. The manual weeding was also performed throughout the growing period. The weeds that were controlled by clomazone include broadleaf weeds and grassy weeds.

3.4 Data collection

3.4.1 Root length

The ruler was used to measure the length of the longest root (tap root) on specific days. In order to prevent the roots from damage, careful handling was put into consideration. This involves the application of water on the plant, such that roots are easily accessible as the soil becomes moist. This method minimized the risk of breaking down the roots and the plants.

3.4.2 Vine length

The tape measure was used to measure the vine length. The vine length was measured from the base of the stem to the tip of the highest point of the plant. The measurement was in centimetres.

3.4.3 Number of roots

The observations were made daily for the signs of root development, such as visible roots. The number of roots per plant and recording number of roots per plant were recorded.

3.4.4 Yield

The plant was harvested at maturity, and the tubers were sorted based on size, shape, and quality. The yield per plant was calculated.

3.5 Data Analysis

The data was analysed using the ANOVA technique with the Gestalt 14 version software. Where there were significant differences, the means were separated using the least significant Difference at a 0.05 probability level.

CHAPTER 4: RESULTS

4.1 Effect of rooting agents and variety on vine length

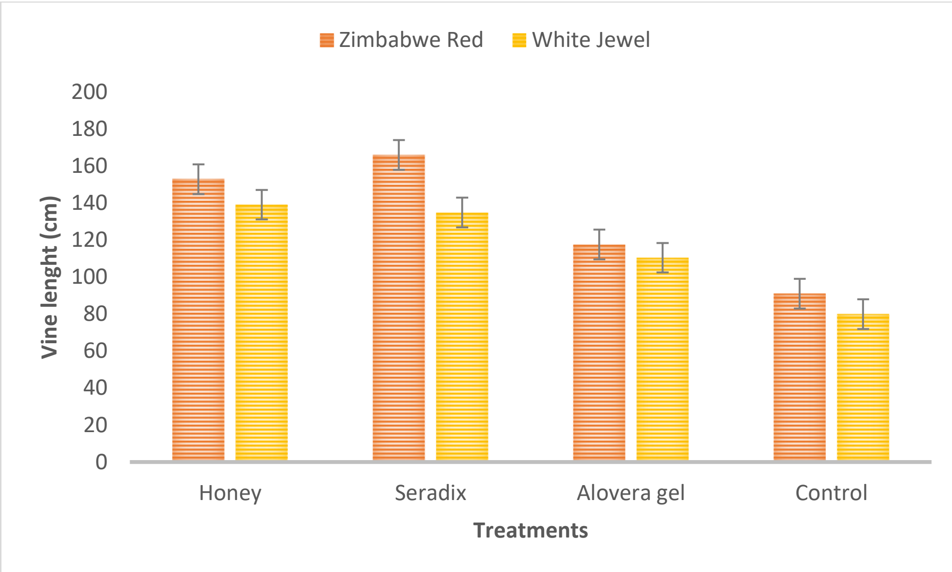

Figure 4.1: Effect of different rooting agents on vine length.

There was an interaction between rooting agents and sweet potatoes variety ($p<0.05$) on vine length. Honey, Aloe vera gel and Seradix had effect on vine length ($p<0.05$) of White Jewel and Zimbabwe Red varieties. Zimbabwe Red had longer vine length in all rooting agents than White Jewel in all rooting agents.

4.2 Effect of rooting agents and variety on root length

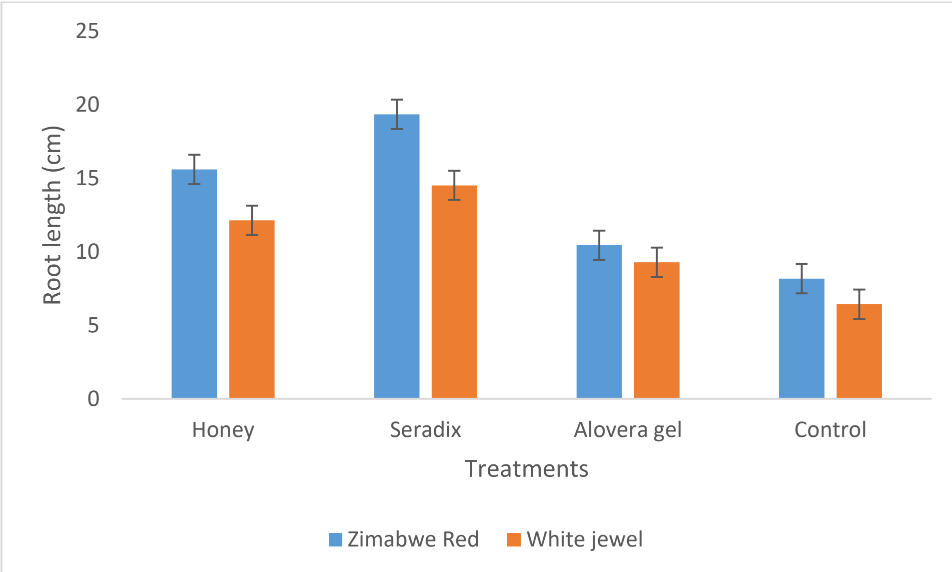

Figure 4.2: Effect of different rooting agents on root length.

There was a significant interaction between rooting agents and variety (P<0.05) on root length. Zimbabwe Red had longer root length in all rooting agents than White Jewel variety had in all rooting agents. Rooting agents (Seradix, Honey and Aloe vera gel) had an effect on root length of all varieties.

4.3 Effect of rooting agent and variety on the number of roots

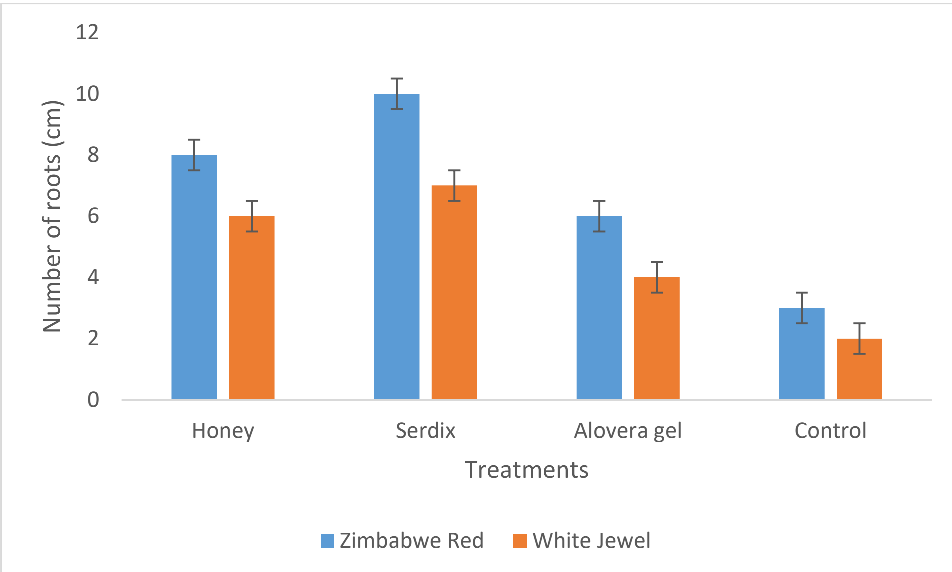

Figure 4.3: Effect of different rooting agents on the number of roots.

There was an interaction between rooting agents and variety ($P<0.05$) on number of roots. Rooting agents (Seradix, Honey and Aloe vera gel) had an effect on number of roots of White Jewel and Zimbabwe Red varieties. Zimbabwe Red had the highest number of roots in all rooting agents and White Jewel variety had fewer number of roots in all rooting agents.

4.4 Effect of rooting agents and variety on yield

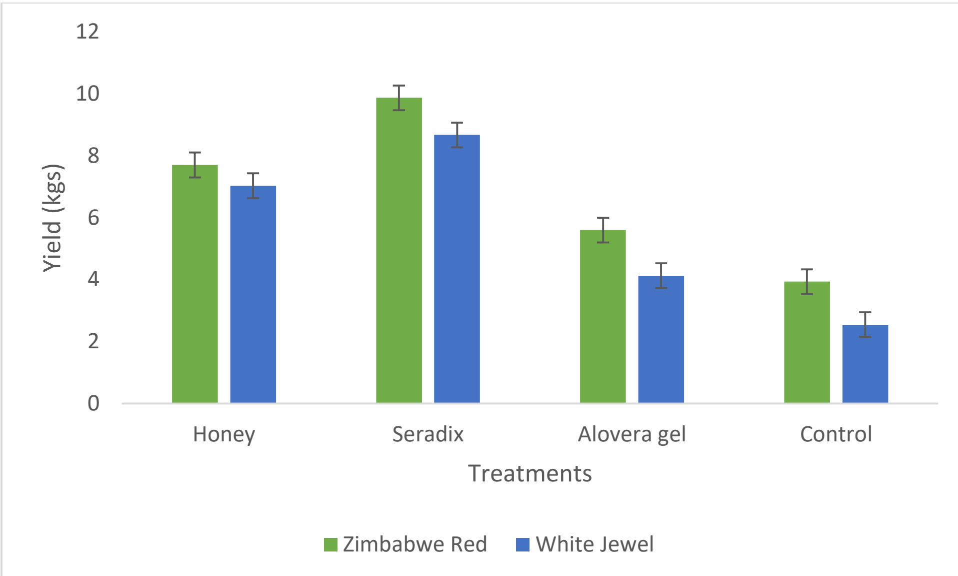

Figure 4.4: Effect of different rooting agents on sweet potato yield.

There was a significant interaction between rooting agents and varieties on yield ($p<0.05$). Seradix, Honey and Aloe vera gel had an effect on yield of White Jewel and Zimbabwe Red varieties. Zimbabwe Red had higher yield in all rooting agents and White Jewel variety had in all rooting agents.

CHAPTER 5: DISCUSSION

5.1 Effects of rooting agents and variety on vine length

Seradix outperformed the best because it is a synthetic plant hormone that contains auxins. This promoted the adventurous root formation which enhanced nutrients uptake this resulted in longer vine length of Zimbabwe Red and White Jewel varieties Dussaubat *et al.*, (2013). Zimbabwe Red had a greater hormonal sensitive to Seradix which allowed it to respond more effectively to Seradix, which made it to have longer vine length. The high sensitive of Zimbabwe Red can also make it respond effectively to natural treatments like Honey and Aloe vera gel, hence it outperformed White Jewel in vine length. The White Jewel has lower auxin responsiveness to Seradix, and this made in have smaller vine length. The White Jewel might have slower root initiation, which limited its vine growth under Honey and Aloe vera gel.

Honey has antimicrobial properties that protect cuttings from pathogens. These properties make Zimbabwe Red and White Jewel perform better than when they are in Aloe vera gel Khan *et al.*, (2023). The sugars in Honey nourish early vine development. Honey lacks auxins, but its protective and nutritive qualities enhance root establishment in the moderately responsive White Jewel variety. Aloe vera gel has got enzymes, vitamins, and salicylic acid that support vine growth in sweet potatoes. Aloe vera gel lacks auxins, which can make it weaker in stimulating vine growth. Without the use of rooting agents, the development of vines was slow because they depended on the plant's natural hormones Dussaubat *et al.*, (2013).

5.2 Effect of rooting agents and variety on root length

Seradix contains synthetic auxins that directly stimulate root growth. This can lead to rapid root formation, hence enhancing nutrients and water uptake. The consistency in hormone stimulation is more beneficial to vigorous cultivars Khan *et al.*, (2023). This can make Zimbabwe Red perform better in root length than White Jewel which have a slow response to auxins Dussaubat *et al.*, (2013). Zimbabwe Red had a greater hormonal sensitivity to Seradix, which allowed it to respond more effectively to Seradix, resulting it to have longer root length. The high sensitivity of Zimbabwe Red can also make it respond effectively to natural treatments like Honey and Alovera gel hence it outperformed White Jewel in root length. According to (Heineman and Kucharik, 2022), practicing crop rotation and soil amendments are effective methods that can be used for root growth development. Honey has got protection compounds and nutrients against pathogens and this can make Zimbabwe Red and White Jewel perform better than in Aloe vera gel which has some salicylic acids and enzymes which root enhance root development slowly.

5.3 Effect of rooting agent and variety on the number of roots

Zimbabwe Red and White Jewel performed better in Seradix than all other treatments. Seradix contains auxins that promote root development in sweet potatoes Dussaubat *et al.*, (2013). This treatment produce the highest root number in Zimbabwe Red which responded more effectively to rooting hormones than White Jewel. The White jewel potato variety has got few roots because it does not respond very effectively to rooting hormones. Honey has got nutrients and sugars that promote root development Khan *et al.*, (2023). This resulted in Honey treatments to have more roots in all varieties than treatments of Aloe vera gel for all varieties. Aloe vera gel contains enzymes and vitamins and less nutrients that promote root growth and this resulted reduced the number of roots formed in this treatment for all varieties. In control treatments where all varieties depended on their natural hormones Zimbabwe Red performed better than White Jewel in number of roots because Zimbabwe Red has a vigorous growth. The results showed that Zimbabwe Red has sensitivity to all rooting agents, which made it outperform White Jewel in the number of roots.

5.4 Effect of rooting agents and variety on yield

The Zimbabwe Red variety produced more yield than the White Jewel variety in all treatments. This is because Zimbabwe Red has high sensitivity to auxins that are in Seradix and this improved its growth hence the yield was also better than the other variety. In natural hormones like Honey and Aloe vera gel Zimbabwe Red showed vigorous growth which resulted in this variety to produce more yield. White Jewel variety showed low sensitivity to rooting hormones, and this affected its yield. This variety has also slow growth rate which affected the final yield in different treatments. The research which was conducted by (Kalashnikova *et al.*, 2021) indicates that a well-developed root system is important for the uptake of nutrients and for the root architecture which determines the performance of a plant. The control treatments depended on the varieties' natural hormones. The Zimbabwe Red performed better than White Jewel, but all varieties in control produced less yield than when they were in rooting agents. This showed that rooting agents can improve the yield of sweet potatoes.

CHAPTER 6

6.1 Conclusions

The interaction between variety and rooting agents affected the vegetative growth of sweet potato varieties. The Zimbabwe Red variety, which was treated with Seradix, demonstrated the greatest root and vine length development. Zimbabwe Red which was treated with Honey performed better in terms of vine length, root length, root number and yield than Zimbabwe Red which was treated with Aloe vera gel. This shows that both variety and rooting agents significantly influenced vegetative growth of Zimbabwe Red. There was a significant interaction between rooting agents and White Jewel variety In White Jewel variety which was treated in Seradix performed better in all parameters than White Jewel variety which was treated with Honey and Aloe vera gel respectively. White Jewel variety showed reduced performance in all parameters and it was outperformed by Zimbabwe Red. This showed that Zimbabwe Red variety had high sensitivity to rooting agents than White Jewel variety.

6.2 Recommendations

From the results, farmers are recommended to use Seradix integrated with Zimbabwe Red for sweet potato propagation, as it continuously produced the longest vines, increased in root numbers especially the Zimbabwe Red variety. This promotes vegetative development of sweet potatoes, this makes Seradix a valuable input for maximizing productivity and improving crop establishments. For farmers with limited resources, Honey provides a practical and effective alternative. Honey is cheap, easily accessible, and naturally promotes root development and protects roots from pathogens in early development stages. Smallholder farmers are recommended to use Zimbabwe Red variety as it more sensitive to rooting agents which can make rooting agents work better on this variety. Farmers may use Honey as an alternative to Seradix because it may be less accessible in rural areas or resource limited farming areas. Seradix maybe too expensive for small scale subsistence farmers operating on tight budgets while it is very effective due to its auxin content.

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APPENDICES

Appendix 1: *Analysis of variance*

Variate: Number of Roots

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	1	0.3125	0.3125	0.47	
Rep.*Units* stratum					
Agent	3	395.2375	131.7458	196.56	<.001
Variety	1	52.8125	52.8125	78.80	<.001
Agent.Variety	3	13.9375	4.6458	6.93	<.001
Residual	15	47.5875	0.6702		
Total	23	509.8875			

Appendix 2 : *Analysis of variance*

Variate: Root_Length

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	1	0.1051	0.1051	0.17	
Rep.*Units* stratum					
Agent	3	1089.0444	363.0148	595.27	<.001
Variety	1	157.0801	157.0801	257.58	<.001
Agent.Variety	3	41.5794	13.8598	22.73	<.001
Residual	15	43.2979	0.6098		
Total	23	1331.1069			

Appendix 3: *Analysis of variance*

Variate: Vine_Length

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	1	55.28	55.28	2.99	
Rep.*Units* stratum					
Agent	3	55233.93	18411.31	995.37	<.001
Variety	1	4969.13	4969.13	268.65	<.001
Agent.Variety	3	1680.37	560.12	30.28	<.001

Residual	15	1313.28	18.50		
Total	23	63251.98			

Appendix 4*: Analysis of variance*

Variate: Yield

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block stratum	1	0.5340	0.5340	5.28	
Block.*Units* stratum					
Agent	3	14.8862	4.9621	49.07	<.001
Variety	1	1.8653	1.8653	18.45	0.004
Agent.Variety	3	0.3988	0.1329	1.31	0.343
Residual	15	0.7079	0.1011		
Total	23	18.3921			