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Agronomic performance of sweet potato genotypes in Eswatini under organic and inorganic soil amendments

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Abstract

Two field trials were conducted at the Lowveld Experimental Station (LES) and Malkerns Research Station (MRS) to determine the agronomic performance of sweet potato genotypes in Eswatini under organic and inorganic soil amendments. A 3 x 5 factorial experiment was laid out in a randomised complete block with three replications. The treatments included four sweetpotato genotypes, Namanga, Cecelia, Melinda and Ligwalagwala with five nutrient amendments: no fertiliser/manure, four rates of cattle manure at 20, 40, 60 and NPK 2:3:4 (39) at 0.45 tonnes per hectare. Field results showed significant differences ($P < 0.05$) among sweet potato genotypes and yield at LES and MRS. Mean petiole and vines lengths at LES and MRS under the different treatments. showed significant differences among sweet potato genotypes. Results from LES and MRS showed that growing Melinda using inorganic fertilizers at 0.45 t/ha gave the highest marketable yield of 29.46 and 26.34 t/ha respectively. The results showed relatively similar levels of performance of inorganic fertilizer when compared with cattle manure applications.

Keywords: Ligwalagwala; Melinda; Cattle Manure; Inorganic Fertilizers; Yield

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1. Introduction

Sweet potato [*Ipomoea batatas* (L.) Lam] originated in South America, with the most significant centre of diversity located in the region spanning Peru, Colombia, and Ecuador (Smith et al., 2019). It is the third most economically important herbaceous perennial root crop worldwide (Marques et al., 2022). Sweet potatoes are cultivated in over 115 countries, with global annual production surpassing 120 million tonnes. The leading producers are China, Nigeria, and Tanzania (FAOSTAT, 2020; Tang et al., 2022 and Xiao et al., 2022). It is typically a smallholder crop, tolerant to adverse growing conditions, and often cultivated on marginal soils with minimal inputs (Namanda et al., 2011). Orange-Fleshed Sweet Potato (OFSP) is a bio-fortified sweet potato with higher β–carotene (Neela and Fanta, 2019). According to Nwankwo et al. (2019), orange flesh comes in various skin colours ranging from light cream, yellow, orange, and deep purple. The flesh colour ranges from light orange to deep orange.

Orange-fleshed sweet potato plays a crucial role in addressing food shortages and malnutrition. It is a nutritionally valuable source of beta-carotene, a precursor to vitamin A, as well as vitamins B6 and C (Robertson et al., 2018). At the same time, it has the potential to maintain human health by mitigating diseases and generating income to improve the livelihood of the people (Nwankwo et al., 2019). Sweet potatoes are considered a high-yield crop with good yield even in nutrient-poor tropical soils (Parecido et al., 2024). The scarcity of chemical inputs, organic matter, and adequate irrigation facilities in Eswatini makes sweet potato an ideal crop for Swazi farmers (Ossom, 2010). Tutu et al. (2022) observed that low production levels of sweet potato can be attributed to factors such as low soil fertility and non-application of nutrient amendments in sub-Saharan African countries including Eswatini. Singh et al. (2017) noted that application of organic manure such as cow manure will improve the physical, chemical and biological properties of the soil that support and facilitate the growth of sweet potatoes, especially the lengthening of sweet potatoes.

According to Antonious (2024), organic fertilizers improve not only the quantity but also the nutritional quality of sweet potatoes, with cow manure increasing vitamin C and β-carotene levels significantly. In agricultural production systems, animal manure (chicken manure, horse manure, vermicompost, municipal sewage sludge), and other organic amendments such as biochar have been recommended as alternatives to elemental inorganic fertilizers (Antonious, 2022; Antonious et al., 2023). The application of organic fertilizers significantly improves soil structure, aeration, water-holding capacity, and temperature regulation, while also providing essential nutrients that support plant growth (Kolawole et al., 2019). According to Gelaye (2023), continuous reliance on chemical fertilizers leads to nutritional imbalances and negatively affects the physicochemical and biological properties of the soil. In Eswatini, farmers apply little or no fertilisers to root and tuber crops, including sweet potato with the notion that the crop is adapted to poor soils and its cooking and nutritional quality will be compromised if the soil is fertilized.

Phungwayo et al. (2021) reported that the Annual Vulnerability Assessment and Analysis of 2019 revealed that, 14.2% of Swazis experienced moderate hunger, while 8.5% faced severe hunger, falling short of meeting the national dietary requirements for grains and protein. Increasing agricultural productivity is a means to achieve the second Sustainable Development Goal (SDG 2), which aims at ending hunger and malnutrition by 2030 (Montagnini and Metzel, 2017) Ejigu. Better food security and nutrition remains a priority in improving the lives of many segments of the Eswatini population. Household dietary diversity had declined, with 23% of the population perceiving that they do not have an acceptable diet (SADC, 2019). Hence, strategies such as integrated nutrient management should be implemented to enhance crop yields. In this context, a study in Eswatini was conducted to identify locally adapted, high-yielding, and farmer-preferred orange-fleshed sweet potato (OFSP) varieties. The evaluation was conducted over a period of two cropping seasons: 2019-2020 and 2020-2021. Four OFSP varieties (Namanga, Alisha, Cecelia and Melinda) tasted better and yielded high than the local varieties hence were recommended for release.

Therefore, there is a need to increase the availability of the beta-carotene-rich, OFSP varieties. Overuse of fertilizers, especially inorganic fertilizers, slows the growth of tubers, which have a watery texture and poor cooking quality (Sandhu and Sandhu, 2023). The need to evaluate the yield efficiency of sweet potato genotypes under organic production systems is necessary mainly because of soil fertility degradation coupled with scarcity and expensive inorganic fertilizers. The cultivation of OFSP genotypes with higher yields could improve the socio-economic conditions of the farming community as well as their nutritional status. Hence the present study aims at evaluating the effects of inorganic fertiliser and kraal (cattle) manure, applied to compare vegetative, yield traits and tuber quality of three OFSP and one local white fleshed variety grown in two ecological zones: Lowveld Experimental Station (LES) in the Lowveld agro-ecological zone and Malkerns Research Station (MRS) in the Middleveld agro-ecological zone of Eswatini.

2. Materials and methods

2.1. Planting materials

Planting vines of the orange fleshed sweet potato and the white fleshed Ligwalagwala were sourced from Malkerns Research Station nursery.

2.2. Site description and experimental design

The field trials were carried out from December 2022 to April 2023 cropping season at two sites; the LES which is located in the Lowveld region (26° 57.95S, 31° 31.52E; 89 metres above sea level), with mean temperatures ranging between 26.4 to 30.5°C and annual rainfall of 450 millimetres. The soils are classified as Vertisolic by Murdoch (1968), which are dark brown clay, neutral and, fertile with a prominent swelling and shrinking nature during the wetting and drying cycles. The second site; MRS (26.57^{o}S, 31.17^{o}E; altitude, 740 metres above sea level; rainfall range, 800-1460 mm during the cropping season; mean temperature range, 7.3-26.6^{o}C during the growing season). Soils in Malkerns Research Station are deep red loam, Ferralsols, or the Mdutjane soil series and are strongly weathered with an oxichorizon (Dlamini, 2017). The rainfall and temperature during the experimental season are shown in Table 1.

Soil fertility was assessed through sampling, and the results were used to determine the appropriate amount of fertilizer to apply. A composite soil sample following a zig-zag pattern was taken using an auger, where soil cores of 20 cm depth were collected every after 15 footsteps. These cores were combined into one composite sample in a plastic bucket and mixed well. Then a cup full sample was taken from the mixture for analysis. Analyses of soil analyses from the experimental sites and cattle manure are shown in (Tables 2 and 3). The Walkley-Black (1947) method was used for quantifying the organic carbon content of soil samples.

Table 1. Rainfall and temperature at LES and MRS during the 2023 growing season

MONTH	LES		MRS	
	Rainfall (mm)	Temperature (°C)	Rainfall (mm)	Temperature (°C)
February	270.7	32.2	168.8	27.4
March	7.5	32.3	84.4	27.9
April	0	31	8.2	27.2
May	59.5	30.3	73.2	24.5
June	0	30.2	0	24.6
July	0	29.7	31.6	21.9
Total	337	185.7	366.2	153.5
Mean		30.95		25.58

Table 2. Chemical analysis of soils from MRS and LES done using soil comprehensive AMBIC procedure at Royal Eswatini Sugar (RES) Laboratory.

Sample Reference Number	Location	Cu (ppm)	Fe (ppm)	Mn (ppm)	Zn ppm	Ca (ppm)	Mg (ppm)	pH	P (ppm)	K (ppm)
1	MRS	5.82	85.09	5.31	3.18	684.88	228.81	6.24	39.29	382.68
2	LES	6.65	7.24	5.36	1.32	4256.44	836.80	8.57	184.00	230.67

Cu = Copper Fe = Iron Mn = Manganese Zn = Zinc Ca = Calcium Mg = Magnesium P = Phosphorus and K = Potassium ppm = parts per million

Table 3. Chemical composition of cattle manure used in the study done using soil comprehensive AMBIC procedure at Royal Eswatini Sugar (RES) Laboratory

Sample Reference Number	Location	Variety	N (%)	P (%)	K (%)	Mg (%)	Ca (%)
1	MRS	Sweet Potato	1.40	0.10	3.01	1.75	3.55

N= Nitrogen / Ca = Calcium / Mg = Magnesium / P = Phosphorus / K = Potassium

2.3. Field experimental design

The field trials were laid out in a 3 × 5 factorial using a Randomized Complete Block Design (RCBD) with three replications per treatment. Each plot measured 6.0 m by 3.6 m wide and consisted of four ridges. There were

1.0 m footpaths separating treatments plots and 2.0 m between blocks thus each plot measuring 21.6 m^2. The first treatment comprised of three OFSP (Namanga, Cecelia and Melinda) and a control, white fleshed (Ligwalagwala). The field trials were planted under rain fed conditions. The sweet potato varieties were selected on the basis of high yield. Four rates of cattle manure at 0, 20, 40 and 60 tonnes per hectare were used. The control used NPK 2:3:4 (39) at a rate of 0.45 tonnes per hectare. To assess soil fertility of the field, soil sampling was done and the results were used to calculate the amount of fertilizer to be applied. A composite soil sample following a zig-zag pattern was taken using an auger, where soil cores of 20 cm depth were collected every after 15 footsteps. These cores were combined into one composite sample in a plastic bucket and mixed well. Then a cup full sample was taken from the mixture for analysis.

The chemical analysis of soils from MRS and LES was done using soil comprehensive AMBIC procedure at RES Laboratory.

2.4. Planting

Sweet potato stem cuttings of the four varieties measuring 30 centimetres in length and taken from a mature stem were used. Cuttings were planted on top of the ridges at an inter row spacing of 90 cm and 30 cm between hills. Fertilizer application was carried out at planting using 450 kilograms per hectare of NPK 2:3:4 (39) and cattle manure at 0, 20, 40 and 60 t/ha. At 6 weeks after planting, 100 kilograms of Limestone Ammonium Nitrate (LAN) was applied as a side dressing. Side dressing was not done in the control plots. In all cases, the fertilisers were applied by the banding and 15 cm away from the sweet potato rows and incorporated into the soil (Ossom, 2010).

2.5. Data collection

Data were collected in the following categories: Six plants from each net plot were sampled and tagged. Petiole and vine lengths were measured at 60, 90, and 120 days after planting (DAP). Six plants were sampled from each plot from which the petiole lengths of six leaves were measured from the base to the canopy, using a tape measure. Each plant was tagged and measured with a measuring tape from the base to the terminal leaf. Total yield of non-marketable tubers, marketable tubers and total yield in tonnes per hectare. To estimate the total yield, all plants harvested per net plot of the experiment were considered and this average multiplied by the total number of plants per hectare.

2.6. Data analysis

All agronomic and yield data were expressed as means. Data on agronomic and yield traits from the sweet potato varieties were pooled and analyzed using one-way and two-way ANOVA. Analysis of variance was conducted using GenStat® version 14 (VSN International, Hemel Hempstead, UK). Significant differences between varieties for agronomic and yield traits were determined using Duncan's New Multiple Range Test (DNMRT) at significance level of $P < 0.05$.

3. Results

3.1. Lowveld Experiment Station (LES), Big Bend

3.1.1. Petiole and vine length (cm)

There were significant (P<0.05) differences observed in the petioles length at 60, 90 and 120 DAP when comparing the different varieties and soil amendments (Table 4). At 60 DAP, the length of petioles ranged from 5.78 cm to 10.5 cm within the different soil amendments. Ligwalagwala planted using 0 tonnes per hectare recorded the longest petiole length of 10.50 cm, while Melinda recorded the shortest at 5.78 cm planted using cattle manure at 0 tonnes per hectare. At 90 DAP the length of petiole ranged from 7.8 to 12.11 cm. Ligwalagwala planted without cattle manure at 0 tonnes per hectare recorded the longest petiole length of 12.1 cm while Namanga planted using 40 tonnes per hectare of cattle manure recorded the shortest petiole length at 7.8 cm. At 120 DAP, the length of petioles ranged from 9.2 to 13.4 cm among the sweet potato varieties. Ligwalagwala planted without cattle manure at 0 tonnes per hectare recorded the longest petioles length of 13.4 cm while Namanga and Melinda both planted using 40 tonnes per hectare cattle manure recorded the shortest petiole length of 9.17 cm.

Table 4. Effects of applying organic and inorganic soil amendments on petioles and vine length (cm) of orange fleshed sweet potato at LES

	Petioles length					Vine length				
	Organic and inorganic fertiliser rates (Tonnes per Hectare)									
Varieties	**0**	**20**	**40**	**60**	**0.45 t/ha NPK**	**0**	**20**	**40**	**60**	**0.45 t/ha NPK**
					60 DAP					
Cecelia	9.4ab	7.6abc	7.6abc	7.9abc	8.6abc	85.2ab	97.4ab	113.1ab	107.9ab	95.1ab
Namanga	9.3ab	7.22abc	6.8bc	8.6abcd	8.1abc	72.4b	112.8ab	99.4ab	112.3ab	97.6ab
Melinda	5.78c	6.8bc	6.05bc	6.9bc	6.0bc	94.3ab	110.4ab	96.4ab	93.0ab	92.6ab
Ligwalagwala	10.5a	7.2abc	6.74bc	9.0abc	7.5abc	100.6ab	101.4ab	106.2ab	129.7a	102.9ab
LSD (0.05) = 2.93						LSD (0.05) = 43.615				
					90 DAP					
Cecelia	10.1abc	10.0abc	9.9abc	8.9abc	10.2abc	96.1ab	107.9ab	139.8a	117.2ab	106.3ab
Namanga	10.3abc	8.48bc	7.83c	11.3ab	9.9abc	83.9c	122.7ab	111.6ab	123.4ab	110.6ab
Melinda	8.00c	8.6bc	7.98c	9.67abc	8.7bc	102.9ab	117.7ab	105.6ab	105.6ab	105.8ab
Ligwalagwala	12.1a	9.4abc	8.40bc	9.96abc	8.40bc	104.1ab	114.0ab	126.1ab	137.2a	115.8ab
LSD (0.05) = 2.99						LSD (0.05) = 42.81				
					120DAP					
Cecelia	10.9abcd	10.8abcd	12.4abc	10.53abcd	10.7abcd	107.1a	141.9a	133.3a	151.4a	134.1a
Namanga	11.1abcd	10.7abcd	9.2d	11.4abc	10.0bcd	116.0a	138.9a	135.4a	139.4a	123.8a
Melinda	10.2bcd	11.3abcd	9.2d	11.00abcd	10.0bcd	131.2a	137.8a	131.7a	138.4a	147.6a
Ligwalagwala	13.4a	12.8ab	10.1bcd	11.7abcd	9.5cd	122.3a	143.9a	140.0a	153.7a	132.2a
LSD (0.05) = 2.79						LSD (0.05) = 63.25				

** Means followed by the same letter, are not significantly different from each other according to Duncan's New Multiple Range Test (DNMRT) at P < 0.05.*
DAP- days after planting

Vines length obtained from the four sweet potato varieties showed significant (P<0.05) differences (Table 4). At 60 DAP, the length of vines ranged from 72.4 cm to 129.7 cm. Ligwalagwala planted using cattle manure at 60 tonnes per hectare recorded the longest vine length of 129.7 cm while Namanga recorded the shortest at 72.4 cm planted using cattle manure at 0 tonnes per hectare. At 90 DAP, the vine length ranged was from 83.9 to 139.8 cm among the sweet potato varieties (Table 4). Cecelia planted using 40 tonnes per hectare cattle manure recorded the longest vine length of 139.8 cm while Namanga recorded the shortest at 83.9 cm planted using 0 tonnes per hectare. At 120 DAP, the vine length range was from 107.1 cm to 147.6 cm among the sweet potato varieties (Table 4). Melinda planted using 60 tonnes per hectare cattle manure recorded the longest vine length of 147.6 cm while Cecelia recorded the shortest at 107.1 cm.

3.1.2. Non-marketable, marketable tubers and total yield

There were significant (P<0.05) differences in non-marketable tubers yield among the different varieties (Table 5). Cattle manure application at 0 tonnes per hectare gave non-marketable tubers yield ranging from 3.5 to 6.13 tonnes per hectare, with Namanga yielding the highest non-marketable yield of tubers. Ligwalagwala showed the least at 3.5 to 5.51 tonnes per hectare of non-marketable tubers. Cattle manure applied at 60 tonnes per hectare gave non-marketable tubers yield ranging from 4.77 to 7.56 tonnes per hectare. Namanga had the highest weight of non-marketable tubers and Melinda showed the least at 7.56 and 4.77 tonnes per hectare, respectively. Inorganic fertiliser NPK 2:3:4 applied at 0.45 tonnes per hectare gave non-marketable tubers yield ranging from 4.24 to 7.53 tonnes per hectare Cecelia and Ligwalagwala.

Table 5. Effects of applying organic and inorganic soil amendments on yield of non-marketable, marketable tubers and total yield (Tonnes per Hectare) of orange fleshed sweet potato at LES

	Non-marketable tubers					Marketable tubers					Total yield				
	Organic and inorganic fertiliser rates (Tonnes per Hectare)														
Varieties	**0 t/h**	**20**	**40**	**60**	**0.45 NPK**	**0**	**20**	**40**	**60**	**0.45 NPK**	**0**	**20**	**40**	**60**	**0.45 NPK**
Cecelia	5.02ab	6.91ab	7.45b	5.51ab	7.53b	13.42c	15.72abc	16.83abc	16.09abc	16.13abc	18.44cd	22.63abcd	24.28abcd	21.60bcd	23.66abcd
Melinda	5.10ab	3.58a	5.76ab	4.77ab	6.01ab	15.88abc	22.76ab	13.25c	19.09abc	23.46a	20.99bcd	22.63abcd	19.01bcd	23.87abcd	29.46a
Namanga	6.13ab	7.50b	7.33b	7.65b	5.60ab	12.06c	13.09c	19.01abc	17.45abc	15.02bc	18.19cd	20.58bcd	26.34ab	25.10abc	20.62bcd
Ligwalagwala	3.54a	4.90ab	5.60ab	5.51ab	4.24ab	19.09abc	16.91abc	11.85c	17.49abc	17.24abc	22.63abcd	21.81bcd	17.45d	23.00abcd	21.48bcd
	LSD (0.05) = 3.12					LSD (0.05) = 6.52					LSD (0.05) = 6.25				

** Means followed by the same letter are not significantly different from each other according to Duncan's New Multiple Range Test (DNMRT) at P < 0.05.*

Different soil amendments application rates had significant (P<0.05) effect on the yield of sweet potato tubers (Table 5). Cattle manure application at 0 tonnes per hectare resulted in marketable tubers yield ranging from 12.06 to 19.09 tonnes per hectare. Ligwalagwala gave the highest yield while Namanga gave the lowest yield at 19.09 and 12.06 tonnes per hectare, respectively. Cattle manure applied at20 tonnes per hectare yielded marketable tubers ranging from 13.09 to 22.76 tonnes per hectare. There were significant (P < 0.05) differences in total tuber yield among the different sweet potato varieties and soil amendments at (Table 5). Cattle manure applied at 0 tonnes per hectare gave a total tuber yield ranging from 18.19 to 22.63 tonnes per hectare with Ligwalagwala yielding the highest 22.63 tonnes per hectare and Namanga yielding the lowest 18.19 tonnes per hectare. Sweet potato applied with cattle manure at 40 tonnes per hectare had total yield ranging from 17.45 to 24.28 tonnes per hectare, with Cecelia yielding 24.28 tonnes per hectare and Ligwalagwala having 17.45 tonnes per hectare. Cattle Manure application at a rate of 60 tonnes per hectare resulted in total yield range from 21.60 to 25.10 tonnes per hectare, with Namanga showing the highest yield of 25.10 tonnes per hectare and Cecelia least yield of 21.60 tonnes per hectare. Plants applied with inorganic fertiliser NPK 2:3:4 at 0.45 tonnes per hectare had total tuber yield ranging from 21.48 to 29.46 tonnes per hectare with Melinda giving the highest and Namanga the lowest, respectively.

3.2. Malkerns Research Station (MRS)

3.2.1. Petiole and vine length (cm)

Table 6. Effects of applying organic and inorganic soil amendments on petioles and vine length (cm) of orange fleshed sweet potato at MRS

	Petioles length					Vine length				
	Organic and inorganic fertiliser rates (Tonnes per Hectare)									
Varieties	**0**	**20**	**40**	**60**	**0.45 NPK**	**0**	**20**	**40**	**60**	**0.45 NPK**
					60 DAP					
Cecelia	5.5a	7.3a	6.1a	6.4a	6.9a	53.5a	68.4a	63.5a	60.8a	49.2a
Namanga	6.0a	6.1a	6.8a	5.9a	5.8a	51.0a	57.7a	56.2a	68.6a	55.5a
Melinda	6.2a	6.1a	5.8a	6.1a	6.6a	65.8a	58.2a	65.4a	62.6a	62.8a
Ligwalagwala	5.2a	7.4a	5.8a	6.5a	6.1a	58.6a	71.7a	42.9a	49.8a	73.5a
LSD (0.05) = 2						LSD (0.05) = 31.5				
					90 DAP					
Cecelia	7.5ab	8.1ab	8.7ab	8.1ab	8.2ab	61.8a	76.9a	70.4a	74.1a	72.6a
Namanga	7.4ab	8.0ab	7.7ab	7.6a	7.4ab	75.2a	83.1a	75.7a	85.4a	73.1a
Melinda	8.0ab	7.8ab	7.8ab	8.2ab	8.2ab	87.1a	85.0a	85.7a	75.8a	65.1a
Ligwalagwala	7.2b	9.4a	7.8ab	8.1ab	7.8ab	66.9a	85.2a	55.3a	55.4a	86.2a
LSD (0.05) = 1						LSD (0.05) = 31.35				
					120DAP					
Cecelia	10.7abc	11.0abc	11.4ab	10.6abcde	11.7a	134.4ab	121.4abc	131.4abc	119.2bc	136.0ab
Namanga	10.7abcde	10.4abcde	11.2ab	10.4abcde	10.7abcde	118.4bc	138.8ab	121.0abc	133.5ab	127.3abc
Melinda	10.9abcde	10.5abcde	10.7abcde	11.5ab	10.2abcde	144.9a	120.7bc	128.9abc	117.2bc	125.1abc
Ligwalagwala	9.33c	11.6a	10.7abcde	9.8bcde	11.0abcd	118.1bc	128.9abc	121.0abc	108.2c	133.3ab
LSD (0.05) = 1.5						LSD (0.05) = 20.1				

** Means followed by the same letter, are not significantly different from each other according to Duncan's New Multiple Range Test (DNMRT) at P < 0.05. DAP- days after planting*

Mean petioles length at Malkerns Research Station (MRS) are shown in (Table 6). The mean petioles length did not show significant differences ($P < 0.05$) at 60 DAP in both soil amendments applications and sweet potato varieties. At 60 DAP the means petioles length ranged from 5.2 to 7.4 cm. Ligwalagwala planted using cattle manure rate of 20 tonnes per hectare recorded the longest mean petiole length measuring 7.4 cm while again same variety Ligwalagwala recorded the shortest mean of 5.2 cm planted using cattle manure at 0 tonnes per hectare. At 90 DAP the means petiole length ranged from 7.2 to 9.4 cm. Ligwalagwala planted using 20 tonnes per hectare cattle manure recorded the longest mean petiole length of 9.4 cm while Ligwalagwala planted using cattle manure at 40 tonnes per hectare recorded the shortest mean petiole length of 7.2 cm. At 120 DAP the means petiole length ranged from 9.3 to 11.67 cm. Cecelia grown using inorganic fertiliser NPK 2:3:4 at a rate of 0.45 tonnes per hectare recorded the longest mean petiole length of 11.67 cm while Ligwalagwala grown without a soil amendment (0 tonnes per hectare) recorded the shortest mean petiole length of 9.33 cm.

The results did not show significant differences (P>0.05) in mean vines length among the four sweet potato varieties grown using organic and inorganic soil amendments at different rates. At 60 DAP the mean length of vines ranged from 49.2 to 73.5 cm. Ligwalagwala planted using inorganic fertiliser NPK 2:3:4 at a rate of 0.45 tonnes per hectare recorded the longest mean vines length of 73.5 cm while Cecelia also planted with the same rate of inorganic fertilizer recorded the shortest mean vine length of 49.2 cm.

At 90 DAP the mean vines' length ranged from 55.3 to 87.1 cm. Melinda planted using 40 tonnes per hectare cattle manure recorded the longest mean vine length of 87.1 cm while Ligwalagwala planted without a soil amendment, 0 tonnes per hectare recorded the shortest at 55.3 cm. At 120 DAP the mean vines' length ranged from 108.0 to 144.9 cm. Melinda planted without a soil amendment recorded the longest mean vine length of 144.9 cm while Cecelia recorded the shortest at 108.0 cm.

3.2.2. Non-marketable, marketable tubers and total yield (tonnes per hectare)

There were significant differences (P < 0.05) observed in mean non-marketable tubers yield among the different sweet potato varieties grown using soil amendments (Table 7). The non-application of soil amendments gave mean non-marketable tubers yield ranging from 2.10 to 2.9 tonnes per hectare, with Namanga showing the highest mean weight of non-marketable tubers and Ligwalagwala showing the least at 2.10 to 2.9 tonnes per hectare respectively. Cattle manure application at 60 tonnes per hectare had mean non-marketable tubers yield ranging from 2.71 to 6.21 tonnes per hectare. Ligwalagwala produced the highest mean weight of non-marketable tubers and Melinda least at 2.71 to 6.21 tonnes per hectare respectively. Inorganic fertiliser application at 450 kilograms per hectare produced mean non-marketable tubers yield ranging from 2.59 to 5.10 tonnes per hectare with Cecelia giving the highest and Ligwalagwala the lowest respectively.

There were significant differences (P<0.05) observed in mean marketable tubers yield among the different sweet potato varieties grown using different soil amendments (Table 7). The non-application of cattle manure at zero (0) tonnes per hectare gave a mean marketable tuber yield ranging from 12.92 to 18.93 tonnes per hectare. Ligwalagwala produced the highest mean weight of marketable tubers and Namanga the least at 18.93 and 12.92 tonnes per hectare respectively. Cattle manure application at 60 tonnes per hectare resulted in mean marketable tubers yield ranging from 14.77 to 17.61 tonnes per hectare, with Melinda having the highest mean weight of marketable tubers and Ligwalagwala with the least at 17.61 to14.77 tonnes per hectare respectively. Yields of mean marketable tubers when using inorganic fertiliser NPK 2:3:4 at 0.45 tonnes per hectare ranged from 14.07 to 23.21 tonnes per hectare with Ligwalagwala attaining the highest and Cecelia the lowest.

Table 7. Effects of applying organic and inorganic soil amendments on yield of non-marketable, marketable tubers and total yield (Tonnes per Hectare) of orange fleshed sweet potato at MRS

	Non-marketable tubers					Marketable tubers					Total yield				
	Organic and inorganic fertiliser rates (Tonnes per Hectare)														
Varieties	**0**	**20**	**40**	**60**	**0.45 NPK 2:3:4 (39)**	**0**	**20**	**40**	**60**	**0.45 NPK 2:3:4 (39)**	**0**	**20**	**40**	**60**	**0.45 NPK 2:3:4 (39)**
Cecelia	2.10abc	1.40a	6.10def	3.91abcdef	5.10bcde	15.10ab	11.40b	13.09b	15.47ab	15.60ab	17.20abc	12.80c	20.74abc	21.60ab	20.70abc
Melinda	2.22abc	1.90ab	3.33abcde	2.71abcde	3.50abcde	12.92b	17.12ab	15.19ab	17.61ab	18.27ab	15.14bc	21.07abc	18.52abc	20.33abc	26.34a
Namanga	2.90abcde	5.72cdef	7.32f	6.30ef	4.80abcdef	13.17b	10.21b	18.60ab	15.14ab	14.07ab	16.05bc	15.93bc	23.74ab	21.44abc	16.30bc
Ligwalagwala	2.63abcde	4.30abcdef	3.53abcd	6.21ef	2.59abcd	18.93ab	16.54ab	12.84b	14.77ab	23.21a	21.56abc	20.82abc	16.38bc	20.95abc	20.25abc
	LSD (0.05) = 3.07					LSD (0.05) = 7.91					LSD (0.05) = 7.79				

** Means followed by the same letter are not significantly different from each other according to Duncan's New Multiple Range Test (DNMRT) at P < 0.05.*

There were significant differences in mean total yield among the different sweet potato varieties grown using soil amendments (Table 7). The treatment rate at 0 tonnes per hectare total yield ranged from 15.14 to 21.56 tonnes per hectare, with Ligwalagwala showing the highest yield at 21.56 tonnes per hectare and Melinda showing the lowest at 15.14 tonnes per hectare. Treatment rate at 40 tonnes per hectare cattle manure total yield ranged from 16.38 to 23.74 tonnes per hectare, with Namanga showing the highest yield of 23.74 tonnes per hectare and Ligwalagwala showing the least at 16.38 tonnes per hectare. Treatment rate at 60 tonnes per hectare total yield ranged from 20.33 to 21.60 tonnes per hectare, with Cecelia showing the highest yield of 21.60 tonnes per hectare and Melinda showing the least at 20.33 tonnes per hectare. Treatment rate of organic fertiliser at a rate of 450 kilograms per hectare yield ranged from 16.30 to 26.34 tonnes per hectare with Melinda giving us the highest and Namanga the lowest respectively.

4. Discussion

4.1. Petiole length

The application of both organic and inorganic soil amendments rates did significantly affect the varieties and length of the petioles during the first 60 DAP at LES. Results showed that treatment application of 0 t ha $^{-1}$ where there no soil amendment added to the soil, petiole length grew and recorded the longest at 13.4 cm while at MRS Ligwalagwala which is the control variety had a mean of 11.6cm was mean petiole length under treatment rate at 40 t ha $^{-1}$ cattle manure. The significant response among varieties for may be due to genetic variability. The significant differences in petiole length between varieties agrees with (Ochieng, 2019). Cecelia which is an orange fleshed sweet potato variety gave the longest petiole length at MRS of 11.7 cm. Similar findings were obtained by Ayimbire et al., (2021) who reported that orange flesh variety exhibited the longest petiole length at 19.08 cm, significantly longer than other varieties such as Agric white (13.55 cm) and Red local (12.18 cm).

4.2. Vine length

The results indicated significant variation in vine length among the sweet potato varieties at both locations, across different days after planting, and under varying soil amendment application rates. These findings align with those of Ochieng (2019), who also reported significant differences in vine length among varieties. Melinda, planted with a treatment application rate of 0 t/ha, recorded the longest vine length of 144.9 cm. However, the results suggest that the application of soil amendments at different rates did not affect vine length. The observed differences in vine length among the varieties can likely be attributed to inherent genetic differences (Dlamini et al., 2021).

In terms of yield, Melinda consistently gave the highest yield at both sites, with 29.46 t/ha at LES and 26.24 t/ha at MRS under the application rate of NPK 0.45 t/ha. This contrasts with the findings of Law-Ogbomo and Osaigbovo (2017), who reported that a vine length of 40 cm combined with organic fertilizer (cattle dung) resulted in the highest tuber production, demonstrating a positive correlation between vine length and other growth variables.

4.3. Non-marketable tubers

The performance of different sweet potato varieties under various soil amendments and application rates showed significant differences at $P < 0.05$. This variability could be attributed to the genetic composition of the varieties, which influences their ability to effectively partition photosynthates into storage roots (Tutu et al., 2022). The significance of non-marketable tubers extends beyond agricultural output, impacting nutrition, market dynamics, and food security. Therefore, varieties that produce fewer non-marketable tubers are generally preferred by farmers. At LES, Ligwalagwala and Melinda had the lowest non-marketable yields of 3.45 t/ha and 3.58 t/ha, respectively, under the application rates of 0 t/ha and 20 t/ha. These results suggest that these two rates were optimal for minimizing non-marketable tuber yields. In contrast, the application of inorganic NPK fertilizer resulted in the highest yield of non-marketable tubers, with Cecelia producing 7.53 t/ha. The findings from this study indicate that Ligwalagwala, under no soil amendment, yielded the lowest amount of non-marketable tubers, which is beneficial for farmers. Looking at the overall trends, organic amendments tended to result in lower yields of non-marketable tubers. At MRS, Cecelia and Melinda produced the lowest non-marketable tuber yields of 1.4 t/ha and 1.9 t/ha, respectively. These results are consistent with those of Cavalcante et al. (2010), who found similar trends in eleven sweet potato genotypes grown without fertilization and liming in the municipality of Junqueiro, AL, where yields of non-commercial roots ranged from 4.1 t/ha to 7.8 t/ha for total yield.

4.4. Marketable tubers

The findings of this study indicate that both organic and inorganic soil amendments positively affected sweet potato production, though the effects varied between genotypes. At LES, Melinda achieved the highest yield of 23.46 t/ha under the treatment of NPK at 0.45 t/ha, while under organic amendment, the second highest yield was recorded at 22.76 t/ha with a cattle manure application rate of 20 t/ha. Namanga, the second variety, gave the second highest yield of 22.76 t/ha under an organic amendment application rate of 40 t/ha. This differs from the results obtained by Paracido et al. (2024), who found that the combined use of synthetic NK fertilizers with the highest rates of organic fertilizers (castor meal or CM + HP mixture) led to average increases of 116% and 128% in total and marketable yields of storage roots, respectively, compared to the control treatment without fertilization. Results from the study at MRS showed that Ligwalagwala achieved the highest yield of 23.21 t/ha under the application of NPK at 0.45 t/ha. It is worth noting that organic fertilizer application rates had no effect on the marketable yield of Ligwalagwala, which attained the highest yield at the 0 t/ha rate. This contrasts with the findings of Duan et al. (2019) and Wang et al. (2022), who noted that deficiencies in nutrients can significantly reduce productivity by decreasing the size of marketable storage roots and limiting starch accumulation in reserve tissues, ultimately affecting key market characteristics, such as texture and firmness.

4.5. Total yield

Total yield includes all types of tuberous roots, both marketable and non-marketable. The results of this study revealed significant variations in root yield performance among the sweet potato varieties and the application rates of both organic and inorganic soil amendments. Paracido et al. (2024) found that synthetic NK fertilizers played a crucial role in promoting the growth of sweet potato storage roots, increasing their weight by an average of 31%, regardless of the organic fertilizer applied. In this study, results from LES and MRS showed that Melinda, under the treatment with inorganic fertilizer NPK 2:3:4 (39), yielded the highest at 29.46 t/ha and 26.34 t/ha, respectively. The second highest yield was recorded in Namanga following the application of 40 t/ha of cattle manure at both LES and MRS. These findings are in agreement with those of Hlawe (2015), who reported higher storage root yields with 40 t/ha of cattle manure. However, contrary to the findings by Désiré et al. (2017), who found that mineral fertilization did not result in increased yields in sweet potato genotypes grown in Nigeria. This study's findings are consistent with those of Ejigu et al. (2022), who also observed significant differences in total tuberous root yield among varieties in their trials.

4.6. Impact of soil amendments

Modern agriculture emphasizes the precise application of nutrients to meet the crop's needs at critical growth stages, ensuring optimal genetic potential. Depending on the combination of fertilizers (inorganic and organic), farmyard manure has been shown to increase the average yield of potato tubers by 38-82% (Harraq et al., 2022). In line with these findings, Wang et al. (2022) demonstrated that applying an activated humic acid-nitrogen, phosphorus, and potassium compound fertilizer in sweet potato production can enhance soil quality, promote sweet potato growth, and boost yield. In this study, organic amendments (cattle manure) at LES, with application rates of 0 and 20 t/ha, produced similar yields for the varieties Ligwalagwala and Melinda. The highest yield of 26.34 t/ha was obtained with the 40 t/ha application rate for Namanga. Surprisingly, the highest application rate of 60 t/ha of cattle manure resulted in the second-highest yield of 25.10 t/ha with Namanga. These results align with those of Magagula et al. (2010), who observed that increasing chicken manure levels significantly raised nutrient concentrations in sweet potato tubers and leaves, although the highest application (60 t/ha) was associated with the lowest tuber yield (13.4 t/ha). One of the main challenges with organic fertilizers is their inability to provide sufficient levels of essential nutrients like nitrogen, phosphorus, and potassium (NPK), even when these minerals are present in manure-based fertilizers, which are still considered organic (De Corato, 2020). As a heavy feeder of nutrients, sweet potato requires high amounts of nitrogen, phosphorus, and potassium, and chemical fertilizers are the primary source of these nutrients for potato cropping (Koch et al., 2020) By comparing organic and inorganic amendments, the study could encourage the adoption of organic fertilizers (such as compost or manure) alongside or instead of inorganic fertilisers. This shift could reduce the environmental impact of chemical inputs, lower production costs, and improve the ecological balance in agricultural ecosystems. Organic fertilizer sources can offer themselves as alternatives to the predicament of small-scale farmers in Eswatini because of their relative availability in most homesteads, and significantly lesser cost. Additionally, coupled with many advantages which help to improve soil and soil microorganism health, they are not without their own challenges including bulkiness and non-standardization of the fertilizer content.

5. Conclusion

The findings of this study revealed that the application of organic fertilizer (cattle manure) at different rates significantly influenced the growth and yield of sweet potato varieties in the studied environments. Varying environmental conditions at the two locations had a significant effect on plant growth and yield. Knowledge of sweet potato genotypes performance and yield adaptation in the diverse agro-ecological zones would be highly beneficial for cultivar deployment. However, the results also clearly indicated that inorganic amendments (NPK 2:3:4 (39) generally outperformed organic fertilizers. At both LES and MRS, Melinda yielded the highest under the treatment of NPK 2:3:4 (39), with 29.46 t/ha and 26.34 t/ha, respectively. Namanga achieved the second highest yield following the application of 40 t/ha of cattle manure at both locations. Modern agriculture emphasizes the precise application of nutrients to meet the crop's needs at critical growth stages, ensuring optimal genetic potential. From the perspective of food security, sweet potato is an excellent crop as it often survives where staple crops fail. This finding emphasizes the importance of proper nutrient management for optimizing crop performance, the study will inform local agricultural policies and extension services, encouraging the integration of sustainable farming practices into agricultural development programs. It could also help design training programs for farmers on the use of soil amendments since smallholder farmers don’t apply any manure or fertiliser when producing sweet potato, and sustainable farming practices. Based on the findings, it is recommended to apply (NPK 2:3:4 (39) at a rate of 0.45t/ha and 40t/h of cattle manure for better yields. Future research could benefit from focusing not only on yield but also on nutritional analysis, health benefits for consumers, and factors influencing profitability, in addition to yield-focused assessments. The findings from Melinda, an Orange-fleshed sweet potato variety, show that it produced high yields in both locations, especially when cattle manure was used as a soil amendment. Promoting this variety alongside integrated nutrient management strategies in Eswatini could greatly enhance food security and nutrition while improving farmers' economic stability. By encouraging sustainable practices and empowering farmers, this approach directly supports SDG 2 (Zero Hunger) by creating resilient, diverse, and nutritious food systems that are both environmentally and economically sustainable.

6. Limitations and future research

Genotype selection: The number and variety of sweet potato genotypes evaluated were very few, there is a need to test many so that farmers can have a choice based on their preferences and yield potential. The findings might not represent the broader genetic diversity of sweet potato, and different genotypes could have shown varying responses to soil amendments**.**

Environmental constraints: The study's findings may be specific to the climatic and soil conditions of Eswatini. These results might not be directly applicable to other regions with different environmental conditions or agricultural practices.

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